CONFEDERATED TRIBES AND BANDS OF THE YAKAMA NATION

Yakama Nation Pacific Lamprey Project

Annual Progress Report
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March 2013 – February 2014

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I. Executive Summary

In accordance with Bonneville Power Administration (BPA) Contract 2008-470-00 the Confederated Tribes and Bands of the Yakama Nation (YN) has prepared this Annual Progress Report for the Yakama Nation Pacific Lamprey Project (YNPLP). This report outlines the most current activities undertaken by the YNPLP from March 1, 2013 through February 28, 2014.

WE185: Produce Pisces Status Report
The quarterly Pisces Status Report for July 1, 2013 – September 30, 2013 was completed on October 3, 2013.

WE165: Environmental Compliance Documentation
Obligated by BPA COTR Environmental Compliance Officer.

WE141: Produce Other Report
Nine elder interviews (in which a total of fourteen people were interviewed) were conducted on March 4, 6, and 11, 2013, using the new set of questions that were developed in 2012-2013. Each interview was videotaped and archived for future viewing. Based on these nine interviews, we were able to gain a much better understanding of the historical distribution and abundance of Pacific lamprey within the Yakima Subbasin and Ceded Lands as well as the historical importance of lamprey in terms of food, culture, and medicine for the Yakama Nation tribal members.

WE157: Collect/Generate/Validate Field and Lab Data
In 2013, we surveyed a total of 44 sites in Yakima Subbasin, 9 sites in Methow Subbasin, 12 sites in Klickitat Subbasin, and 9 sites in White Salmon Subbasin. Of the 74 sites, 19 were quickly examined for primarily lamprey presence/absence using an electrofisher or a fine-mesh hand net (12, 4, 1, and 2 spot check sites in Yakima, Methow, Klickitat, and White Salmon subbasins, respectively). Larval Pacific lamprey were only found in the Lower Yakima and Klickitat watersheds, and the mean ratio of Pacific lamprey (vs. Western brook lamprey) were 12% and 59%, respectfully. Findings thus far confirm the status of Pacific lamprey is "functionally extinct" in the Yakima Subbasin.

WE28: Trap and Haul
The YNPLP collected 640 adult Pacific lamprey (*Entosphenus tridentatus*) from the lower mainstem Columbia River during 2013 and these fish will be and are being used for radio telemetry passage studies, adult translocation projects, and artificial propagation research.

WE162: Analyze/Interpret Data

To improve our understanding of the Pacific lamprey population status within the Yakima Basin, the YNPLP have collected, gathered and analyzed existing data by the three major life stages 1) adults, 2) macrophthalmia, and 3) larvae. Evaluating passage for adults and juveniles and irrigation diversion entrainment have been the focus for 2013-2014 research.

WE161: Disseminate Raw/Summary Data and Results

The YNPLP continues to be substantially involved in all local and regional activities associated with Pacific lamprey research and recovery efforts. These include, but are not limited to activities undertaken by the US Army Corps of Engineers, Mid-Columbia Public Utility District FERC license implementation of associated Pacific Lamprey Management Plans, the CRITFC and member tribes, support and development of the USFWS Pacific Lamprey Conservation Initiative, support and development of Reclamation's Pacific Lamprey Management Plan, and with the Lamprey Technical Work Group.

WE119: Manage and Administer Projects

Throughout 2013-2014, the YN has continued to maintain a strong presence in supporting and guiding Pacific lamprey recovery in the Yakima River Subbasin and in the Columbia River Basin. Partnerships include but not limited to US Bureau of Reclamation, USACE, USFWS, US Geological Survey, CRITFC and member tribes, WDFW, ODFW, and PNNL.

WE99: Outreach and Education

Technical representative of the YN have been actively involved with public outreach, providing presentations to professional meetings and local schools and organizations. Over 30 outreach events were held during the project period and we estimate that we have reached or are reaching over 50,000 people through these activities. Seven of these events were professional presentations targeting scientists and employees from partnering agencies.

WE174: Produce Plan – Produce Propagation and Rearing Plan

The YN is working in close coordination with the CRITFC and the Umatilla Tribes in the development of a broad scale Research, Monitoring and Evaluation (RME) Framework towards Pacific lamprey supplementation (focusing on artificial propagation). We anticipate this Framework document will be the basis from which the tribes move forward for additional research and funding towards potential future supplementation and lamprey recovery efforts. In conjunction with the drafting of the Supplementation Framework, we have also started developing a Research Monitoring and Evaluation (RME) strategy for the upper Columbia River in partnership with CRITFC and member tribes. This planning effort, with a clear focus on activities within the Yakima River basin, is anticipated to be vetted through the Northwest Power and Planning Council (NPCC) and the Independent Scientific Review Board, such that activities associated with long-term status and trend monitoring and research into potential supplementation activities can move forward.

WE176: Produce Hatchery Fish – Research into Juvenile

Since we first succeeded in conducting a pilot project to successfully hold, propagate, incubate, and rear juvenile larvae in 2012, the YN have made remarkable progress in these techniques over the years through partnership with CTUIR. In 2013, protocols and best management practices were refined further to rear over 30,000 larvae using available space at Prosser Fish Hatchery and learned more about critical life stages (especially prolarva to larva stage at the onset of the feeding and burrowing) that are subject to high mortality rates.

WE132: Produce (Annual) Progress Report

The Annual Progress Report for the period March 2013 through February 2014 refers to this summary report and covers all the work elements that are part of the contract. This report summarizes project goals, objectives, complete and incomplete deliverables, problems encountered, lessons learned, and the information gathered, synthesized, and updated to assist in long term planning.

II. Introduction

The Goal of the Yakama Nation is to restore natural production of Pacific lamprey to a level that will provide robust species abundance, significant ecological contributions and meaningful harvest throughout the Yakama Nations Ceded Lands and in the Usual and Accustomed areas (Figure 1).

Pacific lamprey (*Entosphenus tridentatus*) has always been important to Native Americans throughout the Pacific Northwest. Since time immemorial, the Fourteen Bands (Palouse, Pisquose, Yakama, Wenatchapam, Klinquit, Oche Chotes, Kow way saye ee, Sk'in-pah, Kah-miltpah, Klickitat, Wish ham, See ap Cat, Li ay was, and Shyiks) who make up the YN, have shared a commonality treating lampreys as a medicine, food source, and cultural icon. These fish are native to the Columbia River Basin, spawning hundreds of kilometers inland within the states of Washington, Oregon, and Idaho (Kan 1975; Hammond 1979; Hamilton et al. 2005).

Over the past three decades the tribes of the Columbia River Basin have noticed drastic declines from the previous era. These trends are now well known and documented within most current literature about Pacific lamprey throughout their range. In the present day, remnant populations of Pacific lamprey still migrate up the Columbia River at a fraction of their historical numbers; daytime counts of adult Pacific lamprey at Bonneville Dam have declined from an estimated 1,000,000 in the 1960's and 1970's to lows of approximately 20,000 in 2009 and 2010 (CRITFC 2011). Pacific lamprey have been extirpated from many subbasins in the interior Columbia River Basin (Beamish and Northcote 1989; Close et al. 1995; Luzier et al. 2011).

Studies on this disturbing downward trend of Pacific lamprey declines to date cite various contributors for the decline, including but not limited to hydroelectric / flood control dams, irrigation and municipal water diversions, degraded habitat, water quantity and quality (contamination), increased predation, targeted eradication through the use of rotenone, and host species abundance in the ocean (Close et al. 2005; CRITFC 2011; Luzier et al. 2011; Murauskas et al. 2013). The ecological consequences associated with the decline of these fish in both marine and freshwater environments are also largely unknown. Despite the implementation of various long-term actions intended to address large-scale limiting factors, adult returns remain low (CRITFC 2011a; Luzier et al. 2011; Ward et al. 2012).

The purpose of the YNPLP is to 1) collect and report critical information to evaluate status, trends and other biologic characteristics, 2) identify known and potential limiting factors for Pacific lamprey within Columbia River tributaries, and 3) develop, implement and evaluate the effects of Pacific lamprey restoration actions within the YN Ceded Lands. All of the Work

Elements described herein (WE185, WE165, WE141, WE157, WE28, WE162, WE161, WE119, WE99, WE174, WE176, WE132) are oriented toward meeting one of these three project goals.

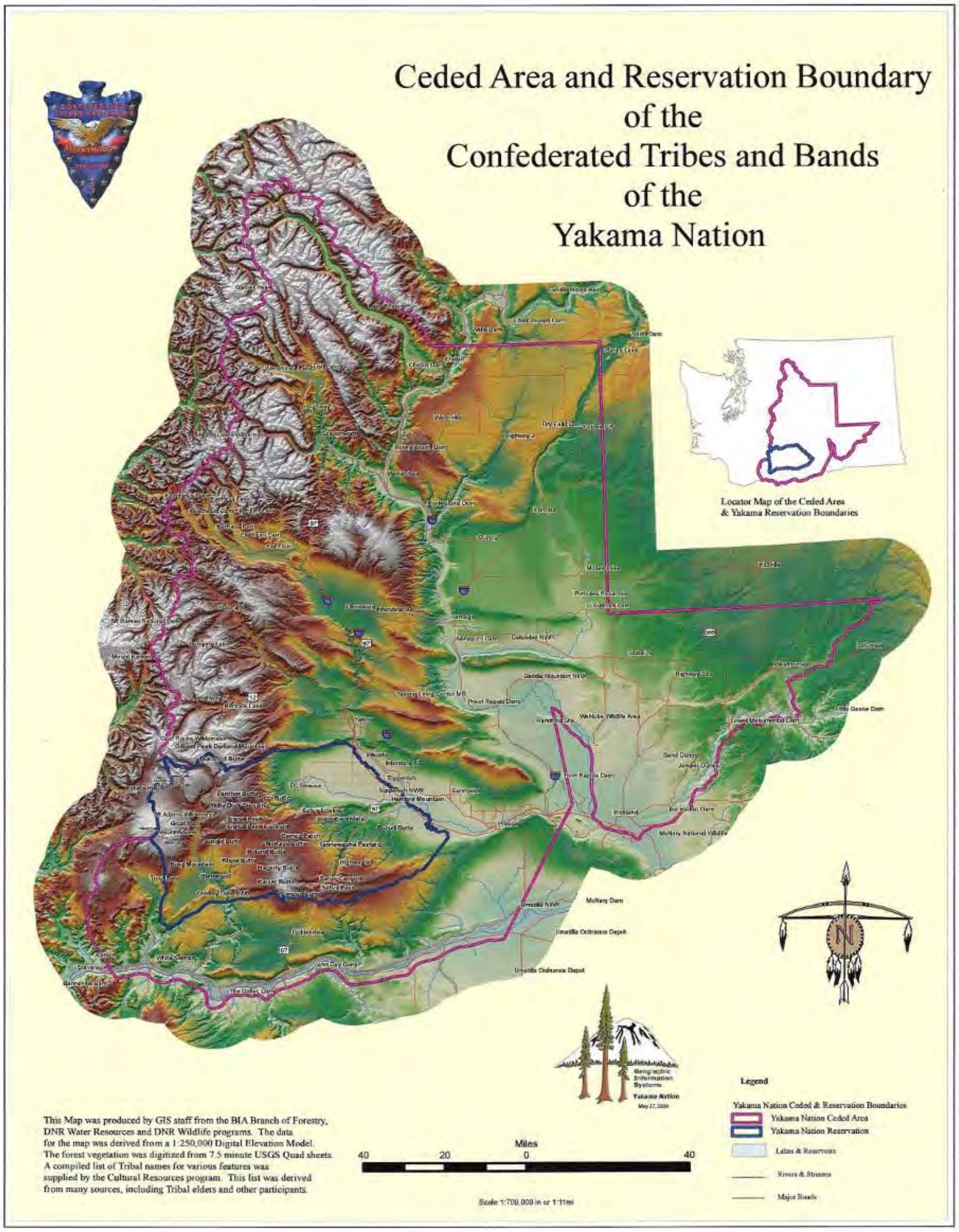

Figure 1. Ceded Lands and Reservation Boundary of the Confederated Tribes and Bands of the Yakama Nation

III. Deliverables

A. Work Element 185 – Pisces Status Report

The quarterly Pisces Status Report for July 1, 2013 – September 30, 2013 was completed on October 3, 2013.

B. Work Element 165 – Environmental Compliance Documentation

Obligated by BPA COTR Environmental Compliance Officer.

C. Work Element 141 – Other Reports (Cultural Information)

Nine elder interviews on lamprey eels were conducted on March 4, 6, and 11, 2013, at the Yakama Nation Museum (in which a total of 14 tribal members were interviewed). We used the new set of questions that were developed in 2012-2013, focusing on six key elements: biography, abundance, biology, ecology, culture, and human impacts. These interview questions were largely based on interview questions that the Umatilla Tribe has previously conducted to document Traditional Ecological Knowledge (TEK) surrounding Pacific lamprey (Close et al. 2004) and was modified based on our project staff and archeologist input.

Listed below are introductions for the tribal members we interviewed:
Johnson Mininick - As the Program Manager for the Yakama Nation Cultural Resources Department, he brings the knowledge of traditional culture, and as a former Tribal Councilman, Mr. Mininick brings the knowledge of policy to help keep intact the various Trust Responsibilities. He is a source in numerous publications, such as "Return of the Wapato," "Indigenous Rights, Water, and Development in Washington State: The Skokomish and the Yakama." For more information about him, see http://yakamafish-nsn.gov/honor/johnson-meninick-meninokt.

Elmer Schuster - Mr. Schuster works for the Yakama Nation Housing Department, but he previously served as a Tribal Councilman and participated in the Yakama Nation Fish & Wildlife Committees as well.

Russell Jim - Mr. Jim serves as the Program Manager for the Environmental Restoration and Waste Management Department. As a former Tribal Councilman he shared how the Yakama language is vital to understanding the history and how the traditions of the Yakama people are tied to this land. He shares the belief that the Yakama people only seek wild fish, because they are the fittest and strongest fish, and these strong fish is what made the Yakama people very strong healthy, spiritually, and culturally. For more information about him, see http://yakamafish-nsn.gov/honor/russell-jim-kiiah%C5%82.

Johnny Jackson & Wilbur Slockish - Both Mr. Jackson and Slockish serve the Yakama Nation as Klickitat Chiefs of the lower Columbia River. Currently they are CRITFC Commissioners, Fisherman, and take part in a wide variety of cultural traditions. These two gentlemen have harvested and interacted deeply with Pacific lamprey for many years. They shared information related to abundance of lamprey and their harvest locations over the past five decades.

Tony Washines - Mr. Washines is a former Tribal and General Council officer for the Yakama Nation and has fished all his life. He brings a unique knowledge of current and historical issues related to lamprey. For more information about him, see http://yakamafish-nsn.gov/honor/tony-washines.

Veronica Wallulatum, Pam Miller, and Lowell Miller - These three are siblings who still practice their traditional ways catching and preparing lamprey. Amongst all three, they have over 60 years of experience with harvesting lamprey. During the interview, they introduced dried lamprey, the different methods of harvest, and locations with relative abundance over the years.

Lester Umtuch, Johnny Buck, & Tatiwyat Buck (Johnny's daughter) - This family is from Priest Rapids, Washington. Mr. Umtuch shared stories as a young person growing up in Wanapum area. He is now retired and works as a senior cultural specialist for Wanapum Grant County PUD, Cultural Resources Department. Johnny and his daughter traveled with Lester to help share traditional knowledge of the Priest Rapids and Wanapum areas.

Lindsey Selam - Mr. Selam is an elder who grew up in the Yakama Valley fishing mostly the Yakima and Columbia rivers. He shared times of when lamprey were abundant at Prosser Dam and this informed us more about historical run timing and abundance. He interacted with many of the elder fishers of the past and had knowledge of the river/stream conditions five decades ago.

Melvin Sampson - Mr. Sampson serves as the Policy Adviser / Project Coordinator with the Yakima/Klickitat Fisheries Project. He also brings his expertise as a former Chairman of the Yakama Nation Tribal Council and from a life time of fishing on the Columbia and Yakima rivers. He shared his memory of when he was actively involved in harvesting lamprey throughout those two rivers and how the definition of restoration has changed from a single species to a multispecies approach today. His passion in restoration surely has complemented his points of view in lamprey species. For more information, see http://infr.org/HOF/Mel_Sampson.html.

Photo C. Still photos from the 2014 elder interview project. Names of the interviewees starting from upper left (left to right, top to bottom) were Johnson Meninick, Elmer Schuster, Russell Jim, Tony Washines, Wilber Slockish / Johnny Jackson, Mel Sampson, Veronica Wallulatum / Pam Miller / Lowell Miller, Johnny Buck and Lester Umtuch, and Lindsey Selam (Patrick Luke, interviewer, is shown on the right side in some of the photos).

The interviews ranged in length between 40 min and 90 min and each interview was videotaped and archived for future viewing for educational purposes through the generous help of Gaylord Mink (a retired photographer / film maker and Yakama Nation volunteer). Based on these nine interviews which provided critical information regarding lamprey harvest and usage within the Yakima Subbasin and Ceded Lands, we were able to gain a much better understanding of the historical importance of lamprey in terms of food, culture, and medicine for the Yakama Nation tribal peoples. These interviews are being transcribed by tribal high school interns in 2014 and are currently being proof-read and edited by Pacific Lamprey Project staff. The summary and analysis of these interviews will be provided in the 2014-2015 Annual Progress Report. Based on these past interviews and the information they provided regarding eel harvest, we were able to estimate the approximate rate of population reduction within the Yakima Subbasin; by the mid-1970s, the number of adult Pacific lamprey have declined to approximately 8% of the peak numbers since the mid-1960s and dropped further down to 3% of the peak counts after the 1970s. We will update the cultural report in the near future with the new results from the recent tribal interviews and we plan to work collaboratively with the YN archeologists to add and enhance the report with additional insights from other disciplines.

D. Work Element 157 – Collect/Generate/Validate Field and Lab Data

Since 2009, the YNPLP has begun conducting juvenile lamprey surveys to document their distribution and relative abundance within the Ceded Area of the YN. Our primary objectives for the juvenile lamprey surveys in project year 2013 were: 1) to assess the presence/absence, distribution, and relative abundance of juvenile Pacific lamprey (primary focus) and Western brook lamprey (secondary focus) and 2) to evaluate the relative abundance of juvenile lamprey habitat and 3) to establish "Index Sites" for long-term status and trend monitoring within the Ceded Area of the YN. Yakima and Klickitat subbasins have been the primary focus of this project since we started in 2009, and in project year 2012, we have expanded this area to include the Wenatchee, Entiat, and White Salmon subbasins.

In Upper Yakima watershed, a total of 16 sites were surveyed throughout the Upper Yakima watershed, with three sites located in the Cle Elum River, a major tributary to the Yakima (Table 1). Larval lamprey habitat was found primarily in side channels and, in less frequent instances, along the mainstem channel margins. Full surveys were performed at 8 out of the 16 sites. On average the temperature below the sediment was cooler than the plot temperature (mean difference of -0.8°C). Within Type I habitat, fish were found in higher densities in areas with detritus (both thick and thin levels of detritus). Of the 254 lamprey observed, all identifiable fish were Western brook with a large percentage of the observed fish remaining unknown (90 %). No fish were observed in the Cle Elum hatchery side channel (rkm 302.2), though an abundance of

Type I habitat was present. Available Type I habitat was patchy in the Yakima River Canyon (rkm 215.0-247.9), but increased in area immediately above Roza Dam (rkm 210.5). Larval lamprey were found up to the town of Cle Elum just below the hatchery (rkm 300.9). Future efforts will focus on reducing the percentage of unknown lamprey by increasing capture efficiency of the electrofisher (many observed lamprey managed to escape). Within the upper Yakima River, index sites (sites to be surveyed regularly over the long-term for status and trend monitoring) were chosen based on findings from these surveys.

In Lower Yakima watershed, a total of 21 sites were surveyed throughout the Lower Yakima watershed, focusing on the mainstem Yakima, Ahtanum Creek, Satus Creek, Simcoe Creek, and Toppenish Creek (10 sites, 3 sites, 4 sites, 1 site, and 3 sites respectively; Table 2). Full surveys were performed at 17 of the 21 sites. Larval lamprey habitat was, more so than the Upper Yakima, along the mainstem channel margins. Fine sediment was more abundant and were observed in places besides side channels. Larval lamprey were found at 16 of the 21 sites, with the lowest distribution on the Yakima River at the I-82 bridge in Prosser. We confirmed the presence of Pacific Lamprey in Ahtanum Creek, Satus Creek, and in the lower Yakima River (rkm 4.1, 31.4, and 73.5 repectively). Pacific Lamprey constituted 2, 50, and 9 percent of the captured identifiable lamprey (>60 mm), respectively, per surveyed watershed. Again, similar to the Upper Yakima watershed, most fish were found in locations with thick or thin detritus over areas with only sand or aquatic vegetation. On average the temperature below the sediment was considerably cooler than the plot temperature (-2.2 °C). Of the 269 lamprey captured, the majority were identified as either Western brook lamprey or unknown, with a small percentage identified as Pacific Lamprey (64.3, 32.7, and 3.0 respectively). More than half of the lamprey were only observed and not captured (345 total). Future efforts will focus on reducing the percentage of unknown lamprey by increasing capture efficiency of the electrofisher (many observed lamprey managed to escape). Within the lower Yakima River, index sites, sites to be surveyed every year for multiple years, were chosen based on our findings from these surveys.

In Lower Yakima watershed, a total of 21 sites were surveyed, focusing on the mainstem Yakima, Ahtanum Creek, Satus Creek, Simcoe Creek, and Toppenish Creek (10 sites, 3 sites, 4 sites, 1 site, and 3 sites respectively; Table 2). Larval lamprey habitat was, more so than the Upper Yakima, along the mainstem channel margins. Fine sediment was more abundant and were observed in places besides side channels. Larval lamprey were found at 16 of the 21 sites, with the lowest distribution on the Yakima River at the I-82 bridge in Prosser. Satus Creek was the only location where we confirmed the presence of Pacific Lamprey (rkm 31.4; Pacific Lamprey constituted 14.3 percent of the total observed lamprey in Satus Creek). Again, similar to the Upper Yakima watershed, most fish were found in locations with thick or thin detritus over areas with only sand or aquatic vegetation. On average the temperature below the sediment was considerably cooler than the plot temperature (-2.2 °C). Of the 534 lamprey surveyed, a large percentage were unknown, followed by Western Brook, and a small percentage were identified as Pacific Lamprey (69.3, 28.0, and 2.7 respectively). Future efforts will focus on reducing the percentage of unknown lamprey by increasing capture efficiency of the electrofisher (many observed lamprey managed to escape).

In the Naches watershed, a total of 7 sites within the Naches watershed, with sites located in the Naches River, Little Naches River and Cowiche Creek (5 sites, 1 site and 1 site respectively). Full surveys were performed at 6 out of the 7 sites. We did not find any Pacific lamprey in Naches River this year, though in past years we have found some. The mean number of lamprey per site was also lowest in the Naches watershed (average of 9 lamprey compared to 26 and 34 lamprey in Upper and Lower Yakima watersheds, respectively). Larval lamprey habitat was found primarily in backwater areas along the mainstem channel or in side channels. Very few sites had fine sediment collection along mainstem channel margins. On average the temperature below the sediment was moderately cooler than the plot temperature (-0.9°C). The highest densities of larval lamprey were found in areas of only sand (very little to no detritus present). Within the Naches watershed, index sites, sites to be surveyed every year for multiple years, were chosen based on our findings from these surveys.

All previous surveys starting in 2009 paint the general same picture for the Yakima Subbasin. That is, Pacific lamprey is rare and primarily limited to the Naches and Lower Yakima watersheds and the majority that we have detected were found in side channels of the Yakima River (primarily in the Wapato reach area) and the lower reaches of major tributaries, including Satus and Ahtanum Creek. Ammocoete habitat. Western brook lamprey, on the other hand, are fairly abundant in the Lower and Upper Yakima watersheds. For more details on the 2013 Yakima Subbasin larval lamprey surveys, see **Appendix D1**.

For more information on survey results from the Methow, Klickitat, and White Salmon subbasins, Lower Columbia River tributary sampling, and a rafting survey in Upper Yakima (in which available habitat was enumerated for the entire 5.1 km survey reach), see **Appendix D2**, **D3**, **D4, D5** and **D6**, respectively.

E. Work Element 28 –Adult Lamprey Collection from Columbia River

The YN collected 640 adult Pacific lamprey from the lower mainstem Columbia River between June 19 and August 5, 2013 (Table E1, Figure E1, Photo E1) according to and within the limits set by the Tribal Collection Allocation Guidelines (Table E2). Collection was closely coordinated with the USACE (Portland District) and the Umatilla and Nez Perce tribes. Forty-five of these fish were used in the autumn months (2013) for radio-telemetry studies in the Yakima River with an additional 45 used in the spring of 2014 for this same study in the upper Yakima River (see **Appendix E1** for more information on the results of the adult passage study). In addition, 104 adults collected from Bonneville Dam were transferred to Douglas PUD between July 16 and July 30 for a passage study at Wells Dam; of these, 100 were double tagged with radio and pit tags and six were only pit tagged. The remainder of the adults will be used for translocation restoration projects in Ahtanum, Satus, and Toppenish creeks and for pilot research on artificial propagation, larval rearing, and offspring outplanting within selected sites in the Upper Yakima and Naches watersheds in the future.

An estimated $35,000 was spent on planning, staff time, travel and equipment in order to collect these adult lamprey. This is in addition to associated costs incurred by our cost-share partnership with the Umatilla Tribes. Overall mortality rate was 6.3% in 2013. Ways to reduce mortality was discussed thoroughly among all team members so that we can reduce mortality rates as much as possible. Every year protocols are being updated and revised to incorporate past lessons to reduce overall fish mortality and improve efficacy of collection and transportation overall.

Table E1. Yakama Nation adult Pacific lamprey broodstock collection in 2013

Date	Personnel	John Day Dam			The Dalles Dam	Bonneville Dam	Daily Total Collection	Mortality	Accumulated Total Collection (Live)
		North Ladder	South Ladder	Total	East Ladder	West Shore			
6/19/2013	PL	0	0	0	0	141	**141**	**13**	**128**
6/20/2013	PL	0	0	0	0	51	**51**	**5**	**174**
6/27/2013	PL, MP	3	1	4	30	0	**34**		**208**
6/28/2013	PL, MP	0	0	0	14	0	**14**	**1**	**221**
6/29/2013	PL, MP	5	0	5	16	0	**21**	**2**	**240**
6/30/2013	PL, MP	0	0	0	16	0	**16**		**256**
7/2/2013	RL, TB, DL	0	0	0	0	46	**46**		**302**
7/11/2013	PL, MP	22	0	22	19	0	**41**		**343**
7/12/2013	PL, MP	26	0	26	12	0	**38**	**6**	**375**
7/13/2013	PL, MP	18	0	18	14	0	**32**	**6**	**401**
7/14/2013	PL, MP	2	0	2	14	0	**16**	**7**	**410**
7/19/2013	PL, DL	12	0	12	0	0	**12**		**422**
7/20/2013	PL, DL	14	0	14	7	0	**21**		**443**
7/21/2013	PL, DL	5	0	5	3	0	**8**		**451**
7/25/2013	DL, MP	0	15	15	0	0	**15**		**466**
7/26/2013	DL, MP	10	0	10	7	0	**17**		**483**
7/27/2013	DL, MP	4	0	4	5	0	**9**		**492**
7/28/2013	DL, MP	11	0	11	4	0	**15**		**507**
8/1/2013	TB, MP	12	0	12	4	0	**16**		**523**
8/2/2013	DL, TB	15	17	32	17	0	**49**		**572**
8/3/2013	DL, TB	2	0	2	7	0	**9**		**581**
8/4/2013	DL, MP	4	0	4	2	0	**6**		**587**
8/5/2013	PL, MP	2	4	6	7	0	**13**		**600**
Total		167	37	204	198	238	**640**	**40**	**600**

Table E2. 2013 Tribal Collection Allocation Guidelines (per Tribe)

Location	Allocation
Bonneville Dam	238
The Dalles	281
John Day	204
Total	**723**

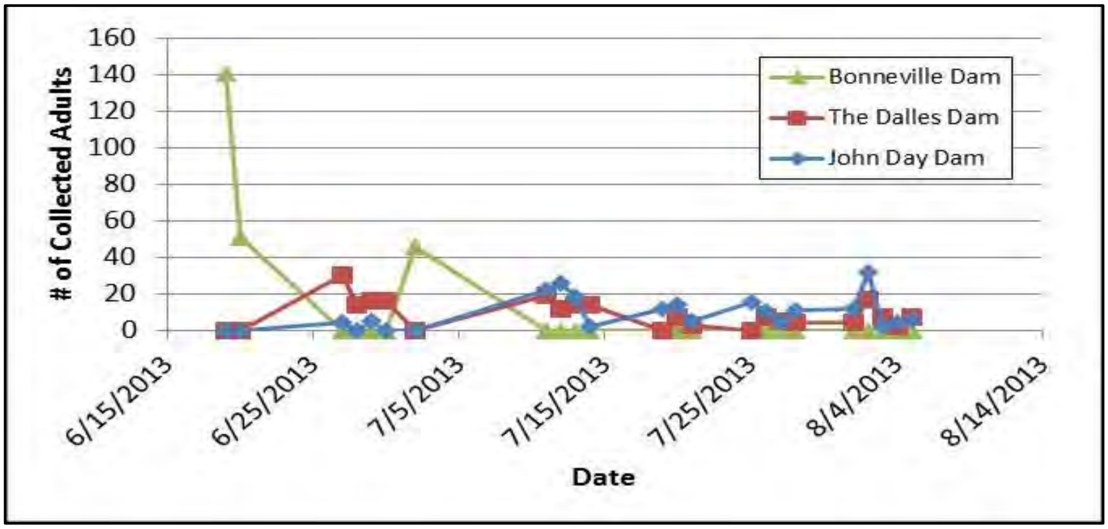

Figure E1. Yakama Nation adult Pacific lamprey broodstock collection in 2013

Photo E1. Markeyta Pinkham pulling adult traps on the North Shore fish ladder of John Day Dam

F. Work Element 162 – Data Input, Analysis and Interpretation

To accomplish the goal of restoring natural production, YNPLP has focused activities on five general objectives 1) establishing baseline information for the presence and absence of Pacific lamprey, 2) understand primary limiting factors affecting abundance of local populations, 3) continuously updating subbasin "Action Plans" that identify key activities to promote Pacific lamprey recovery, and 4) continue research, development into adult supplementation practice and reintroduce by translocation where local populations have been extirpated or functionally extirpated and 5) establish long term status and trend monitoring with index sites. Since initiation of the YNPLP in 2008, we have gained a better understanding on program development and prioritizing action plans based upon our Three Phase approach for the last few years.

- Phase I has been simply the establishment of the Project, developing general protocols, initiating preliminary surveys throughout several subbasins, and beginning a basin wide coordination at a regional scale. For the most part, this effort has been successful. In particular, we have a much higher understanding of the biology, ecology, and distribution of lamprey species within the Ceded Lands of YN. We surveyed and covered lamprey habitat extensively which helps set the stage for our Yakima Subbasin "Action Plan" that is live and ongoing. We have gained cost share partners and have stayed engaged with other agencies and public at both regional and local levels.
- Phase II focuses on adult and juvenile passage issues as well as the establishment of index monitoring sites, from which status and trend is captured over the years to come. These sites include, but are not limited to, Entiat, Klickitat, Methow, Wenatchee, White Salmon, and Yakima subbasins. Based on our current assessment of Pacific lamprey status numbers, we conclude that well thought-out restoration plans and supplementation research activities will provide crucial avenues and directions for long-term lamprey recovery. We will continue to develop Action Plans that focus on key subbasins within the YN Ceded Lands. These activities are taking place in close coordination with Bureau of Reclamation and Yakama Klickitat Fisheries Project. YNPLP continues to be engaged and committed to work with the Army Corp of Engineers and the Mid Columbia Public Utility Districts towards the improvement of Columbia River mainstem passage issues. We are also continuing to coordinate closely with the USFWS through the "Conservation Initiative" and the Yakima Basin radio telemetry project and the Columbia River InterTribal Fish Commission through the "Tribal Pacific Lamprey Recovery Plan" and the many projects that stem off of the Plan.
- Phase 3 will focus on implementation of the knowledge we have gained from Phase 1 and 2. Specifically (but not limited to) we anticipate (1) passage and entrainment issues within the Yakima Basin will begin to be addressed, (2) supplementation research and related management activities will be well defined, developed and initiated in a manner to measure the biological performance of re-introduced local populations, (3) habitat restoration activates oriented primarily towards salmonid recovery will have lamprey habitat needs incorporated, (4) initiate programmatic actions that will reduce toxic chemical levels within juvenile lamprey tissues, (5) fully engage a regional, if not international effort to better understand the ecology of Pacific lamprey within the marine environment, and (6) continued coordination as described in Phase 2.

Quality control on data has been an issue in the past, but much of the data has been examined thoroughly for quality control. All mapping data is currently stored in the Google Earth program and all quantitative data is stored in Microsoft Excel. The YN plans to merge these two types of data together so that they can be stored on a data depository, such as StreamNet, and/or shared with other entities. A few meetings were held to discuss data depository options with YN GIS specialists (Leon Ganuelas) and StreamNet staff (Van Hare and Michael Banach), and these options will be pursued further in 2014. The USFWS has also set up a data archival recently in 2014 for ArcGIS map related data as well as other types of documents for lamprey, and this database has the potential to serve as a shared archive for all Pacific lamprey related data and information contributed by an assortment of collaborating agencies. All of this data / information is available upon request.

To improve our understanding of the Pacific lamprey population status within the Yakima Basin, the YNPLP have collected, gathered and analyzed existing data by the three major life stages 1) adults, 2) macrophthalmia, and 3) larvae. Shown below are some highlights of this analysis for adults and macrophthalmia using data from Prosser Dam and Chandler Fish Counting Station and summary of monitoring of larval/juvenile entrainment in irrigation diversions:

<u>Passage Data:</u>

<u>Adults</u>

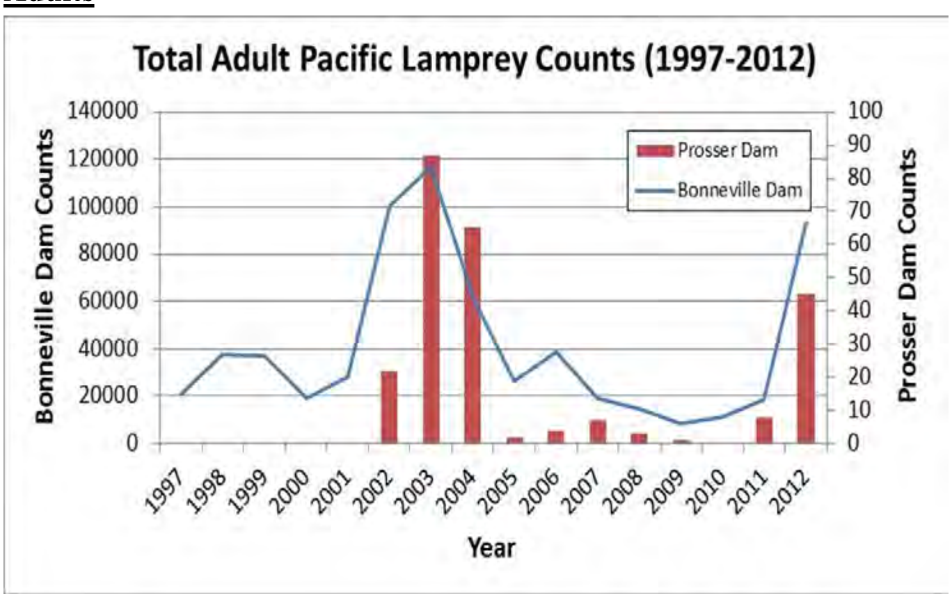

Figure F1. Adult Pacific lamprey counts at Prosser Dam vs. Bonneville Dam between 1997 and 2012 – the general trend in relative abundance is surprisingly very similar.

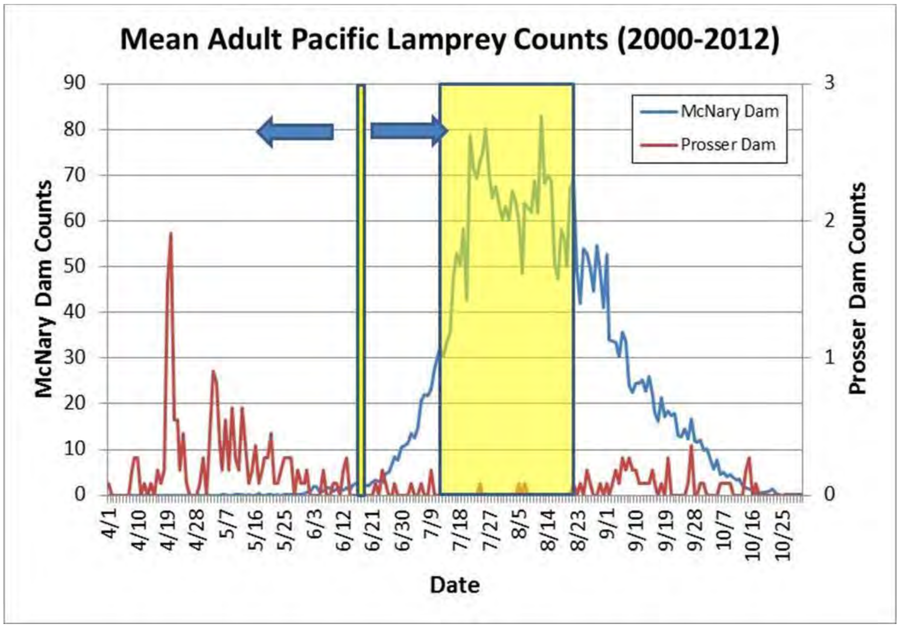

Figure F2. Mean migration timing of adult Pacific lamprey at Prosser Dam vs. McNary Dam based on 13 years of combined data – the majority of migrants at McNary Dam are new migrants (adults that haven't overwintered) while a large number of the Prosser Dam migrants are overwintered migrants (adults that are ready to spawn the same year). The threshold date for the two runs are still unknown, but is most likely in mid-June based on the movement timing of early run lamprey from McNary Dam (yellow line). There is also a large gap in migrants between early July and mid-August at Prosser Dam (yellow box), which may be due to the high water temperature conditions in lower Yakima River during the mid-summer.

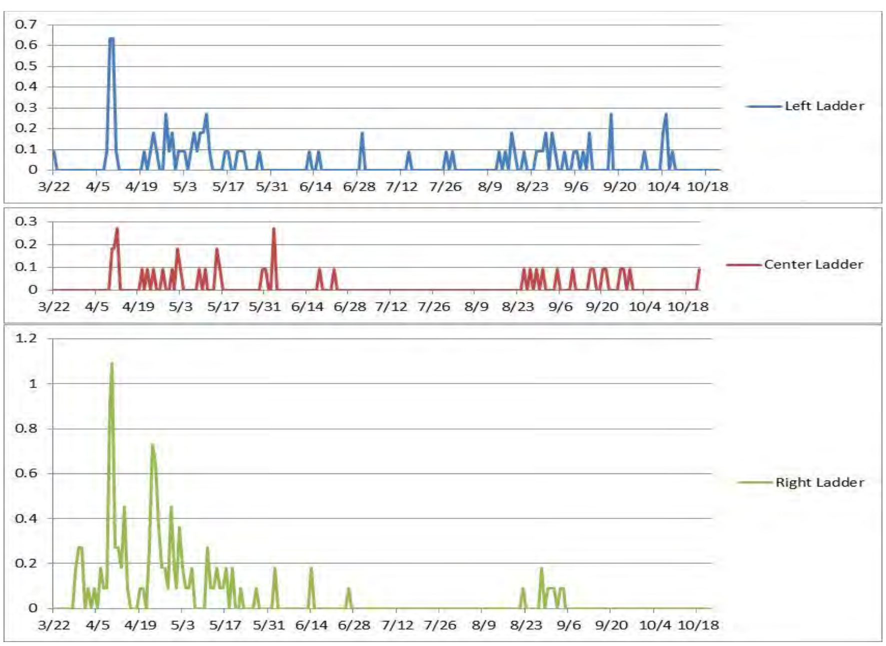

Figure F3. Mean migration timing of adult Pacific lamprey at Prosser Dam based on 13 years of combined data by fish ladder (left, center, and right). This information will help us understand migration behavior of adult Pacific lamprey at the dam by season and flow conditions and will provide crucial input on passage improvement projects.

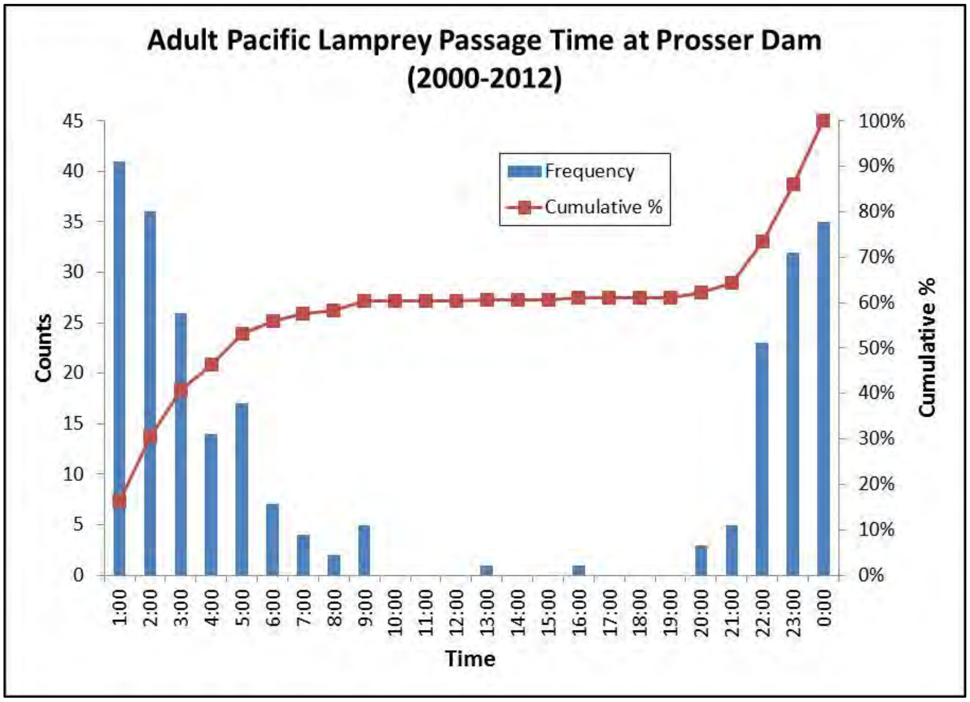

Figure F4. Adult Pacific lamprey passage time at Prosser Dam between 2000 and 2012 – as shown by other studies, the majority of passage was documented in the evening hours between 8pm and 9am.

Macrophthalmia

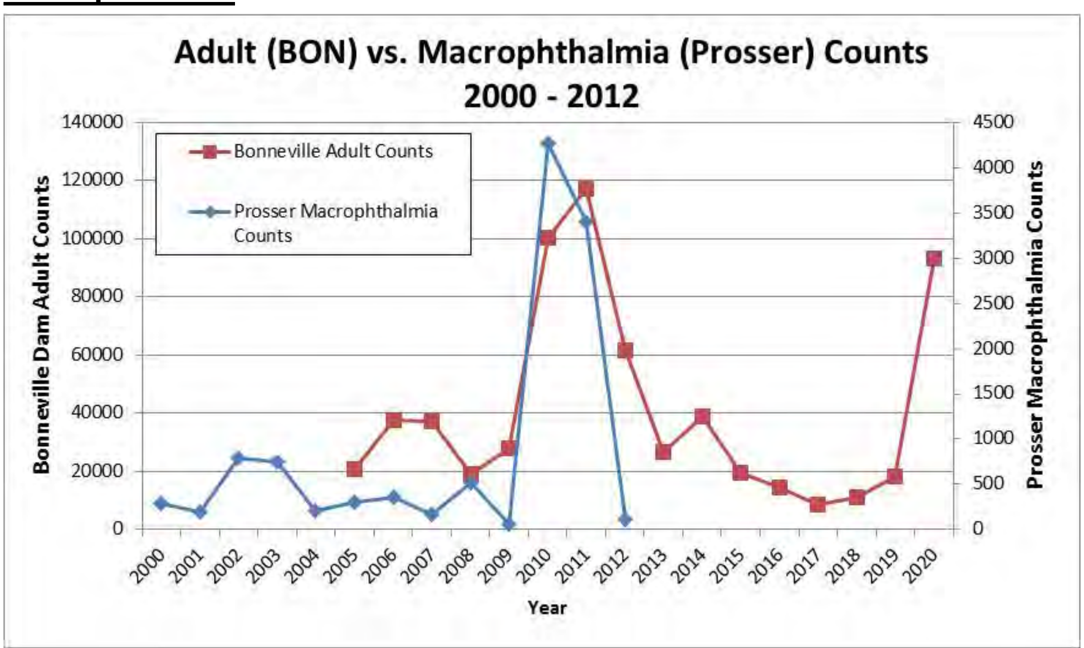

Figure F5. Macrophthalmia counts (extrapolated) from Prosser Dam facility vs. Bonneville adult counts between 2000-2012 (with a 8-year lag) – this indicates that macrophthalmia may be outmigrating as 7 year old juvenile, if the large adult return was responsible for the large outmigrants that was observed at the Prosser Dam facility (adults overwinter and then spawn, so

the 8 year lag will mean that the juveniles are 7 year old). Given the past adult counts, it is likely that outmigrant numbers will be relatively low for some years to come.

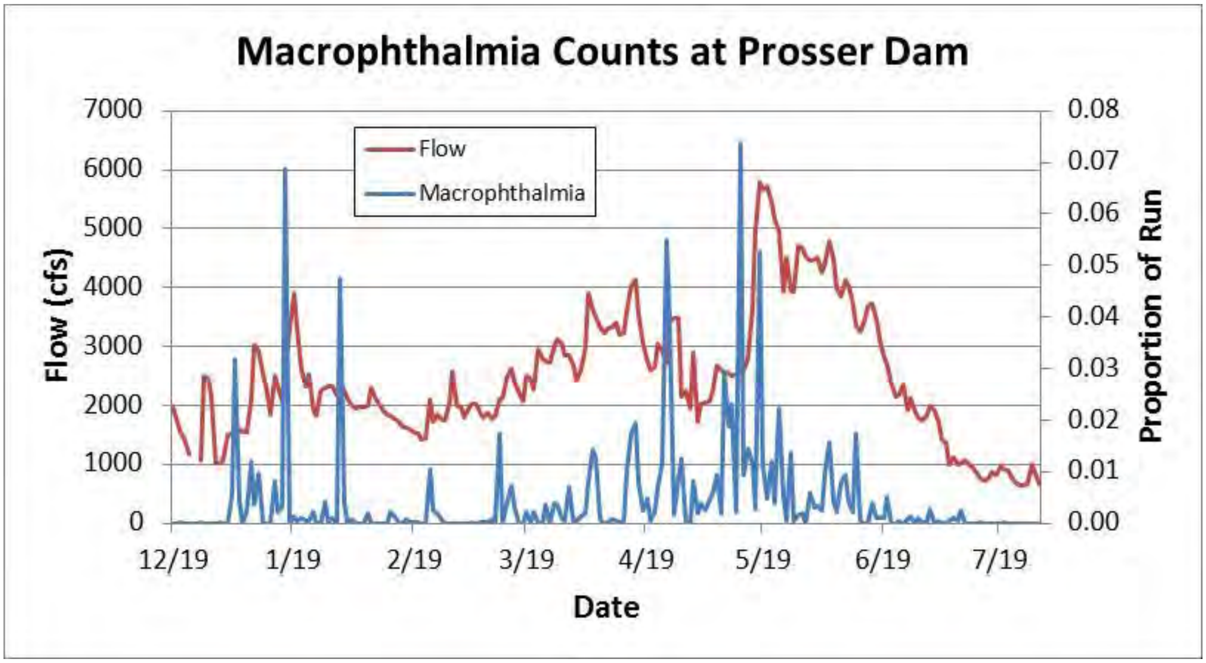

Figure F6. Proportion of the macrophthalmia run (13 years combined) during the juvenile fish collection season. Most of the high counts appear to be triggered by increases in river flow conditions.

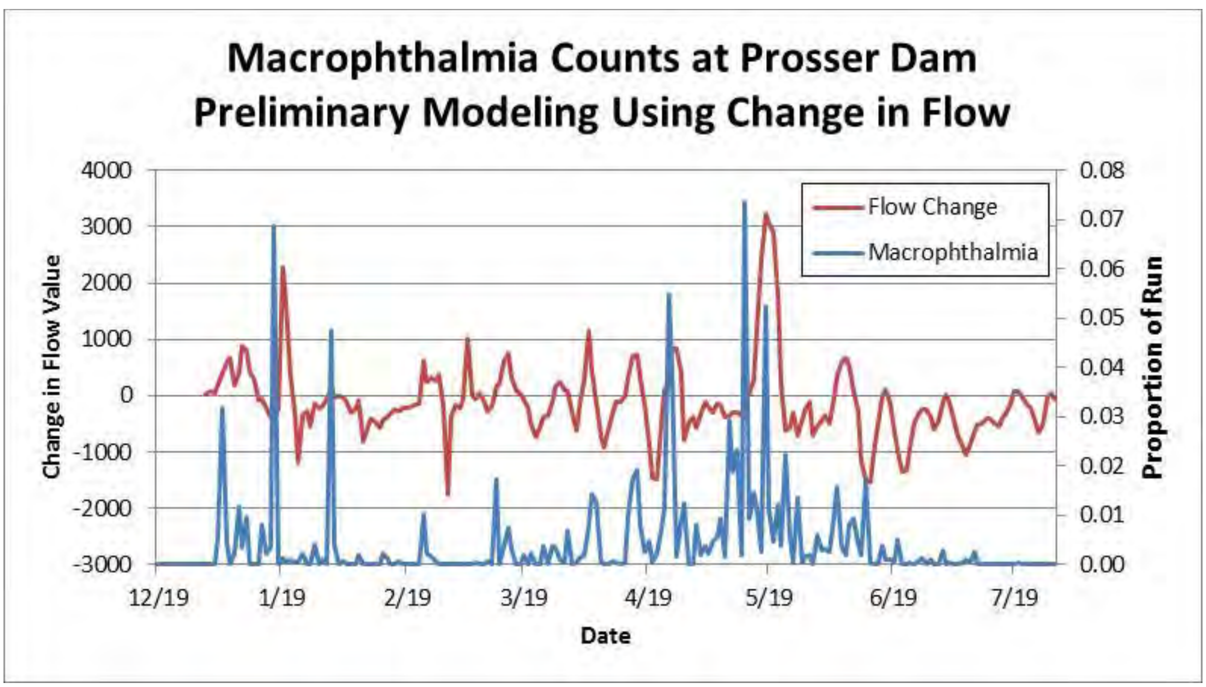

Figure F7. Macrophthalmia counts and preliminary modeling using flow change as a predictor

*A Western river lamprey (*lampetra ayresi*) was captured on January 23, 2014, which confirmed that this species also inhabits the Yakima River besides the two other lamprey species (Pacific lamprey and Western brook lamprey) (see **Appendix F1** for more information). Also, many of the lamprey captured later in the season in May and June were spawning and post spawned Western brook lamprey based on species identification. More monitoring is needed, but a significant portion of the early summer migrants may actually be adult Western brook lamprey instead of Pacific lamprey macrophthalmia.

<u>Larval/Juvenile Sampling and Salvage in Canals:</u>
Juvenile survey planning and sampling within Yakima River Subbasin irrigation canals were first initiated during the dewatering period in 2010 and are ongoing for 2011, 2012 and 2013 through cost sharing partnership and assistance from Bureau of Reclamation. Similar to the previous year, planning/coordination meetings between representatives of the YN and Reclamation was held in early October and sampling for 2013 occurred primarily between mid-October through the end of November, a period of approximately six weeks. More surveys will likely be conducted in Spring 2014, after spring snow melt season, to evaluate the status of overwintering lampreys in the canal system.

Figure F8 displays the total number of observed lamprey (combined totals of captured and missed larval/juvenile lamprey) above and below fish screens at each surveyed diversion in 2013[1]. A total of 1,765 lamprey were captured and 3,378 lamprey were observed at these 17 diversions. Based on site specific sampling density (mean value: 0.82 fish/m^2 above screens; 0.64 fish/m^2 below screens) and a crude conservative assessment of available Type I habitat (preferred larval lamprey habitat) area from each diversion (total: 13,746 m^2 above screens; 28,612 m^2 below screens), we estimate the total number of entrained lamprey within the Yakima River Subbasin to be close to 14,615 (6714 lamprey above screens and 7902 lamprey below screens). Although less fish are observed below fish screens at some individual facilities, the results in the effectiveness of fish screens in deterring lamprey entrainment are mixed at best (Figure F8). In fact, our analysis indicate that while values of fish density are slightly lower below screens, more lamprey overall reside downstream of the fish screens compared to upstream of them (Figure F9). When we compare size classes of lamprey, we see some clear difference in upstream vs. downstream groups (Figure F10). There is a distinct spike in the proportion of small size class larvae (0-50 mm) in the "Below Screens" group, whereas the large size class larvae (>90 mm) are much more prevalent in the "Above Screens" group. For more

[1] Lamprey numbers described in these figures refer to either of the two species of lamprey present in the subbasin – Pacific lamprey or Western brook lamprey. In many instances, identification of each individual fish was not possible due to the large number of lamprey being salvaged and size limitations (larvae smaller than 50-60 mm generally cannot be identified to species).

detailed analyses of these canal survey results, including the effects of screen type, mesh size, and paired size class analysis, see **Appendix F2**.

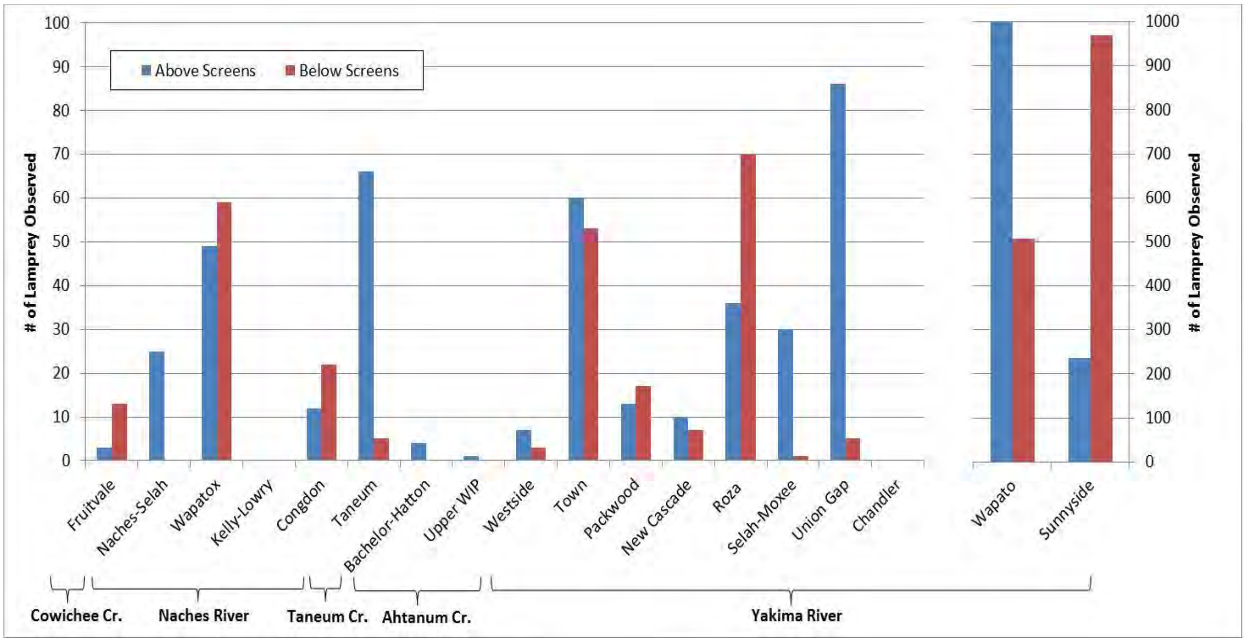

Figure F8. Total number of lamprey observed above and below fish screens for each diversion surveyed in the Yakima River Subbasin. The diversions are ordered from upstream to downstream (left to right) within their respective watersheds; bar graphs for Wapato and Sunnyside diversions, however, were placed all the way to the right next to a secondary y-axis due to their substantially higher values.

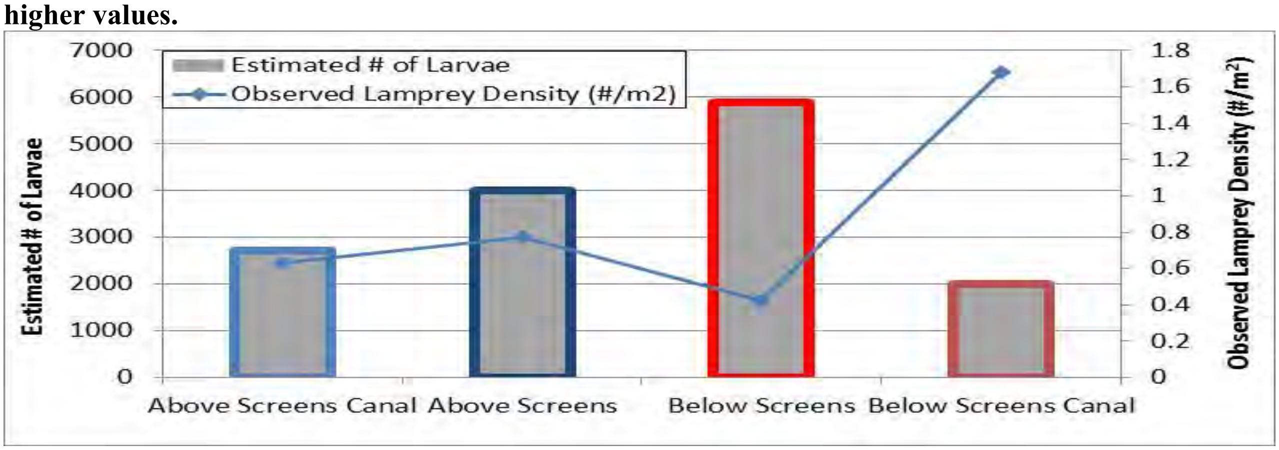

Figure F9. Estimates of the total number of entrained lampreys within the Yakima River Subbasin by location based on site specific habitat availability (primary y-axis) and density of observed lamprey (secondary y-axis). "Canal" refers to the habitat away from the fish screens.

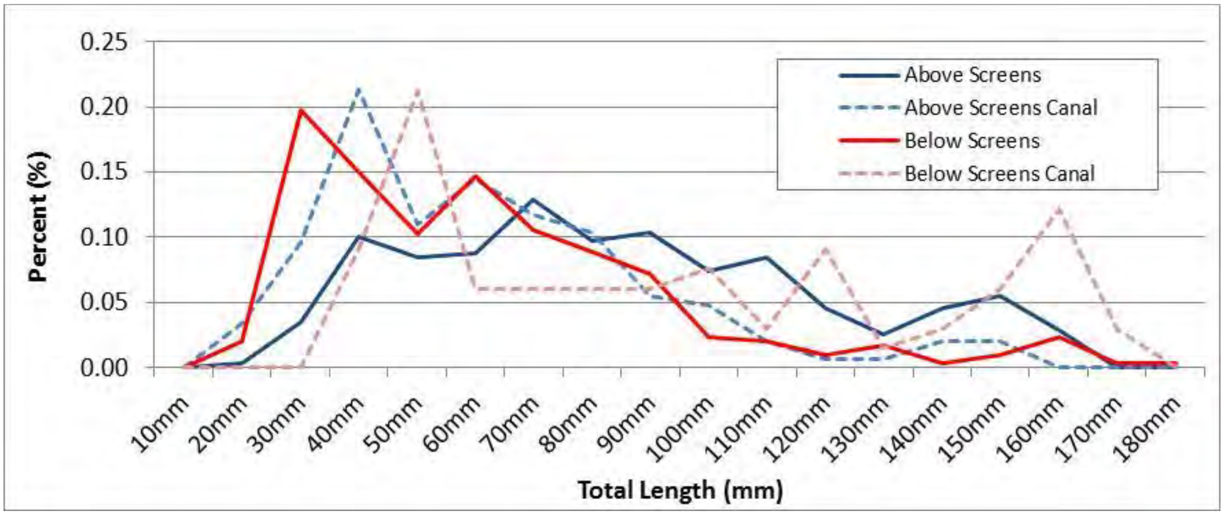

Figure F10. Histogram of size classes for all sampled lamprey grouped by its captured location.

Sunnyside and Wapato diversions have many things in common: 1) they are both large scale diversions (1300 cfs and 2000 cfs, respectively), 2) they are located in close proximity of each other, and 3) they both entrain a lot of juvenile/larval lamprey. However, there are also distinct contrasts between the two: 1) Wapato entrains more larval lamprey directly upstream of the screens than downstream, 2) Sunnyside entrains more larval lamprey directly downstream of the screens compared to upstream, and 3) more larval lamprey appear to reside further downstream in the canal in Wapato (18.7 miles) compared to Sunnyside (1.7 miles). In 2014-2015, we thought it would be worthwhile to carefully examine the two sites using all available data, and see if any of these contrasts and comparisons can be logically explained through the insights we have gained over the years.

Photo F1: Hundreds of 1-ton sediment bags ready to be shipped off site at Sunnyside Diversion are indicative of the voluminous amount of fine sediment collected behind the fish screens there.

Larval/Juvenile Entrainment Studies:

After some discussions among the project partners in 2012-2013, Sunnyside and New Rez diversions were selected as suitable sites for focused, intensive monitoring primarily because these two sites have been found to entrain the largest numbers of juveniles from past monitoring (Figure F8). For macrophthalmia (smolt stage) entrainment evaluation, Chandler fish counting station (part of Chandler Diversion) will most likely be the best location as hundreds of macrophthalmia naturally migrate through this area and get counted each year. There are many biological questions that needs to be answered, including 1) when are lamprey entering the diversion and past the screens and/or the bypass system, 2) what is the mechanism behind screen passage, 3) approximately what proportion of the overall population enter these canals, and 4) how many of the lamprey are able to overwinter and reside over multiple years within these canals? This mechanism is most likely different for larval and macrophthalmia lamprey.

A field visit to Sunnyside Diversion was made by Reclamation (Susan Camp, Zach Sutphin, and Eric Best) and the YN (Ralph Lampman and Patrick Luke) staff on November 5, 2012. During this visit, several monitoring strategies that may be applicable to this particular site was brainstormed and discussed. The consensus was that although there was no catch-all solution that would answer all the given questions, 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 we discussed specific locations where these types of gear could be employed.

Before the start of the irrigation season in mid-March, 2013, we explored means to survey for larvae in the reservoir water just upstream of major diversion headgates. The objective was to assess whether many of the larvae move into the canal at the beginning of the irrigation season when they first open the head gates. A lot of fine sediment seem to accumulate directly upstream of the head gates over winter time and it is possible that many larvae are being entrained at this occasion. We contacted and coordinated with both the Pacific Northwest National Laboratory and USFWS to see if they could help us with the deep water sampling, but unfortunately we were not able to conduct those surveys for 2013 due to time constraints. In lieu of this deep water electrofishing, the YN conducted a pilot assessment of the head gate inlet conditions at Sunnyside Diversion on March 3, 2013, using dry suits and fine mesh nets. Due to the difficulty in surveying with a net in deep water, we were able to survey only 15 sites (0.3m x 0.3m each totaling 1.35 m^2). Based on the lamprey captured (5 larvae) and available Type I habitat (196 m^2), we estimated the total number of larvae at this site to be approximately 725. However, most of the area directly in front of the head gate was too deep to evaluate the presence of Type I habitat. On August 20, 2013, we conducted a standard electrofishing survey in the shallow water habitat at this site, but did not capture any larvae. See **Appendix F3** for more detailed information.

In 2013-2014, the YN planned for and conducted intensive entrainment monitoring during the irrigation season at two key facilities (Sunnyside and Congdon diversions) to enhance our understanding of entrainment mechanism. At Sunnyside Diversion, we placed sediment lamprey traps upstream and downstream of the rotary drum fish screens to evaluate lamprey dispersal and movement within the facility. Two students (a PhD student from Portland State University and an undergraduate student from Heritage University) were primarily in charge of this project. Although trapping larval lamprey was a lot more difficult than previously thought, the students identified and confirmed locations where larval lamprey can be readily found during the irrigation season. In fact, more larvae were found on the downstream side of the fish screens. For more detailed information, see **Appendix F4**.

We also monitored larval/juvenile lamprey movement past the fish screens into the canal for the very first time by deploying an 8-foot rotary screw trap 110 m downstream from the Sunnyside fish screens. As many as 14 fish species were detected from this trapping effort that started in August, but only one lamprey (Western brook lamprey transformer) was ever found. It is not clear whether the number of lamprey migrating down the canal is naturally low or the trap efficiency is low. In future years, we recommend setting up the screw trap in an alternate location within the Sunnyside canal, such as directly downstream of a grade control weir to maximize trap efficiency, or an alternate site, such as Wapato Diversion, which may potentially contain more fish migrating down the canal due to lack of habitat immediately downstream of the fish screens. Furthermore, being able to start the monitoring prior to the high flow season in spring will be critical as well.

At Congdon Diversion, a short-term mark-release-recapture study was conducted with the help of Jarod Hutcherson (BOR Denver Colorado Office) and others to further our understanding of lamprey entrainment mechanism with wire cloth mesh rotary drum screens. We selected Congdon Diversion because we needed a small site that allowed us to track fish movement practically throughout the entire site. It was also the best surrogate site for Sunnyside Diversion in terms of screen type, flow conditions, and fine sediment availability. As shown in Figure 4, we discovered that the modes of behavior displayed by lamprey highly depended on the size classes of the fish; the majority of large larval lamprey were able to either escape or avert the fish screens, whereas medium and small larval lamprey displayed a variety of behavior including rolling, impinging, and passing. However, despite the high percent of entrainment behavior shown by the medium and small size class larvae (53.3% and 100.0%, respectively), less than 3% of the released lamprey appeared to move towards either the canal outflow or bypass route. This indicates that these larval lamprey are being sedentary and burrowing into the available fine sediment upstream and downstream of the fish screens in the short-term. This work complements and supplements the USGS efforts to study the entrainment mechanism of juvenile lamprey within the lab settings by demonstrating the practical implications of larvae behavior in the field. For more details on this study, see **Appendix F5**.

Table F1. Definition for the six modes of behavior that juvenile/larval lamprey displayed at Congdon Diversion (Naches, WA).

Behavior Category	Definition
Unseen	Unseen or disappeared before we could identify what behavior it displayed
Escaped	Moved away and disappeared from fish screen without approaching the screen at all
Averted	Approached the screen at one point, but actively swam away from it before disappearing
Rolled	Approached the screen, became impinged, and rolled over at least above the water line as the screens rotated
Impinged	Approached the screen, became impinged, and but moved through the mesh screen before rolling over the water line
Passed	Approached the screen and moved through the screen without any impingement

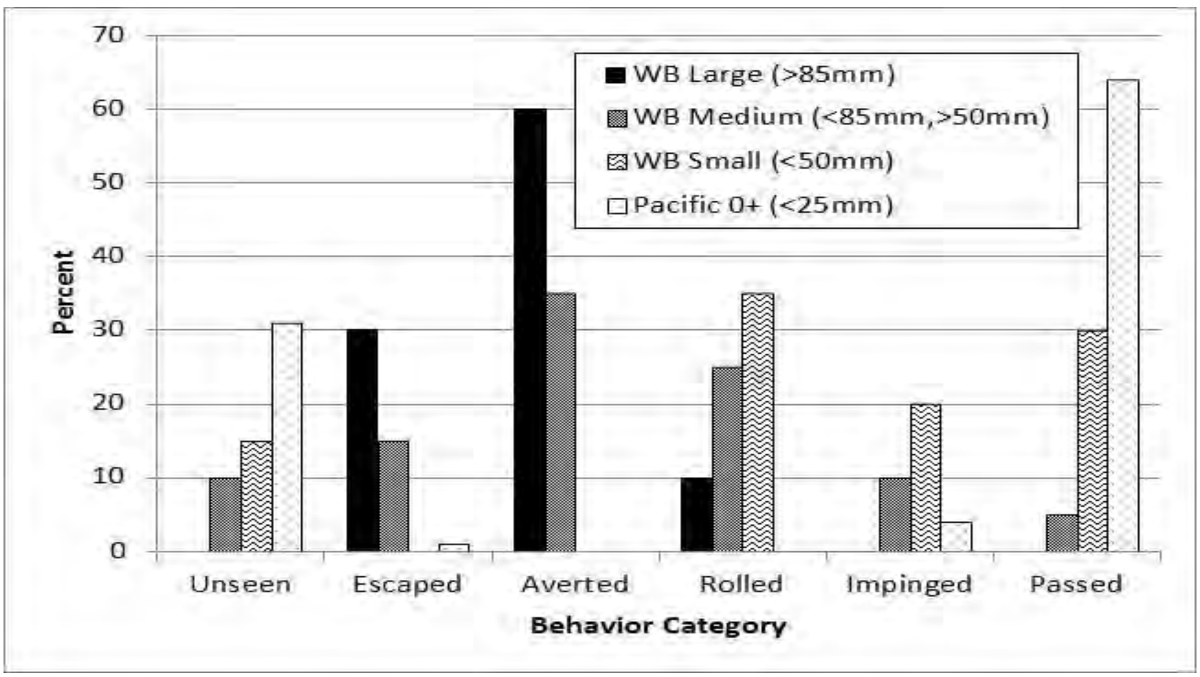

Figure F11. Percent histogram of the six modes of behavior displayed by juvenile/larval lamprey at Congdon Diversion (Naches, WA) after releasing them in front of the rotary drum screens. See Table 1 for the definition of the modes of behavior.

The YN is also monitoring juvenile entrainment, survival, and migration rates by pit tagging macrophthalmia captured at Chandler Juvenile Fish Collection Facility (Prosser, WA) between January-May using 8 mm Pico tags in 2014. The YN personnel obtained valuable training for pit tagging juvenile lamprey from the Umatilla Tribes in November, 2013.

We would like to thank the many partners that helped us conduct these entrainment studies, including Jim Trull, Dave Bos and Tim King (Sunnyside Valley Irrigation District), Robert

Smoot (Yakima Valley Canal Company), Joel Hubble (BOR), Arden Thomas (BOR), David Child (DC Consulting), Gaylord Mink (Photographer/Filmmaker), and Al Potter (Hydro Engineering). The partnership and collaboration made these creative projects possible, and we could not have done this without everyone's assistance.

Photo F2: Video clip snapshot of a larval lamprey interacting with the wire cloth mesh screen at Congdon Diversion during the release immediately in front of the screens (special thanks to Gaylord Mink for all the filming support).

In addition, with the help of partners (CRITFC, USGS, Pacific Northwest National Laboratory), the YNPLP has been investigating the potential impacts of water quality (toxicants and pollutants) on Pacific lamprey (see **Appendix F6** and **F7** for more information).

G. Work Element 161 – Disseminate Raw/Summary Data and Results and Participation in Regional Efforts

The YN has continued to maintain a strong presence in supporting and guiding Pacific lamprey recovery in the Yakima River Subbasin and in the Columbia River Basin. The following outlines some of the key activities YN staff has been involved with in 2013-2014:

<u>Coordination with Bureau of Reclamation in the Yakima River Subbasin</u>

Technical representative for both the YN and Reclamation continue to meet regularly on an "as-needed" basis to coordinate studies and findings on Reclamation facilities, primarily in the lower Yakima River. These meetings have focused primarily on (1) juvenile collection in irrigation ditches, and (2) initial - or pilot -activities associated with juvenile entrainment into irrigation ditches. In relation to adult passage, important discussions occurred concerning alternative options for lamprey passage devices to be employed on both Prosser and Sunnyside dams. Initial designs were developed by Mr. Jim Simonson (contracted by the YN) and Mr. Pat McGowan (Reclamation engineer) in coordination with technical representatives from the YN, Reclamation, USFWS and others (see **Appendix G1** and **G2** for more information on the new passage improvement designs) and a passage task force was created to tackle this task. This discussion will continue in 2014-2015 with the intent to implement one or more of these experimental structures in the foreseeable future.

Coordination with the USACE in the Columbia River Basin

Technical representatives of the YN continues to meet quarterly with technical representatives of the USACE with the single intent to improve juvenile and adult passage conditions through the FCRPS hydro-electric facilities on the mainstem Columbia River. Over the past year the emphasis has been in the development of a new 5-10 year planning document which will incorporate (1) monitoring newly constructed passage structures at Bonneville, John Day and McNary dams, (2) design and development of a micro-tag for future juvenile research and (3) prioritization of research for both juvenile and adult passage interests. Many of these considerations are also well coordinated with the USACE sponsored Study Review Work Group (SRWG) which meets periodically throughout the year to review and recommend priority future lamprey studies. Development and employment of the micro-tag will be fundamental in future work at Reclamation facilities.

Coordination with the CRITFC in the Columbia River Basin

A considerable amount of planning and coordination has occurred with CRITFC in the development of the "Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin." In addition, the YN policy and technical representatives met with the CRITFC Pacific Lamprey Tribal Task Force on five different occasions. Typical agenda items associated with these meetings include, but are not limited to the USFWS Conservation Agreement, progress in passage at the FCRPS facilities, progress in adult and juvenile supplementation, and progress between the Umatilla Tribes, YN, and Reclamation in the Umatilla and Yakima River subbasins. Without doubt, of greatest interest to CRITFC and tribal policy representatives is when we are going to accelerate implementation of passage structures. YN is also collaborating with CRITFC and USGS on a toxicological study of larval/juvenile lamprey and fine sediment from their rearing habitat.

Coordination with the USFWS: Conservation Initiative

In June, 2011 the USFWS initiated a Conservation Agreement in which both Reclamation and the YN are signatories. To date, little progress has been made towards the advancement of this Conservation Initiative. Both technical and policy representatives are communicating with the USFWS at multiple administrative levels to strengthen the commitment of this agreement. With respect to the Yakima River Subbasin, the YN recognizes that multiple threats exist that limit abundance, productivity and spatial distribution throughout the subbasin and that multiple agencies, jurisdictions and publics are needed to realize recovery objectives. In 2014-2015, the YN anticipates working closely with these multiple partners to accelerate activities at the subbasin scale, within the context of the Conservation Initative.

The YN spearheaded the effort in formulating the “Pacific Lamprey Actions Table,” which stemmed from the Lamprey Summit III in 2012. Basin-specific Pacific Lamprey Action Plans are being completed for other basins as well, and we are working directly with all partners that are actively involved in Pacific lamprey management in these other subbasins (Wenatchee, Entiat, Methow, White Salmon, etc.) to determine the primary actions needed for local population recovery. **Appendix G3** is the most updated draft of the Pacific Lamprey Actions Table for the Yakima Subbasin based on the 2014 subbasin meeting. Additionally, we will continue regional collaboration towards development of a regional RME framework and continue to develop subbasin specific Action Plans within this "framework".

Coordination with the Lamprey Technical Work Group (LTWG)

Technical representatives continue to meet periodically with the LTWG; however, for the most part this work group has been relatively inactive over the past two years. With respect to the Yakima River Subbasin, one of the primary considerations brought to the LTWG over the past year has been with the introduction of the “Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin” initiated by the YN and Umatilla Tribes and coordinated by the CRITFC. Substantial efforts occurred throughout 2013-2014 in the development of this Draft document, which has been updated and revised after input from multiple federal and state agencies. The latest draft was completed in March, 2014 and will be updated periodically as new information becomes available. A significant component of this document outlines both adult and juvenile supplementation research which will occur within the Yakima River Subbasin, including elements of future research funded through this project. The importance of standardizing larval/juvenile lamprey sampling methods among the various agencies and entities is another topic that the YN have emphasized and proposed through the LTWG, but very little progress has been made consecutively as a team. Two conference calls were initiated early in 2013 to discuss the variety of objectives and methods associated with larval/juvenile sampling. A power point presentation was later presented by the YN staff in August, suggesting core elements for a standard survey, but the topic has been put on hold at the moment.

Coordination with the Mid-Columbia Public Utility Districts

Both YN policy and technical representatives participate and provide significant leadership in implementation of PUD mitigation associated with their FERC licenses. The YN technical representatives regularly attend monthly meetings associated with the implementation of each of the PUD's Pacific Lamprey Management Plans. None of these activities occur directly within the Yakima River Subbasin.

H. Work Element 119 – Manage and Administer Projects

The YNPLP continues to be substantially involved in all local and regional activities associated with Pacific lamprey research and recovery efforts. These include, but are not limited to activities undertaken by the US Army Corps of Engineers (both Walla Walla and Portland Districts) associated with adult and juvenile passage at the FCRPS mainstem hydroelectric projects, Mid-Columbia Public Utility District FERC license implementation of associated Pacific Lamprey Management Plans, through all activities within the CRITFC, including the development and submission of the Tribal Pacific Lamprey Recovery Plan (CRITFC 2011), support and development of the USFWS Pacific Lamprey Conservation Agreement, support and development of Reclamation's *Effects on Pacific Lamprey (Lampetra tridentata)* and Reclamation's *Pacific Lamprey Plan,* and with the Lamprey Technical Work Group. Provided below is a brief summary of various activities that we have been involved with in 2013-2014:

Army Corps of Engineers: The YNPLP meets quarterly with the US Army Corps of Engineers, CRITFC and CRITFC member tribes to evaluate and prioritize adult and juvenile lamprey issue associated with the Federal Columbia River Power System. These meetings are a direct result of the 2008 Fish Accords with the primary issue discussed involving both adult and juvenile passage over these facilities. Another key element of these meetings is the identification and development of additional research topics that the ACE / Tribal workgroup supports through the annual Study Review Work Group for future funding from the Columbia River Mitigation Funds.

Mid- Columbia Public Utility Districts: Each of the three Public Utility Districts (Grant, Chelan and Douglas counties) have Pacific Lamprey Management Plans as a component of their FERC licenses. Although these management plans pertain specifically to the Project Areas of the individual PUDs there is a strong linkage regionally to these activities. The YNPLP meets monthly with each of the PUDs to review progress and to initiate new activities associated with the Management Plan objectives

USFWS Conservation Assessment and Agreement: The YNPLP has worked closely with the USFWS during the development of the Conservation Initiative and more recently with the development and signing of the Conservation Agreement, which was be a primary topic for the upcoming Lamprey Summit, co-sponsored by the CRITFC and the USFWS. The YNPLP will take a leading role in establishing and prioritizing restoration actions within the Yakima Basin and all YN Ceded Lands at large in close collaboration with USFWS and all other partners.

Pacific Lamprey Technical Work Group: The YNPLP is an active member of the Pacific Lamprey Technical Work Group, whose meetings are held biannually focusing on regionally important lamprey coordination / conservation projects. We intend to work closely with this group through the development of the Supplementation Framework discussed above.

The YNPLP is working closely with the USFWS towards the implementation of an annual radio-tagging study of adult Pacific lamprey. The primary objective of this study is to identify adult movement and passage characteristics within the Yakima River and at irrigation facilities, respectively. The USFWS is primarily responsible for implementation of this study - which is being funded through a cost share agreement between the YN, USFWS and the USACE (Seattle District). The USACE provided to the USFWS approximately $90,000 to implement this study, in addition to direct funding of approximately $50,000 from Reclamation. In addition, the Northern Wasco County Public Utility District contributed $50,000 to purchase the radio tags needed for the ongoing study. A similar arrangement and funding level is anticipated for the years 2012-2013. Interim findings for this study can be found in Appendix E1 “Passage of Radio-tagged Adult Pacific Lamprey at Yakima River Diversions 2012 Annual Report.”

USGS Screening Criteria for Juvenile Lamprey: The YNPLP is working closely with USGS (Dr. Matt Mesa) in furthering our understanding of entrainment mechanism of Pacific lamprey at diversion screens. This investigation will most likely require a combination of both in-the-field investigations and lab-oriented studies (which allows for intensive monitoring with much fewer complications and variables). The USGS lab in Cook, WA, now has a test flume, in which various types of real-life diversion screens (such as drum screens with bypass structure) can be tested for impacts on juvenile lamprey. Efforts will be made in 2013 to take advantage of this great opportunity to advance these studies and strengthen our partnership.

Bureau of Reclamation “Project Alternatives Solution Study”: In collaboration with Bureau of Reclamation and USFWS, the YNPLP is working on the implementation of adult Pacific lamprey passage improvement at Prosser Dam and other lower Yakima River irrigation diversion dams. Starting this year, we are implementing a 3-year passage improvement project targeted at Prosser and Horn Rapids dams (the two lowermost dams in the Yakima basin) using primarily a USFWS fish passage grant. We are also in the process of scheduling a “Project Alternative Solution Study (PASS)” through Bureau of Reclamation in which over a period of 3-4 days, experts from various agencies will propose and assess an extensive list of alternative solutions for improving adult lamprey passage in the Yakima basin. Once we finish this, we will likely schedule another PASS for juvenile passage/entrainment, potentially in 2015. The over-arching objective of these rapid assessments are to anticipate potential funding needs, such that steady progress can be made in correcting passage issues as they are identified.

I. Work Element 99 – Outreach and Education

Technical representative of the YN were actively involved with public outreach, providing presentations to professional meetings and local schools and organizations in 2013-2014. Outreach activities play a vital role in informing and educating a diversity of audiences about the importance of lamprey to the YN tribes and stream ecology in general. Given the widely held misconceptions that stems from invasive sea lamprey in the Great Lakes, it is especially more important to clear those infamous stereotypes and inform audiences of their true roles in food chains as well as YN culture. We have targeted a wide range of audiences from early childhood to elders. We have connected greatly with many of the local school districts to expose and familiarize students with lamprey through "Lamprey in the Classroom" and restoration activities, such as adult translocation projects. We also had the opportunity to work with a film crew for a show on Animal Planet in mid-May to demonstrate "eeling" or lamprey harvest. Patrick Luke and Dave'y Lumley participated in the Animal Planet show titled "No Limits" and this is scheduled to air on August 18, 2014. A list of outreach events from 2013 are shown below in Table I1.

Table I1. Summary of Yakama Nation Fisheries Pacific Lamprey Project outreach and education events in 2013.

Date	Event	Location	Presenter(s)	Audience	# of People Reached
3/7/2013	Rivers Operator Meeting	Yakima, WA	Ralph	Irrigation Districts, Scientists	30
3/19/2013	Columbia Gorge Fisheries & Watershed Sci. Conf.	Hood River, OR	Ralph	Scientists	100
3/20/2013	Lamprey Shuffle White Swan Longhouse	White Swan, WA	Patrick	YN Tribal Members	50
3/22/2013	Yakima Basin Joint Board Meeting	Yakima, WA	Ralph	Irrigation Districts	30
4/15/2013	Youth Career Fair	Yakima, WA	Patrick, Emily	High School / College	>50
4/17/2013	Toppenish Longhouse Youth Meeting	Toppenish, WA	Patrick	YN Tribal Members	30
4/20/2013	Salmon Run	Ellensburg, WA	Ralph, Emily	Public	>100
4/30/2013	Lamprey Translocation Release	Toppenish / Satus Cr	Patrick, Ralph, Dave'y, Tyler, Emily	Public	50
5/2/2013	Lamprey Translocation Release	Ahtanum Cr	Patrick, Ralph, Dave'y, Tyler, Emily	Ahtanum High School	40
5/3/2013	Prosser Tour	Prosser Fish Hatchery	Dave'y, Tyler	Sunnyside Elementary School	100
5/14/2013	Lamprey Translocation Release	Toppenish Cr	Patrick, Ralph, Dave'y, Tyler, Emily	Public+Newspaper	30+>2,000
5/15/2013	Lamprey Translocation Release	Satus Cr	Patrick, Ralph, Dave'y, Tyler, Emily	Public	30
5/17/2013	Animal Planet Shooting	Willamette Falls	Patrick, Dave'y, Emily	Public	>50,000
5/20/2013	Prosser Tour	Prosser Fish Hatchery	Patrick, Ralph, Dave'y, Tyler	Middle School	60
5/21/2013-5/22/2013	Salmon Summit	Prosser Fish Hatchery	Patrick, Ralph, Dave'y, Tyler	K-12	>200
5/22/2013	Elders Luncheon	Legends Casino	Patrick	Elders	>100
5/23/2013	Lamprey Translocation Release	Ahtanum Cr	Ralph, Dave'y, Tyler, Emily	Ahtanum High School	40
6/7/2013	Treaty Day	Toppenish, WA	Patrick, Emily	YN Tribal Members	>500
6/12/2013	Yakima B Sci. & Manag. Confer.	Ellensburg, WA	Ralph	Scientists	100
6/27/2013	Prosser Tour	Prosser Fish Hatchery	Ralph, Dave'y	Summer School	30
8/7/2013	Luna the Lamprey	Facebook	Patrick, Ralph, Emily	Public	>1,000
8/18/2013	Prosser Tour	Prosser Fish Hatchery	Ralph, Emily	Japanese Exchange Students	30
8/20/2013	Backpack Giveaway	YN Cultural Center	Patrick, Emily	K-12	>500
8/28/2013	NSA Coordinator	Prosser Fish Hatchery	Ralph, Vincent, Basma	Scientist	1
8/30/2013	YN Family Fishing Day	Marion Drain	Patrick, Emily	YN Tribal K-12	200
10/3/2013	Guest Speaker	Toppenish, WA	Patrick	Toppenish Middle School	80
10/28/2013	Whitman College Filming	Prosser Fish Hatchery	Ralph, Dave'y	Public+Filming	2+>100
11/8/2013	Lamprey in the Classroom	Prosser Fish Hatchery	Ralph	Yakima Middle School	100
11/23/2013	USFWS Hatchery Mngmt. Training	Tricities, WA	Patrick	Scientist	75
12/9/2013	The Lost Fish (Lamprey Film Premiere)	YN Cultural Center	Patrick, Dave'y	Public	30
				Total Estimate	**55,792**


Photo I1: Ralph Lampman showing and teaching middle school students from Yakima, WA, about adult lamprey and their biology.

J. Work Element 174 – Propagation and Rearing Plan

As a result of the "First International Forum on the Recover and Propagation of Lamprey" held in 2011, a wealth of useful information for lamprey propagation was shared and discussed among the international participants. The knowledge that was shared and the support we gained from the network of participants really helped set the stage for the YN to embark on the new exciting research. In 2012, the YN succeeded in conducting a pilot project to successfully hold, propagate, incubate, and rear juvenile larvae. In 2013, protocols and best management practices were refined further to rear over 30,000 larvae using available space at Prosser Fish Hatchery and learned more about the critical life stages (prolarva to larva stage – at the onset of the feeding and burrowing stage) that are considerably more subject to high mortality rates.

Considerable planning has occurred in preparation of pilot propagation research activities. The YN is working in close coordination with the CRITFC and the Umatilla Tribes in the development of a broad scale Research, Monitoring and Evaluation (RME) Framework towards Pacific lamprey supplementation generally and artificial propagation specifically. We made the first draft available in September, 2013, to federal (USFWS, USGS, and USACE) and state (ODFW, WDFW, and IDFW) agencies and are planning for a wider distribution once the document is reviewed and updated appropriately. We anticipate this Framework document (see **Appendix J1**) will be the basis from which the tribes move forward for additional research and funding towards potential future supplementation and lamprey recovery efforts.

In conjunction with the drafting of the Supplementation Framework, we have also started developing a Research Monitoring and Evaluation (RME) strategy for the upper Columbia River in partnership with CRITFC and member tribes (at this time, it focuses on Upper Columbia, but we expect to encompass the entire Columbia River over the next few years). This planning effort, with a clear focus on activities within the Yakima River basin, is anticipated to be vetted through the Northwest Power and Planning Council (NPCC) and the Independent Scientific Review Board, such that activities associated with long-term status and trend monitoring and research into potential supplementation activities can move forward. Much of the funds that supported this initial work came from the YN and CRITFC and other large scale cost-share projects. It is anticipated that during 2014, much of this work relevant to the Yakima River basin, will be incorporated in the NPCC tri-annual Amendment Process.

K. Work Element 176 – Produce Hatchery Fish / Research into Juvenile

In 2012, the YN succeeded in conducting a pilot project to successfully hold, propagate, incubate, and rear juvenile larvae. Strong partnership with the Umatilla Tribes (such as Mary Moser) was extremely valuable. Important highlights from 2012 include:

- Propagation success (namely fertilization and hatching) appeared to depend on four main variables: 1) quality of gametes (sexual maturation level, being neither immature nor too ripe); 2) seasonality (eggs' adhesiveness seem to vary depending on whether it was early or late in the season); 3) water quality (water with high silt content made it difficult to keep high survival rates); and finally 4) incubation methods.
- Although many methods of incubation can successfully incubate viable eggs, such as McDonald jars, flow-through buckets, and the Japanese "Tupperware" technique, among the most successful methods we discovered were 1) modified heath trays, 2) Eager upwelling jars, and 3) spawning mats within incubation troughs.
- Feed ready larvae cannot be reared and fed indefinitely in open water (without the fine sediment), although from a hatchery standpoint, adding fine sediment contributes to a lot of problems, such as the difficulty in regularly monitoring survival and growth.

From this actual hands-on experience, as well as the countless trials and errors, valuable lessons were learned, and this created a path forward for future research. Over a 10-week period between April 12 and June 14, 2013, 41 adults were propagated successfully at Prosser Fish Hatchery. In 2013, the following was discovered:

- Sexual maturation improved greatly by switching the source of water from primarily well water (2011-2012) to primarily river water (2012-2013).

- Fertilization can be improved by 1) maintaining fertilization wait time at three minutes (compared to 6 and 12 minutes), 2) mixing eggs and milt before adding water, and 3) not rinsing eggs. However, when we examined hatching success from the same eggs, 1) mixing eggs and milt after adding water and 2) rinsing eggs contributed to higher success, showing that initial (fertilization) and final (hatching) success may not always be in harmony with each other.
- Limited success in fertilization was observed with 1) dead adults (male and female), even if they have died within a 24-hour period and 2) milt that was preserved for longer than a day.
- XperCount – a device sold by XpertSea that automatically counts small fish/larvae/eggs within a 5-gallon bucket - showed great promise with lamprey prolarvae counting. Egg counting was difficult due to its adhesive nature (preventing eggs from laying flat). With prolarvae, more calibration work needs to take place before it can be used with maximum accuracy (>95% confidence). The difficulty lay in the fact that prolarvae needs to be initially counted manually in order to calibrate and improve the equipment's accuracy. Counting 200,000 prolarvae manually can take an enormous amount of time, so methods of estimating counts through multiple subsamples were developed over time.
- Larval feeding trials from large outside tanks indicate that survival is improved in 1) trough tanks compared to circular tanks, 2) tanks containing fine sediment from diversion (with natural, rich organic material) compared to Prosser Fish Hatchery plain sand, and 3) a combination of salmon carcass and yeast feed compared to yeast only feed.
- Larval feeding trials from small 10 gallon aquarium tanks show that growth may be limited in tanks with yeast only feed compared to lamprey carcass feed, hatchfry encapsulon feed (Argent Chemical Laboratories), or a combination of yeast and lamprey carcass or hatchfry encapsulon feed.

In addition, we have experimented and evaluated the use of VIE and pit tags in tracking individual lamprey over time. Considering that only larger ammocoetes can be tagged with pit tags (8 mm full duplex pico tags – not practical with larvae <60mm), VIE tagging is likely the best known way to tag smaller larval lamprey. We have shown that even 30 mm long larvae can be successfully tagged and monitored over a long period of time (see **Appendix K1** for more information). Through the work of producing artificially produced larvae, we have documented changes in tail features over time, which is a key element for identifying Northwestern USA lamprey species. This has allowed us to see gradual changes in tail features as the larvae grow and understand the difference between Pacific lamprey and Western brook lamprey at various size ranges (see **Appendix K2** for more information).

Photo K1. Prolarvae (7 mm) slowly absorbing their yolksacs from the anterior region.

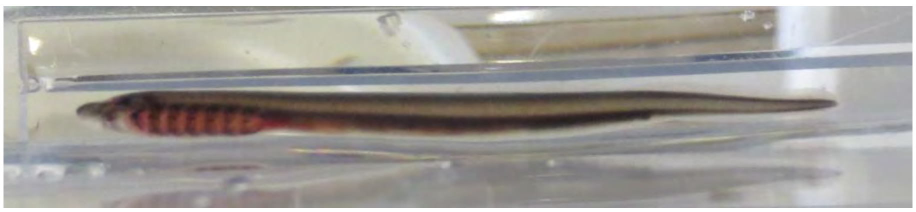

Photo K2. One of the larger larvae (52 mm) from the 2012 propagation efforts (+1 age class) in January 2013.

L. Work Element 132 – Annual Progress Report

The Annual Progress Report for the period March 2012 through February 2013 refers to this summary report and covers all the work elements that are part of the contract. This report summarizes project goals, objectives, complete and incomplete diverables, problems encountered, lessons learned, and the information gathered, synthesized, and updated to assist in long term planning.

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IV. Appendices

Appendix D1 – Yakima Subbasin Larval Lamprey Survey Report

Appendix D2 – Methow Subbasin Larval Lamprey Survey Report

Appendix D3 – Klickitat Subbasin Larval Lamprey Survey Report

Appendix D4 – White Salmon Subbasin Larval Lamprey Survey Report

Appendix D5 – Lower Columbia Tributary Survey Report

Appendix D6 – Upper Yakima Larval Lamprey Rafting Survey Report

Appendix E1 – Passage of Radio-Tagged Adult Pacific Lamprey at Yakima River Diversion Dams, 2013 Annual Report, Phase 2: Sunnyside and Wapato Dams (USFWS)

Appendix F1 – Assessment of Larval/Juvenile lamprey Entrainment in Irrigation Diversions and Canals in the Yakima Subbasin

Appendix F2 – Pilot Assessment of Larval Lamprey Habitat Occupancy at the Inlet of Sunnyside Diversion Prior to the Beginning of Irrigation Season

Appendix F3 – Sunnyside Diversion and Prosser Hatchery Experiments

Appendix F4 – Mark-Release-Recapture Study in Congdon Diversion to Assess Dispersal and Entrainment of Larval/Juvenile Lamprey

Appendix F5 – Preliminary Report of the USGS-CRITFC Toxicology Study on Lamprey and Fine Sediment

Appendix F8 – Mercury Concentrations in Pacific Lamprey (Entosphenus tridentatus) and Sediments in the Lower Columbia River Basin – Preliminary Report

Appendix G1 – Pacific Lamprey Passage Structures Report (Jim Simonson)

Appendix G2 – Collection of Design Drawings for Adult Pacific Lamprey Passage Improvement Structures within the Yakima River Subbasin

Appendix G3 – Pacific Lamprey Action Table, Yakima Subbasin (Working Draft)

Appendix J1 – Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin 95% Draft

Appendix K1– Evaluating Persistence in Visibility of Visible Implant Elastomer Tags

Appendix K2 – Collection of Macro Photos from Various Larval Lamprey Size Classes to Differentiate Pacific Lamprey and Resident Lampetra species

Appendix K3 – “Do You Really Know Who I Am?” (An article submitted and published in the Feburary 2014 edition of “The Tributary,” a Western Division AFS newsletter).

Confederated Tribes and Bands of the Yakama Nation

Department of Natural Resources, Fisheries Resources Management Program

Yakama Nation Pacific Lamprey Project

Larval Lamprey Surveys in the Yakama Nation Ceded Lands:

Yakima River Subbasin

Prepared for:

U.S. Department of Energy
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2012 Annual Preliminary Report

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Introduction

Pacific lamprey, *Entoshenus tridentatus*, which is among the earliest fish species in fossil records from 450 million years ago, has inhabited the rivers, streams and coastal waters of the western U.S. relatively unchanged in its primordial form (Schwab and Collin 2005; Bond 1996). Historically, Pacific Lamprey were abundant throughout much of the Columbia River Basin (Hamilton et al. 2005; Hammond 1979; Kan 1975), yet populations have drastically decreased over the last 30-50 years due to a variety of factors. Adult counts at Roza Dam (river km 210) continue to indicate no Pacific lamprey entering the upper Yakima basin. Adult counts at Prosser Dam fish counting station continue to indicate very few adult lamprey passing this location each year. Only in the years 2002, 2003, and 2004, larger numbers were counted (22, 87, 65, respectfully) whereas in all following years, very few if any were counted. Since 2009, the Yakama Nation Pacific Lamprey Project (YN PLP) has begun conducting larval lamprey surveys to document their distribution and relative abundance within the Ceded Area of the Yakama Nation (Figure 1). We have focused primarily on larval lamprey (or ammocoetes) life stage, but transformed lamprey (or macrophthalmia) are also documented and monitored in these surveys as well. Here we summarize our assessment of larval lamprey distribution in the Yakima River Subbasin.

Our primary objectives for the larval lamprey surveys (Yakima River Subbasin) in project year 2013 were: 1) to assess the presence/absence, relative abundance, and distribution of larval Pacific lamprey (primary focus) and Western brook lamprey (secondary focus) and 2) to evaluate the relative abundance of larval lamprey habitat and 3) to establish new, and revisit previously established "Index Sites" for long-term status and trend monitoring. We targeted habitat that had the highest potential of Pacific lamprey being present (based on existing knowledge) and explore premium sites, not previously surveyed, where Pacific Lamprey could reside. The information from this project will fill important data gaps on the current status of both Pacific lamprey and Western brook lamprey region wide and will be vital to any future conservation / restoration activities. In this report, we will outline the key findings discovered up to date related to these objectives.

Study Area

The Yakama subbasin is one of the major tributaries of the Columbia River basin, with its confluence 335 miles from the ocean (Figure 1). The Yakima River flows 214 miles and is located in central Washington. The watershed contains an area of approximately 6,155 square miles with nearly 2,000 miles of perennial rivers and streams from the crest of the Cascade Mountain to the Columbia River. Its large size contributes not only to sheer volume of available lamprey habitat but the wide variety of geologic, topographic, and ecological conditions producing a wide range of habitat types. These habitats are suitable for a variety of species and provide habitat diversity that supports multiple life stages of lamprey species. Specifically, Pacific Lamprey larvae, juveniles (macrophthalmia), and adults have different optimal habitat types necessary to carry out essential life functions, including feeding, rearing, migration, and spawning. The rivers and streams of interest for the Pacific Lamprey Project include Satus, Toppenish, and Ahtanum creeks in the lower reach, Naches (including Little Naches, Cowiche and Tieton) and Wenas rivers/streams in the mid reach, and Wilson, Manastash, Taneum, Swauk, Teanaway, Cle Elum rivers/streams in the upper reach. There are five major reservoirs located in this subbasin, and form the storage components of the federal Yakima Projects managed by the Bureau of Reclamation, including: Keechelus Lake, Kachess Lake, Cle Elum Lake, Rimrock Reservoir and Bumping Lake. The north fork of the Tieton River connects Clear Lake with Rimrock Lake (Figure 1).

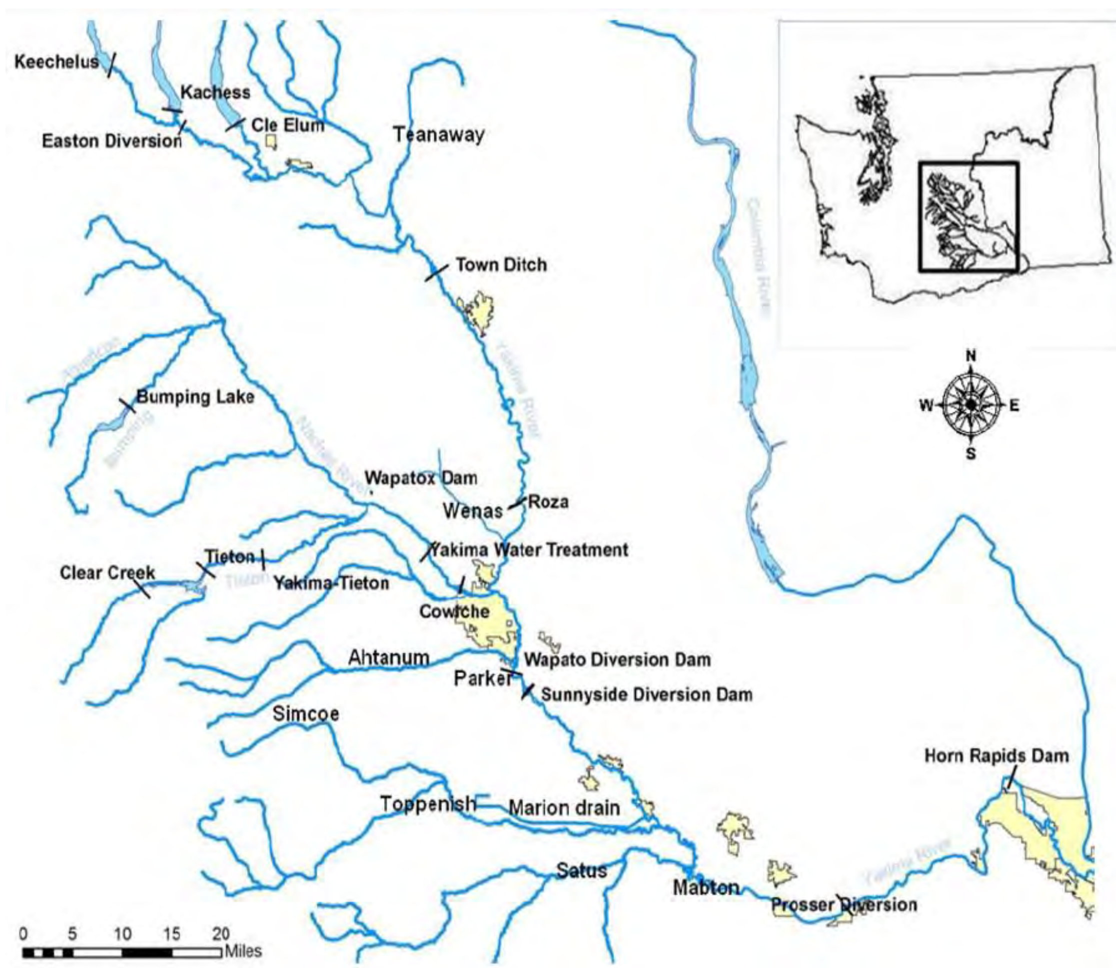


Figure 1. Schematic diagram of the Yakima River and major tributaries and irrigation facilities.

Methods

Larval were surveyed in the Yakima Subbasin during summer low flow season between mid-June and mid-October in 2013. As in previous years, we targeted preferred (Type I) and acceptable (Type II) ammocoete habitat as defined by Slade et al. (2003) within a sampling site. Their definition of the three strata (Type I, II, and III – see below) is qualitatively defined based on substrate components and compactness, as suggested originally by Applegate (1950).

"Type I habitat is located primarily in depositional zones preferred by the filter-feeding larvae, and consists primarily of a mixture of sand and fine organic matter. Type II habitat often consists of shifting sand that may contain some gravel, is utilized by some larvae for burrowing, but it is inhabited at much lower densities. Type III habitat is unacceptable because larvae are unable to burrow into it. Hard packed gravel, hardpan clay, and bedrock are examples of Type III habitat."

Although these habitat types are determined subjectively, agreement in habitat type determination is good among observers (Mullett and Bergstedt 2003) and definitions used to separate habitat types are supported by more than 30 years of data that demonstrate habitat preference by sea lamprey ammocoetes. According to studies from the Great Lakes tributaries, as many as 93% of the sea lamprey ammocoetes were found in Type I habitat (Mullet 1997) and the densities in Type I habitat can be 4-30 times higher than Type II habitat (Slade et al. 2003; Fodale et al. 2003). Therefore, we focused our sampling on Type I (preferred) habitat and subsequently Type II (acceptable) habitat. Type III (unsuitable) habitat was skipped and not surveyed. Type I and II habitat is generally found in backwater areas, side channels, or along the margins of larger pools.

Site potential was based on aerial images from Google Earth and GIS software. Due to their patchy distribution, we primarily selected sites that had higher chances of being a Type I habitat [such as slow water, shallow channel margin with dark tints (usually indicating fine sediment), backwater eddies, confluence of side channels, behind island bars, and tail end of deposition bars, etc.] within the targeted reaches, rather than taking a more systematic or random approach. To evaluate lamprey distribution in the expansive Yakima Subbasin effectively in a limited amount of time, ease of access was a critical issue. Efficient accessibility (bridges, road access, landowners who lived right on the river) was strongly considered when choosing potential survey sites. We focused on road crossings and other areas that both appeared optimal for ammocoete rearing and made site access simpler and easier in order to cover more ground efficiently. Moreover, we determined that targeting the preferred habitat more effectually will provide us with a better framework for evaluating presence/absence, distribution, and relative abundance.

In 2013, the sampling protocols were modified slightly. In 2012, the plot size was broken down to 2m sections, and up to 16 sections (32m of the channel) were surveyed at each site. In 2013, we first measured a 100m section of the stream for sampling. Within the measured 100m section, we identified and estimated the total area (m^2) of Type I and Type II habitat (separated in 50m sections upstream and downstream of a given center point). Of the observed Type I and Type II habitat, three plots were chosen to be surveyed for larval lamprey, with preference towards Type I. Each plot had a maximum channel length of 10m, adjusted based on the amount of available habitat.

The methods of electrofishing remained the same. Using AbP-2 backpack electrofisher (Engineering Technical Services, University of Wisconsin, Madison, Wisconsin), 3 pulses per second (125 V direct current) at 25% duty cycle with a 3:1 burst pulse train (three pulses on, one pulse off) was delivered to elicit ammocoetes to emerge from the substrate (Moser et al. 2007; Pajos and Weisse 1994). After emerging, ammocoetes were stunned with a current of 30 pulses per second for collection (Slade et al. 2003).

As in previous years, we performed single pass electrofishing. Based on studies conducted by others, such as the Confederated Tribes of Warm Springs (2012), single pass electrofishing conducted at a standardized rate of effort showed highly similar trends in relative abundance compared to multiple pass electrofishing. We determined that conducting a thorough single pass electrofishing at a slow deliberate pace will yield just as meaningful results as a multiple pass electrofishing that was conducted at a faster pace. We paid close attention to the rate of electrofishing and aimed at a rate of 90 seconds / m^2 of electrofishing (and ensured that it was no faster than 60 seconds / m^2). We only conducted multiple pass electrofishing (with 200 voltage) when no lamprey were sampled at a site to evaluate further whether lamprey were truly absent in an effort to substantiate presence/absence.

Besides the total number of lamprey observed (captured/missed), the following elements were recorded at each of the official survey site: date, time, stream type (mainstem/tributary), channel type (main/side), flow conditions (high/medium/low), visibility (above and under water), gps location (latitude/longitude/ elevation), and thalwag temperature. Primary and secondary habitat types (thick detritus, thin detritus, aquatic vegetation or only sand) were identified for each plot. Within each of the three surveyed plots we identified a one square meter plot that was observed to have the highest density of larvae, or, if no larvae were found, where we suspected the highest potential for larval rearing. Within these one square meter plots we collected the following data: sample location (left/right/center), substrate composition (% detritus/clay/silt/fine sand/coarse sand/others), mean sediment depth (mean of three measurements), mean water depth, % detritus cover, thalwag habitat type, plot temperature, and the temperature under the sediment. Furthermore, we estimated the channel length and area (m^2) of habitat we surveyed (electrofished) for each plot.

Surveying in three separate plots allowed us to evaluate larval lamprey density in various habitat types within the stream (flow type/location, sediment depth/type). When any larval lamprey was present, we recorded the species and life stages of all captured fish, and measured length for a maximum of 25 fish. Lamprey were labeled unknown if they were below identifiable size (<60mm), or were only observed but not captured. Previously created river kilometer points [created using the "Construct Points" function in ArcGIS 10 software and the stream shapefile available from StreamNet (Portland, OR) calledHydrort_MSHv3,] were used to standardize our survey site nomenclature.

Some sites with minimal larval habitat were surveyed quickly and not all the measurements required for the full survey was taken at these spot check sites. The primary purpose of these spot check sites was to confirm whether lamprey were present or absent at the sites and habitat characteristics or relative abundance was a secondary purpose.

Results / Discussions

Upper Yakima River Subbasin

A total of 16 sites were surveyed throughout the Upper Yakima watershed, with three sites located in the Cle Elum River, a major tributary to the Yakima (Table 1). Larval lamprey habitat was found primarily in side channels and, in less frequent instances, along the mainstem channel margins. Full surveys were performed at 8 out of the 16 sites. On average the temperature below the sediment was cooler than the plot temperature (mean difference of -0.8°C). Within Type I habitat, fish were found in higher densities in areas with detritus (both thick and thin levels of detritus). Of the 254 lamprey observed, all identifiable fish were Western brook with a large percentage of the observed fish remaining unknown (90 %). No fish were observed in the Cle Elum hatchery side channel (rkm 302.2), though an abundance of Type I habitat was present. Available Type I habitat was patchy in the Yakima River Canyon (rkm 215.0-247.9), but increased in area immediately above Roza Dam (rkm 210.5). Larval lamprey were found up to the town of Cle Elum just below the hatchery (rkm 300.9). Future efforts will focus on reducing the percentage of unknown lamprey by increasing capture efficiency of the electrofisher (many observed lamprey managed to escape). Within the upper Yakima River, index sites (sites to be surveyed regularly over the long-term for status and trend monitoring) were chosen based on findings from these surveys.

Table 1. Summary of results for 2013 larval lamprey surveys in Upper Yakima HUC4 watershed. "Total Lamprey Observed" is the sum of larval lamprey captured and missed (observed but not captured). "% Pacific Lamprey" and "% Western Brook" refer to the percent of Pacific lamprey vs. Western brook lamprey. "% Unknown" refers to the percent of observed lamprey that were not identified to species (either too small (<60mm) for identification or were missed and not identified to species) from the overall number of observed lamprey at each site. For sites with more than one plots surveyed, the "Plot Temp," "Sed. Temp," "Primary Hab. Type" are displayed for the plot with the highest number of observed lamprey.

Date	Stream	Rkm	Survey Type	Total Lamprey Observed	Observed Density (Larvae/m^2)	100m Habitat Availability (m^2)	Extrapolated # of larvae / 100m	% Pacific Lamprey	% Western Brook	% Unknown	Plot Temp °C	Sed. Temp °C	Primary Hab. Type
8/20/2013	Yakima	215.0	Full Survey	18	0.7	60	42	0	100	89	20.7	20.2	Only Sand
8/20/2013	Yakima	215.1	Spot Check	6	0.4	30	11	-	-	100	20.6	20.0	Aq. Vegetation
8/21/2013	Yakima	215.6	Full Survey	13	0.3	45	12	-	-	100	20	18.9	Aq. Vegetation
8/20/2013	Yakima	243.8	Spot Check	-	-	15	-	-	-	-	-	-	Thin Detritus
9/9/2013	Yakima	244.2	Full Survey	33	1.7	60	104	0	100	91	21.6	19.4	Thick Detritus
9/5/2013	Yakima	245.1	Spot Check	40	1.2	30	35	0	100	83	-	-	Thick Detritus
8/21/2013	Yakima	246.9	Full Survey	51	2.8	45	128	0	100	98	20.3	19.1	Thin Detritus
9/9/2013	Yakima	247.2	Full Survey	2	0.1	30	3	-	-	100	19.4	18.4	Thick Detritus
9/9/2013	Yakima	247.9	Spot Check	-	-	125	-	-	-	-	20	18.7	Thin Detritus
8/21/2013	Yakima	264.8	Spot Check	5	0.1	350	25	0	100	80	17.5	-	Aq. Vegetation
8/29/2013	Yakima	300.9	Full Survey	24	0.6	45	29	0	100	75	17.6	17.8	Thick Detritus
9/11/2013	Yakima	300.9	Full Survey	63	2.6	30	79	0	100	81	19.2	18.4	Only Sand
9/11/2013	Yakima	302.2	Full Survey	-	-	45	-	-	-	-	19.3	18.2	Thin Detritus
9/25/2014	Cle Elum	7.5	Spot Check	-	-	-	-	-	-	-	-	-	-
9/25/2014	Cle Elum	7.5	Spot Check	-	-	-	-	-	-	-	-	-	-
9/25/2014	Cle Elum	9.2	Spot Check	-	-	-	-	-	-	-	-	-	-
Overall Mean:			**16 sites**	**26**	**1.1**	**70**	**47**	**0**	**100**	**90**	**19.7**	**18.9**	**-**

Photo Representations:

Upper Yakima Mainstem

Upper Yakima (1): Tail of a representative Western brook lamprey (Rkm. 300.9)

Upper Yakima (2): Side channel sediment collection and prime Type I habitat (Rkm. 300.9)


Upper Yakima (3): Type I habitat collection in a small side channel with limited flow (Rkm. 246.9)


Upper Yakima (4): Type I habitat collection along the margin of the Yakima mainstem (Rkm. 247.2)


Upper Yakima (5): Common habitat composition; fine/coarse sand with thick/thin detritus (Rkm. 300.9).

Lower Yakima River Subbasin

A total of 21 sites were surveyed throughout the Lower Yakima watershed, focusing on the mainstem Yakima, Ahtanum Creek, Satus Creek, Simcoe Creek, and Toppenish Creek (10 sites, 3 sites, 4 sites, 1 site, and 3 sites respectively; Table 2). Full surveys were performed at 17 of the 21 sites. Larval lamprey habitat was, more so than the Upper Yakima, along the mainstem channel margins. Fine sediment was more abundant and were observed in places besides side channels. Larval lamprey were found at 16 of the 21 sites, with the lowest distribution on the Yakima River at the I-82 bridge in Prosser. We confirmed the presence of Pacific Lamprey in Ahtanum Creek, Satus Creek, and in the lower Yakima River (rkm 4.1, 31.4, and 73.5 repectively). Pacific Lamprey constituted 2, 50, and 9 percent of the captured identifiable lamprey (>60 mm), respectively, per surveyed watershed. Again, similar to the Upper Yakima watershed, most fish were found in locations with thick or thin detritus over areas with only sand or aquatic vegetation. On average the temperature below the sediment was considerably cooler than the plot temperature (-2.2 °C). Of the 269 lamprey captured, the majority were identified as either Western brook lamprey or unknown, with a small percentage identified as Pacific Lamprey (64.3, 32.7, and 3.0 respectively). More than half of the lamprey were only observed and not captured (345 total). Future efforts will focus on reducing the percentage of unknown lamprey by increasing capture efficiency of the electrofisher (many observed lamprey managed to escape). Within the lower Yakima River, index sites, sites to be surveyed every year for multiple years, were chosen based on our findings from these surveys.

Table 2. Summary of 2013 larval lamprey surveys by Upper Yakima HUC4 watershed. "Total Lamprey Observed" is the sum of larval lamprey captured and missed (observed but not captured). "% Pacific Lamprey" and "% Western Brook" refer to the percent of Pacific lamprey vs. Western brook lamprey. "% Unknown" refers to the percent of observed lamprey that were not identified to species (either too small (<60mm) for identification or were missed and not identified to species) from the overall number of observed lamprey at each site. For sites with more than one plots surveyed, the "Plot Temp," "Sed. Temp," "Primary Hab. Type" are displayed for the plot with the highest number of observed lamprey.

Date	Stream	Rkm	Survey Type	Total Lamprey Observed	Observed Density (Larvae/m^2)	100m Habitat Availability (m^2)	Extrapolated # of larvae / 100m	% Pacific Lamprey	% Western Brook	% Unknown	Plot Temp °C	Sed. Temp °C	Primary Hab. Type
9/12/2013	Yakima	73.5	Full Survey	9	0.2	90	21	60	40	44	23.6	19.5	Thin Detritus
8/12/2013	Yakima	149.8	Full Survey	61	1.5	400	581	0	100	48	29	15.2	Thick Detritus
8/13/2013	Yakima	165.5	Full Survey	23	0.6	125	78	0	100	74	19.4	18.6	Thin Detritus
8/14/2013	Yakima	171.4	Spot Check	-	-	90	-	-	-	-	-	-	Thin Detritus
8/13/2013	Yakima	177.8	Full Survey	12	0.5	-	-	0	100	58	22.4	20.9	Thin Detritus
8/6/2013	Yakima	179.3	Full Survey	47	0.6	-	-	0	100	68	21.5	20.9	Aq. Vegetation
8/6/2013	Yakima	180.2	Full Survey	33	0.7	100	70	6	94	48	20	19.4	Only Sand
8/8/2013	Yakima	180.9	Spot Check	-	-	-	-	-	-	-	21.3	20.9	Thin Detritus
8/8/2013	Yakima	181.7	Spot Check	-	-	-	-	-	-	-	-	-	Only Sand
9/3/2013	Yakima	191.8	Full Survey	24	0.7	30	21	0	100	75	19.5	19.1	Only Sand
10/14/2013	Ahtanum	4.3	Full Survey	80	3.2	45	144	4	96	71	19.8	19.6	Thin Detritus
10/14/2013	Ahtanum	23.6	Full Survey	38	3.2	45	143	0	100	97	8.5	9	Thin Detritus
10/14/2013	Ahtanum	32.1	Full Survey	4	0.4	15	6	-	-	100	8.5	6.7	Thin Detritus
10/16/2013	Satus	12.9	Full Survey	74	2.6	45	119	0	100	74	24.6	23.1	Only Sand
10/16/2013	Satus	21.7	Full Survey	-	-	30	-	-	-	-	29.7	24.2	Only Sand
8/19/2013	Satus	31.4	Spot Check	7	0.2	30	7	100	0	57	24.2	-	Only Sand
10/8/2013	Satus	41.2	Full Survey	1	0.0	300	5	-	-	100	25	23.2	Only Sand
10/8/2013	Simcoe	9	Full Survey	44	1.3	60	75	0	100	86	19.5	19.2	Thin Detritus
10/8/2013	Toppenish	37.4	Full Survey	-	-	175	-	-	-	-	21.9	20.1	Aq. Vegetation
10/8/2013	Toppenish	59.9	Full Survey	62	1.0	60	60	0	100	81	22.2	20.2	Thick Detritus
8/12/2013	Toppenish	73.2	Full Survey	26	0.8	75	61	0	100	50	18.7	17.9	Thick Detritus
Overall Mean:			**21 Sites**	**34**	**1.1**	**101**	**99**	**12**	**88**	**71**	**21.0**	**18.8**	**-**

Photo Representations:

Lower Yakima River

Lower Yakima (1): Overview of a plot showing Type I habitat along mainstem channel margin (Rkm.73.5)


Lower Yakima (2): Common habitat composition of mainstem, fine sand/detritus/ aquatic plants (Rkm.73.5).


Lower Yakima (3): Representative tail of a Western brook lamprey (Rkm. 73.5).

Ahtanum Creek

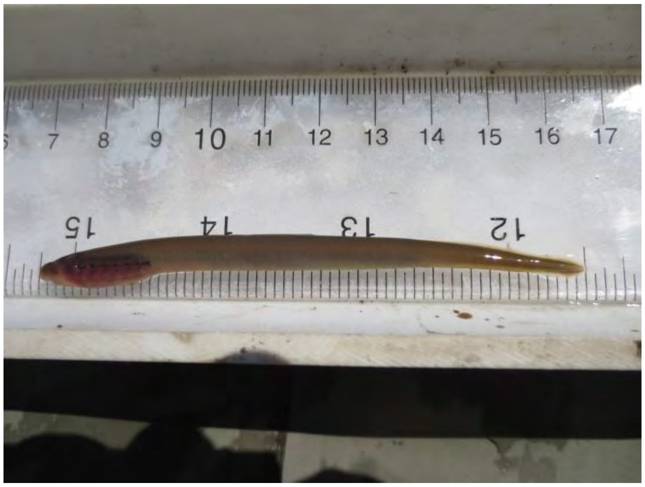

Ahtanum (1): Type I habitat collection along margin of channel mainstem on the edge of a pool (Rkm. 4.1).

Ahtanum (2): Primary Type I habitat type was silt/fine sand mixed with thin detritus (Rkm. 4.1).

Satus Creek

Satus (1): Overview of a plot along the margin of a deep run (Rkm. 31.4).

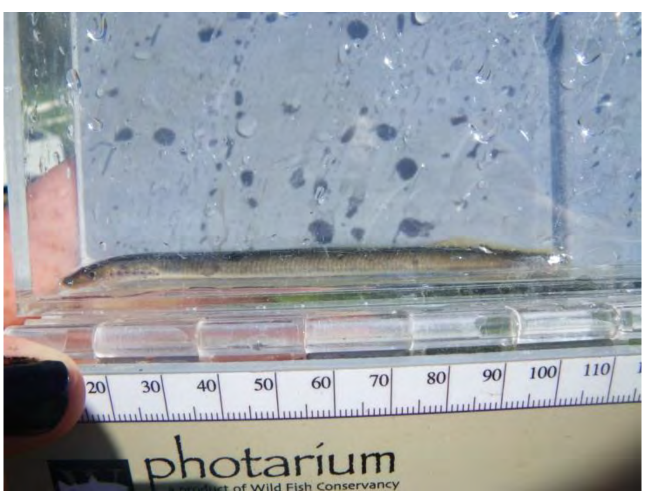
Satus (2): Common habitat composition, fine sand/silt and think or thin detritus accumulation (Rkm. 31.4).



Satus (3): Pacific Lamprey captured in Satus Creek (Rkm. 31.4).

Simcoe Creek

Simcoe (1): Common habitat composition, fine and coarse sand with patches of aq. pants and detritus (Rkm. 9.0).



Simcoe (2): Western Brook macropthalmia captured from coarse sediment (Rkm. 9.0).

Toppenish Creek

Toppenish (1): Overview of Toppenish creek side channel with Type I habitat and little flow (Rkm. 73.2).

Toppenish (2): Common habitat composition; fine sand/silt mixed with detritus and algae (Rkm. 73.2)

Naches River Subbasin

A total of 7 sites within the Naches watershed, with sites located in the Naches River, Little Naches River and Cowiche Creek (5 sites, 1 site and 1 site respectively). Full surveys were performed at 6 out of the 7 sites. We did not find any Pacific lamprey in Naches River this year, though in past years we have found some. The mean number of lamprey per site was also lowest in the Naches watershed (average of 9 lamprey compared to 26 and 34 lamprey in Upper and Lower Yakima watersheds, respectively). Larval lamprey habitat was found primarily in backwater areas along the mainstem channel or in side channels. Very few sites had fine sediment collection along mainstem channel margins. On average the temperature below the sediment was moderately cooler than the plot temperature (-0.9°C). The highest densities of larval lamprey were found in areas of only sand (very little to no detritus present). Within the Naches watershed, index sites, sites to be surveyed every year for multiple years, were chosen based on our findings from these surveys.

Table 3. Summary of 2013 larval lamprey surveys by Upper Yakima HUC4 watershed. "Total Lamprey Observed" is the sum of larval lamprey captured and missed (observed but not captured). "% Pacific Lamprey" and "% Western Brook" refer to the percent of Pacific lamprey vs. Western brook lamprey. "% Unknown" refers to the percent of observed lamprey that were not identified to species (either too small (<60mm) for identification or were missed and not identified to species) from the overall number of observed lamprey at each site. For sites with more than one plots surveyed, the "Plot Temp," "Sed. Temp," "Primary Hab. Type" are displayed for the plot with the highest number of observed lamprey.

Date	Stream	Rkm	Survey Type	Total Lamprey Observed	Observed Density (Larvae/m^2)	100m Habitat Availability (m^2)	Extrapolated # of larvae / 100m	% Pacific Lamprey	% Western Brook	% Unknown	Plot Temp °C	Sed. Temp °C	Primary Hab. Type
8/19/2013	Naches	14.1	Full Survey	-	-	275	-	-	-	-	16.5	16.0	Only Sand
8/19/2013	Naches	20.6	Full Survey	1	0.0	75	2	0	100	0	17.6	16.8	Only Sand
8/19/2013	Naches	29.0	Full Survey	10	0.1	150	21	0	100	70	19.7	18.7	Only Sand
8/19/2013	Naches	41.9	Full Survey	21	0.5	60	28	0	100	33	17.7	16.4	Only Sand
8/19/2013	Naches	51.2	Full Survey	12	0.4	30	11	-	-	100	20.4	18.4	Thin Detritus
8/19/2013	Cowiche	1.3	Spot Check	2	0.1	15	2	0	100	50	19.4	18.7	Only Sand
8/19/2013	Little Naches	7.4	Full Survey	-	-	45	-	-	-	-	14.6	14.4	Thick Detritus
Overall Mean:			**7 Sites**	**9**	**0.2**	**93**	**13**	**0**	**100**	**51**	**18.0**	**17.1**	**-**

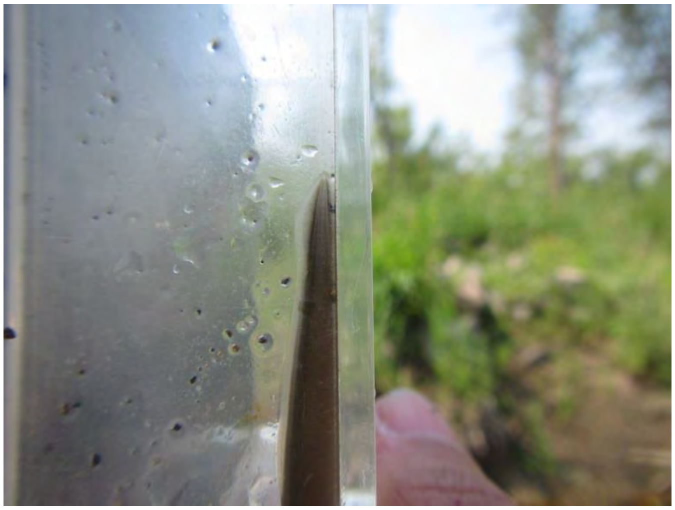
Photo Representation:

Naches River:


Naches (1): Overview of a side channel plot away from the main river and along edge of a pool (Rkm. 20.6).


Naches (2): Common habitat composition; fine and coarse sand with little organic debris mixed in (Rkm. 20.6).


Naches (3): Western Brook lamprey, notice pigment bleeding to outer edge but dark center ridge (Rkm. 29.0).



Naches (4): Pacific Lamprey captured in the Naches River (Rkm. 41.9).

Little Naches

Little Nac. (1): Overview of best habitat collection site we could find (Rkm. 7.4).

Little Nac. (2): Best habitat composition, fine sand and thick detritus collection (Rkm. 7.4).

Cowiche Creek

Cowiche (1): Overview of best habitat site on edge of pool along channel margin (Rkm 1.3).

Cowiche (2): Common sediment habitat type, fine sand with areas of thick detritus cover (Rkm. 1.3).

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Methow River Basin Larval Lamprey Habitat Survey

Yakama Nation Fisheries Resource Management
Tyler Beals and Ralph Lampman

Survey Conducted on 10/07/13 to 10/10/13
by Tyler Beals and Dave'y Lumley

Summary of Findings:

Available Type I and Type II habitat was surveyed throughout the Methow River and three of its connecting tributaries with the use of an Abp-2 electroshocker, designed specifically for the sampling of larval lamprey, and fine mesh (1mm) hand nets. Our survey focused on the upper and lower reaches of the Methow River, Chewuch River, Twisp River, and Beaver Creek. Not all visited sites were sampled due to lack of available habitat in these areas. Depositional areas throughout the basin consisted of coarse sand with small areas of fine sand and accumulated detritus. Fine sediment deposits were limited throughout the basin, with swift, channelized flows being most prominent, with cobble and gravel as the primary substrate. No lampreys were observed throughout the course of our survey.

A Google Earth assessment of potential depositional areas helped us identify sample sites located in the upper reach of the Chewuch River (2 sites), upper and lower reaches of the Methow River (4 sites and 2 sites respectively), upper and lower Twisp River (3 sites and 2 site respectively) and the lower reach of Beaver Creek (3 sites). During our surveys, areas of accumulated fine sediment (sand and silt) and organic material were given higher priority over areas consisting of coarse sand and areas that lacked organic deposition. However, sample sites that consisted primarily of coarse sediment were also sampled. A longer electrofishing sample time was performed for sites that consisted of fine sediment and detritus, prime Type I habitat that typically hold more larval lamprey, compared to coarse shifting sand.

In the upper Chewuch River, potential larval habitat was observed to mostly consist of coarse sand, with small areas of fine sand/silt mixed with leaves and small woody debris. Our two sample sites (C-2 and C-f) along the upper Chewuch, yielded no fish and consisted of coarse sand with very little fine sand and detritus. The backwater area of site C-2 had the most fine sediment and detritus (no photos from this area). In the upper Methow reach, we identified six sites, choosing four of the six sites (UM-1, UM-2, UM-b, UM-e) that had comparatively more Type I and Type II habitat. Sandy Type I and Type II habitat was present at these four sites and no fish were observed. Overall fine sediment seemed to be patchy in the upper reach of the Methow, with available habitat primarily coarse sediment. One site, UM-b, had abundant organic matter and fine substrate. We stopped by two sites (LM-a, LM-b) along the lower Methow River. Site LM-a had fine sediment, but due to people playing in the water, we could not sample. We performed a brief spot-check with the electroshocker (as we were leaving the basin) at LM-b, but did not observe any lamprey. Out of the five sites visited in Twisp River, only one site had Type I habitat. We sampled one site (T-f) at the lower Twisp River that was primarily silt and thick detritus. This area seemed perfect for larval lamprey, compared to sites in other basins where larvae were found, yet yielded no fish. We traveled to sites located in the upper reaches of the Twisp River however this area was swift, steep, and consisted of cobble and boulders with no available larval habitat. Very fine sediment was observed in the lower reach of Beaver Creek, present in small patches along the edges of riffles. We quickly spot checked one site (B-c), that had a larger collection of fine sediment, at with a fine mesh net (1 mm) as we could not access this site with the electrofisher. No fish were observed in Beaver Creek.

Date	Location	Site ID	Rkm	Survey Type	Sed. Temp °C	Plot Temp °C	Thalwag Temp °C	Larvae Present?	Sediment Type
10/08/2013	Upper Methow	UM-1	90.3	Full Survey	11.7	8.3	7.4	No	Coarse sand
10/08/2013	Upper Methow	UM-2	96.3	Full Survey	9.1	9.0	8.0	No	Fine/coarse sand
10/08/2013	Upper Methow	UM-b	107.7	Full Survey	8.2	8.6	8.4	No	Silt and Fine/coarse sand
10/08/2013	Upper Methow	UM-e	117.4	Full Survey	9.2	9.9	10.1	No	Coarse sand
10/07/2013	Chewuch	C-f	52.3	Full Survey	6.7	6.7	6.7	No	Detri/coarse fine sand
10/07/2013	Chewuch	C-2	51.6	Spot Check	-	-	-	No	Fine/coarse sand
10/09/2013	Twisp	T-a	0.2	None	-	-	-	-	None
10/09/2013	Twisp	T-b	1.7	None	-	-	-	-	None
10/09/2013	Twisp	T-f	16.5	Full Survey	7.2	6.4	6.7	No	Silt/fine sand
10/09/2013	Twisp	T-i	28.5	None	-	-	-	-	None
10/09/2013	Twisp	T-j	41.0	None	-	-	-	-	None
10/10/2013	Lower Methow	LM-b	46.3	Spot Check	-	-	-	No	Shifting fine/coarse sand
10/10/2013	Lower Methow	LM-a	1.9	None	-	-	-	-	None
10/09/2013	Beaver	B-b	2.0	None	-	-	-	No	None
10/09/2013	Beaver	B-c	2.5	Spot Check	-	-	-	-	Silt/fine sand
10/09/2013	Beaver	B-d	3.2	None	-	-	-	-	None

Chewuch River

Site C-f (Rkm 52.3) – Full survey with electroshocker

C-f (1): Overview of site; Dave'y Lumley electroshocking available larval habitat

C-f (2): Coarse sediment covered with a thin layer of fine sediment and detritus

C-f (3): Coarse sediment that was primary component of available larval habitat


C-f(4): Close up of fine sediment found in small patches near the shoreline at this sample site

Upper Methow

Site UM-1 (Rkm 90.3) – Full survey with electroshocker


UM-1 (1): Overview of sample site; Tyler Beals electroshocking available larval habitat


UM-1 (2): Close up of fine sediment and detritus collection determined to be the best location for larval lamprey


UM-1 (3): Close up of coarse/fine sediment mix displaying the sediment composition at this site

Site UM-2 (Rkm 96.3) – Full survey with electroshocker


UM-2 (1): Overview of site; Tyler Beals electroshocking small area of available habitat


UM-2 (2): View upstream from available habitat sample area; no other available habitat visible from this location


UM-2 (3): Close-up of fine sediment; mostly sand at this site

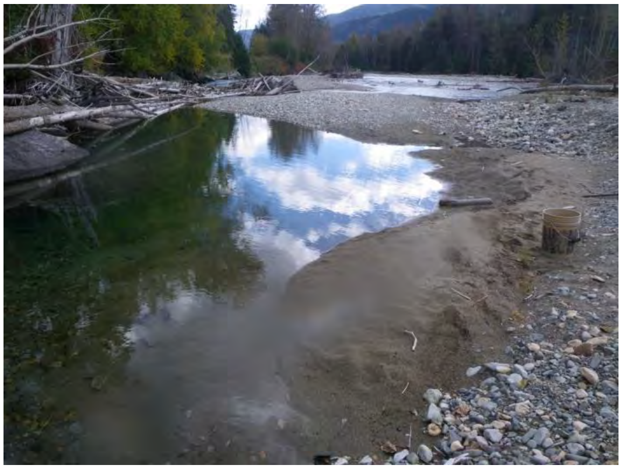
Site UM-b (Rkm 107.7) – Full Survey with electroshocker


UM-b (1): Downstream overview of sample site showing fine sediment and detritus collection


UM-b (2): Another overview showing area determined to be best location for larval lamprey


UM-b (3): Close-up of fine sediment (silt/sand) located at this site (fine and coarse sand mix also present)

Site UM-e (Rkm 117.4) – Full survey with electroshocker



UM-e (1): Overview of sample site showing the available coarse sediment habitat

UM-e (2): Close-up of area determined to be the best location for larval lamprey

UM-e (3): Close-up of coarse sandy sediment that composed of all available habitat in this area

Twisp River

Site T-a (Rkm 0.2) – No survey

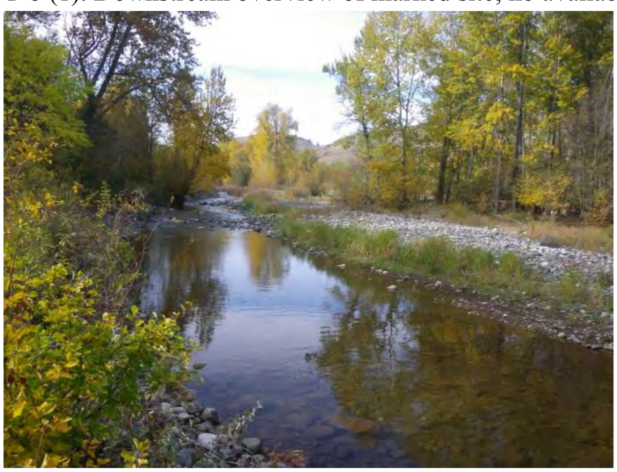

T-a (1): Overview of marked site; no visible potential larval lamprey habitat (boulders and cobble only)


T-a (2): Upstream overview of marked site; no available habitat observed (boulders and cobble only)


T-a (3): Downstream overview of marked site; no available habitat observed (boulders and cobble only)

Site T-b (Rkm 1.7) – No survey

T-b (1): Downstream overview of marked site; no available habitat observed (gravel and cobble only)



T-b (2): Upstream overview of marked site; no available habitat observed (gravel and cobble only)

Site T-f (Rkm 16.5) - Temperature 6.4 °C

T-f (1): Overview of site, located near the mouth of a small side channel, showing our estimated location of the best habitat for larval lamprey

T-f (1): Close-up of site showing our estimated location of the best habitat for larval lamprey, only site where we observed fine sediment and collected detritus

T-f (2): Fine sediment (silt and sand) mixed with detritus located at the sampled site

T-f (3): Upstream view of side channel from site; no visible habitat (primarily gravel with some cobble only)

Site T-i (Rkm 28.5) – No survey

T-i (1): Downstream overview of marked site; no available habitat observed (boulders and cobble only)

Site T-j (Rkm 41.0) – No survey

T-j (1): Downstream overview of marked site; no available habitat observed (boulders and cobbles only)

Lower Methow

Site LM-b (Rkm 46.3) – Spot-check survey with electroshocker

LM-b (1): Downstream view of surveyed area. Best habitat was close to shore downstream of the pictured rock.

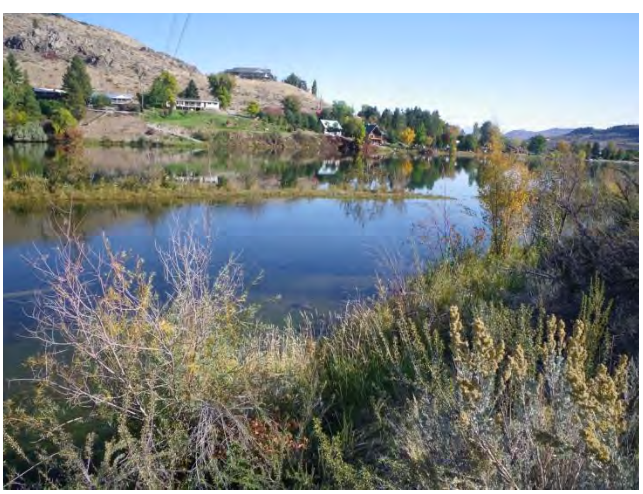
LM-b (2): Close up of shifting sand that was compact and composed of both fine and coarse granules.

LM-b (3): Upstream view of surveyed area consisting mostly of cobble and gravel.

LM-a (Rkm 1.9) – No survey

LM-a (1): Upstream view of potential site. Fine sediment present along the shore becoming too deep to see clearly.

LM-a (2): Forward view of potential site. Fine sediment present, and shore drops off and the depth of the water may be an issue. People were playing in potential shallow access sites.



LM-a (2): Downstream view of potential site. Fine sediment was present, no electroshocking.

Beaver Creek

Site B-b (Rkm 2.0) – No survey

B-b (1): Upstream overview of marked site; channelized, and no available habitat observed (cobble and gravel only)

B-b (2): Upstream overview of marked site; channelized, and no available habitat observed (cobble and gravel only)

Site B-c (Rkm 2.5) – Spot-check with hand nets

B-c (1): Overview of marked site; inaccessible with shocker with little fine sediment on right and left banks

B-c (2): Close-up of fine sediment accessible right bank; small hand net used for brief survey and no fish observed

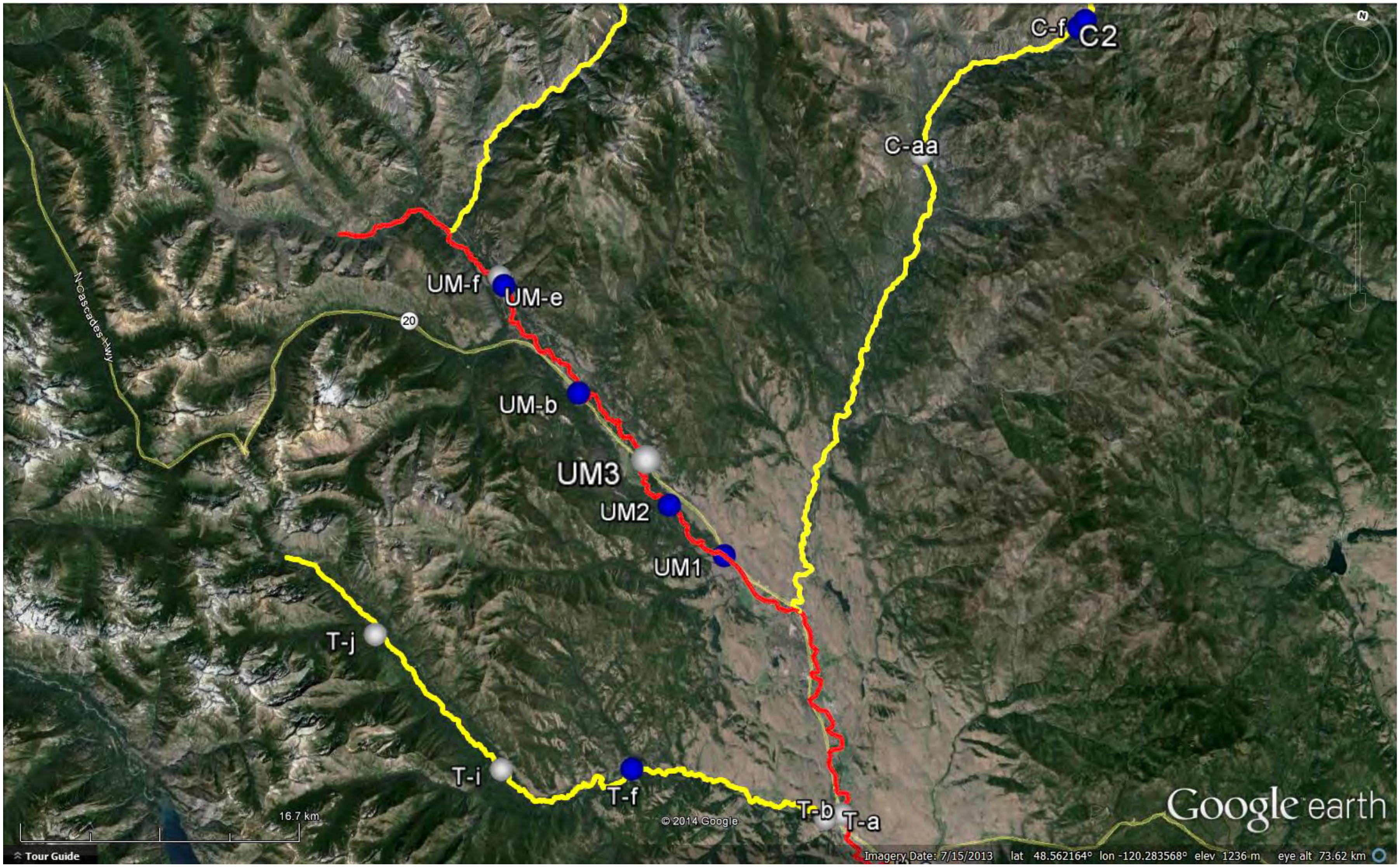
B-c (3): Close-up of fine sediment mixed with organic debris; sediment shallow and available in small patches

Site B-d (Rkm 3.2) – No survey

B-d (1): Downstream overview of marked site; no available observed habitat (boulders and cobble only)


B-d (2): Downstream overview of marked site; no available observed habitat (boulders and cobble only)

Google Earth Aerial Maps of Predetermined Sites



GE Map (1): Upper Methow Basin predetermined survey sites: sites visited but not sampled (grey dots) and sites surveyed with an electrofisher (blue dots).

GE Map (2): Lower Methow Basin predetermined survey sites: sites that were visited but not sampled (grey dots), sites surveyed by use of a fine mesh (1 mm) hand net (green dots) and sites surveyed with an electrofisher (blue dots).

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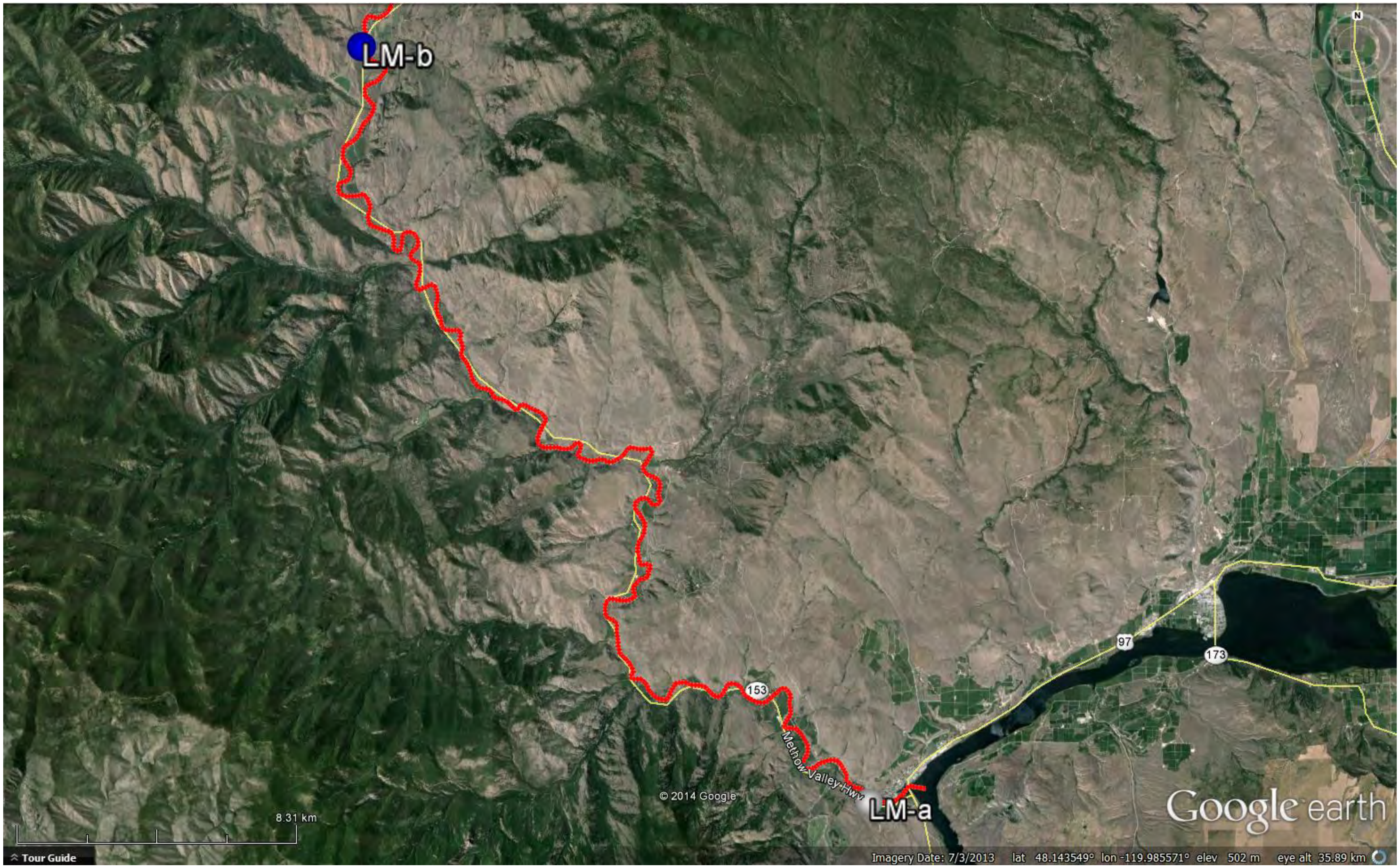


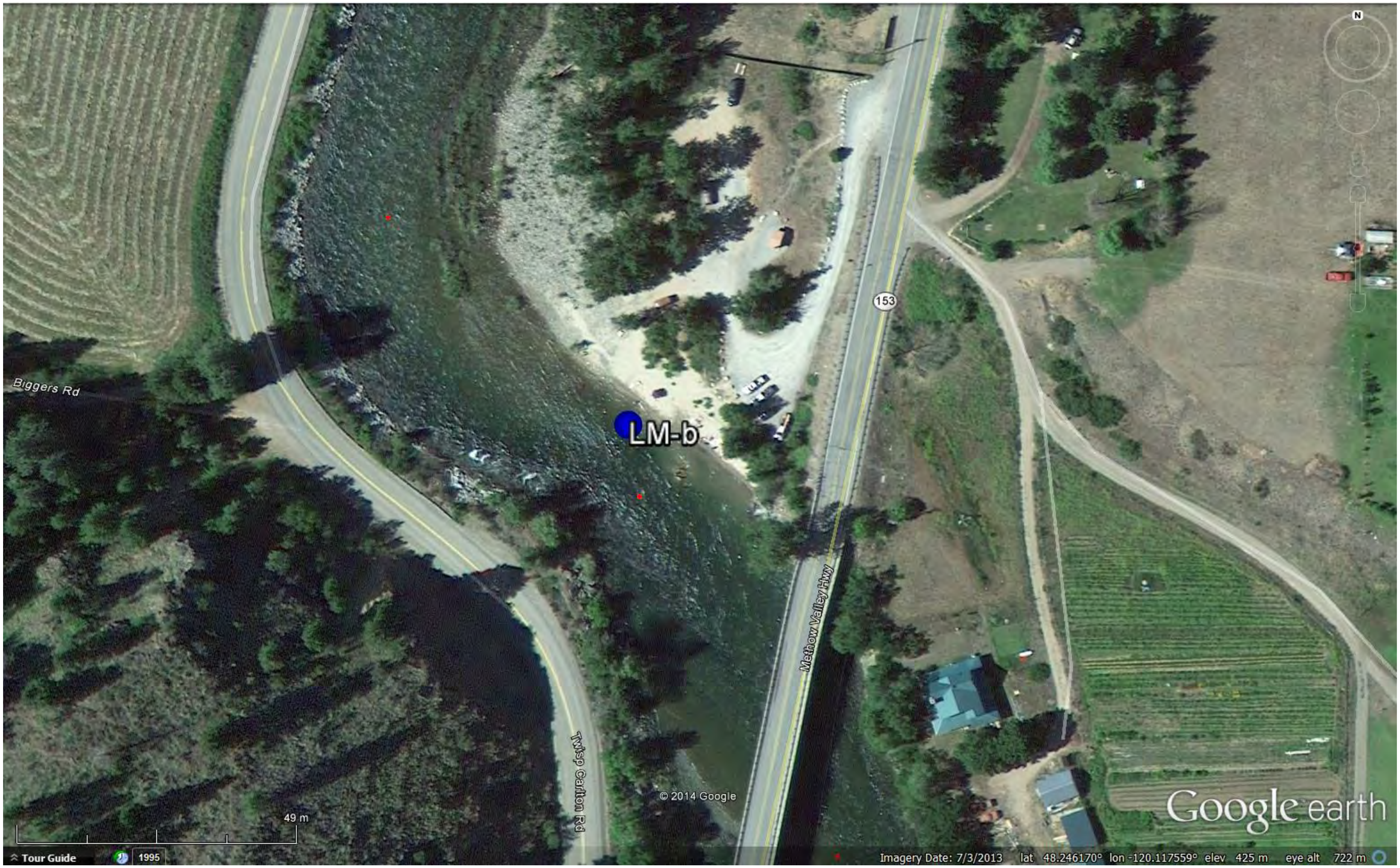
GE Map (3): Lower Methow Basin predetermined survey sites: sites that were visited but not sampled (grey dots) and sites sampled with an electrofisher (blue dots).

GE Map (4): Upper Methow River survey site UM1; site sampled with an electrofisher (primarily coarse sandy sediment present) and no lamprey were observed

GE Map (5): Upper Methow River survey site UM-2; site sampled with an electrofisher (fine sandy sediment present) and no lamprey were observed

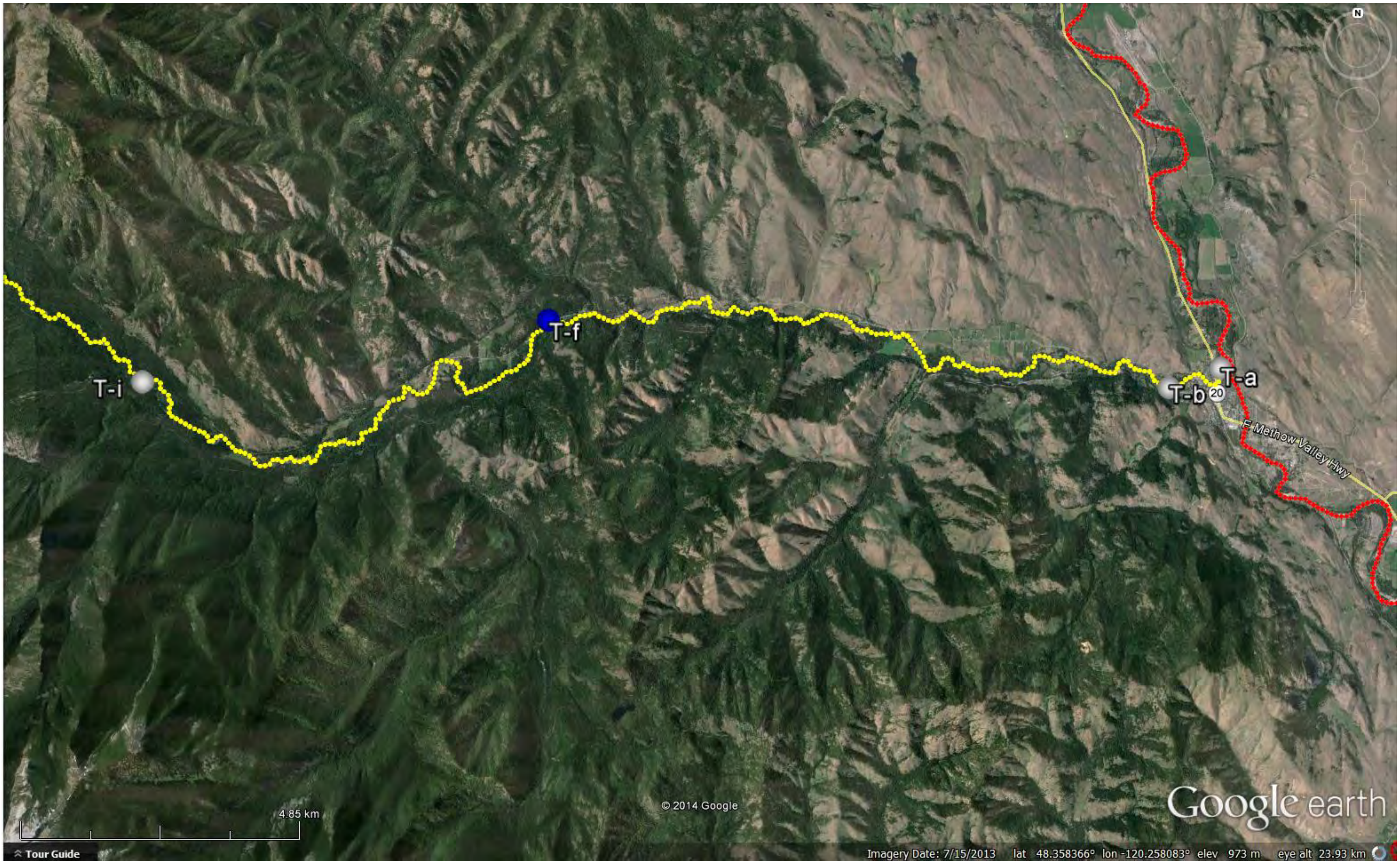
GE Map (6): Upper Methow survey site UM-e had abundant coarse sand present with patchy areas of fine sand, no lamprey observed.

GE Map (7): Upper Methow survey site UM-b had shallow areas of fine sand and silt.



GE Map (8): Lower Methow River survey site LM-b; Fine and coarse shifting sand present along a popular beach. A quick spot check yielded no fish.

GE Map (9): Lower Methow River survey site LM-a; fine sediment present but not sampled due to children playing in the water



GE Map (10): Overall map of our sites on the upper and lower reaches of the Twisp River.

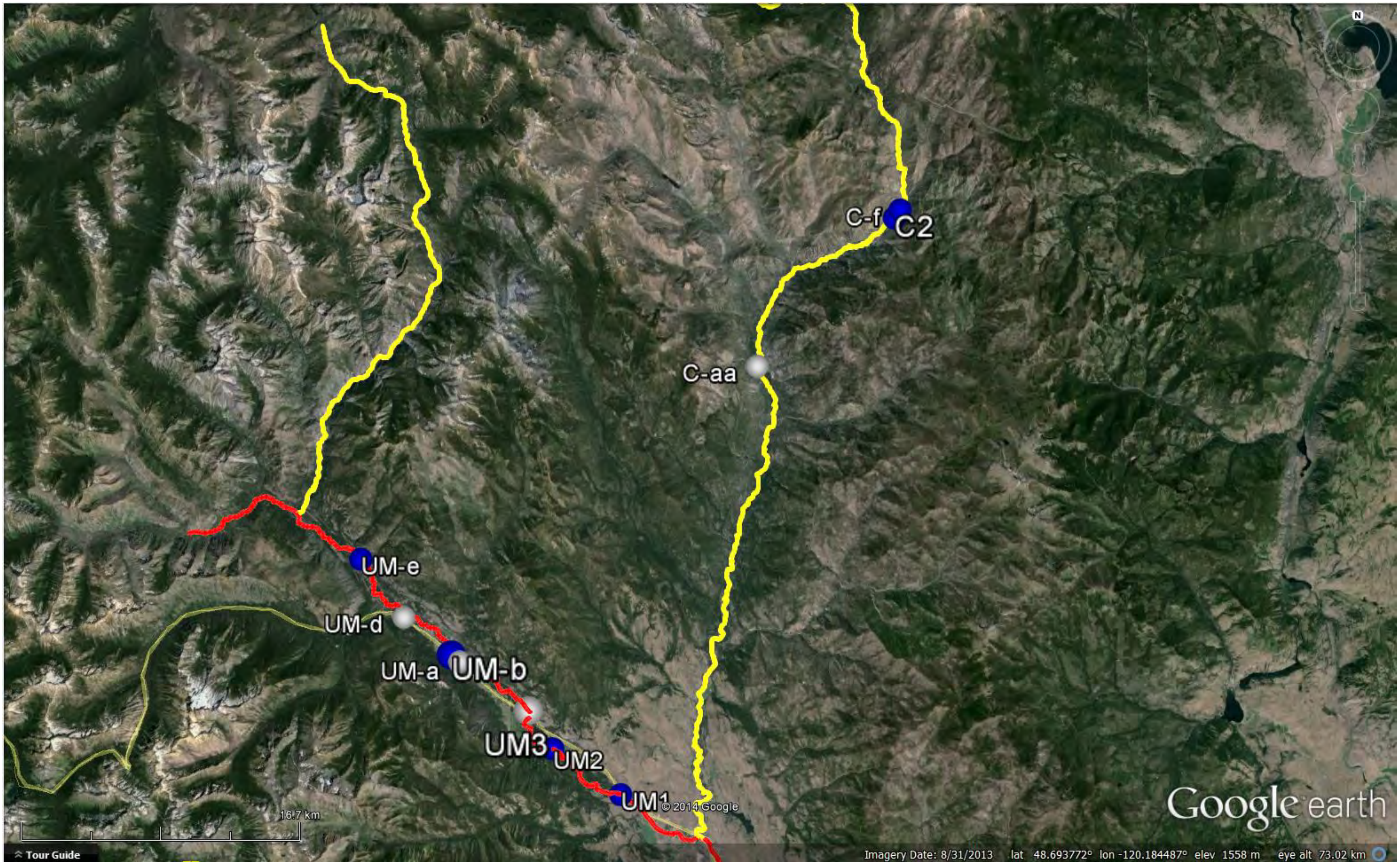
GE Map (11): Lower Twisp site T-a had cobble and gravel and no fine sediment was observed.

GE Map (12): Lower Twisp site T-b had no habitat with only cobble and gravel present.

GE Map (13): Upper Twisp survey site T-f had fine sand and silt deposition and a full survey yielded no lamprey.

GE Map (14): Upper Twisp site T-i had only large cobble and boulders with very swift water.

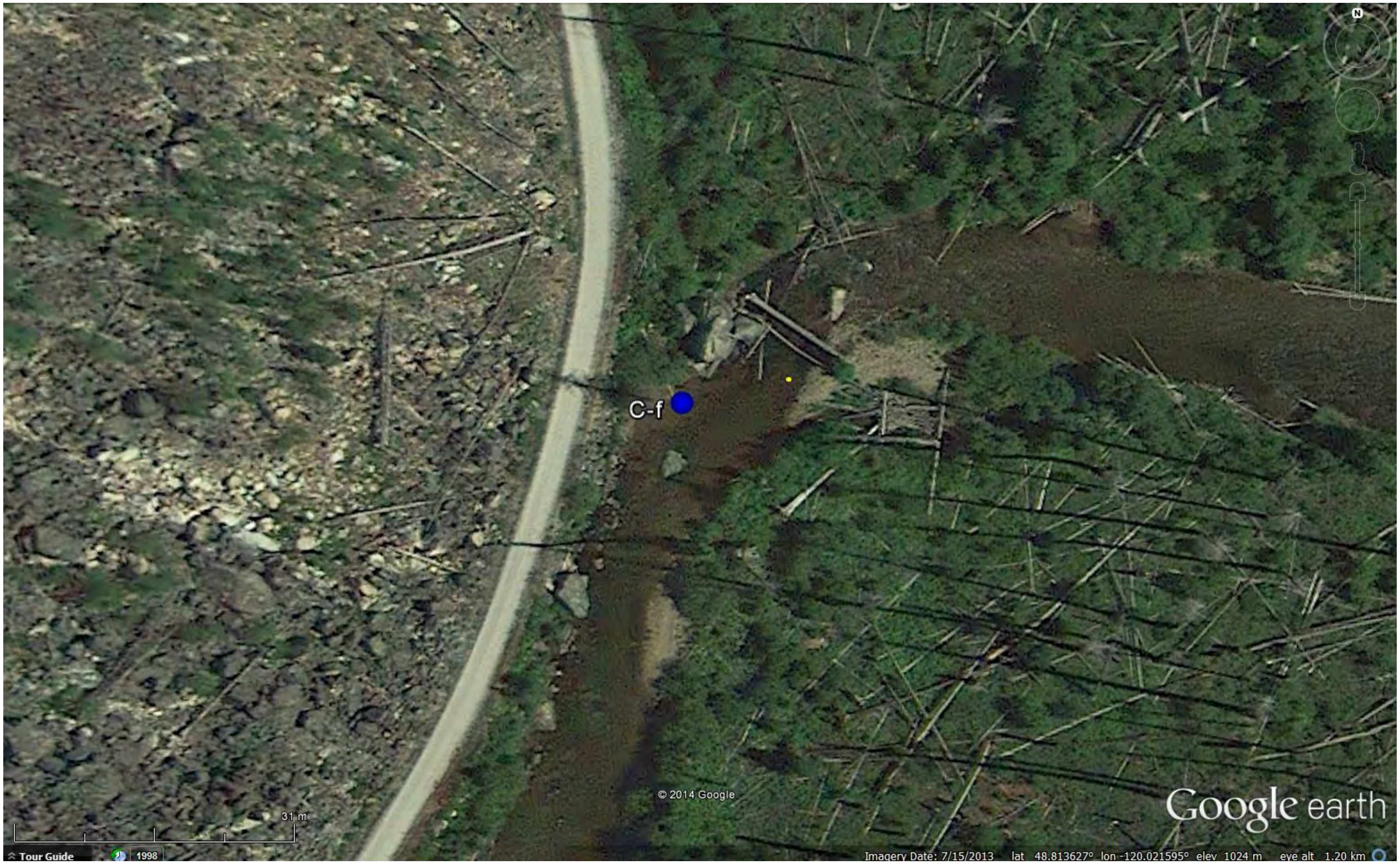
GE Map (15): Upper Twisp site T-j had slow backwater areas, but all substrate was rock (cobble, boulders, large and small gravel).



GE Map (16): Overview of our survey sites on the Chewuch River (C-aa, C-f, and C-2)

GE Map (17): Chewuch survey site C-aa (Rkm 36.1) was visited and only cobble/gravel was observed and very swift water was present. It appears that most of the area below this observed site is the same with swift water and large substrate until the lower reaches.

GE Map (18): Upper Chewuch survey site C-2 was above a log jam with fine sand and silt deposits. A quick spot check with the electroshocker yielded no lamprey.



GE Map (19): Upper Chewuch survey site C-f had fine sand and silt deposits with areas of coarse substrate and detritus. No lamprey were found during our survey.

GE Map (20): Overview of Beaver Creek survey sites.

GE Map (21): Lower Beaver Creek survey site B-b had swift water, with cobble/gravel substrate and no fine sediment.

GE Map (22): Lower Beaver Creek survey site B-c had minimal fine sediment collection and was spot-checked with fine mesh net and observed no lamprey.

GE Map (23): Lower Beaver Creek sample site B-d had no fine sediment, mostly large cobble/gravel and swift water.

2013 Klickitat Larval Lamprey Habitat Surveys

Yakama Nation FRMP, Pacific Lamprey Project
Dave'y Lumley and Ralph Lampman

Surveys Conducted between 10/14/2013 and 10/16/2013
By Dave'y Lumley and Patrick Luke

Overall Findings:

We surveyed for larval/juvenile lamprey in the Klickitat River and one of its tributaries, the Little Klickitat River, in available Type I and Type II habitat (i.e. larval habitat) using an Abp-2-electrofisher designed for larval lamprey sampling. Due to the survey area being large, the survey was broken into three days for the overall surveys. Not all sites we visited had larval habitat that could be sampled due to deep pools or swift currents that resulted in a lack of fine sediment. Index sites, sites to be surveyed repeatedly for long-term status and trend monitoring, were chosen based on findings from past surveys and are at river kilometers 1.9, 28.5, 52.4, 82.7. River km. 28.5 was not visited in 2013, but has been in previous years and has excellent larval habitat.

On the Klickitat River, 10 sites had full surveys conducted between October 14th-16th, 2013. Four more sites were visited but unsurveyable due to lack of suitable habitat. The first site that was sampled was K12 located at the farthest point upstream at RK118.3. This site is located above Castile falls on the Yakama Reservation and is in a small side channel that was made up of mostly cobble mixed with small amounts of clay, fine sand, and organic material. No lampreys were found in this area but small larvae, sculpins, beetles, water striders, and worms were observed. Once the habitat survey was complete, water quality data were taken collecting dissolved oxygen percentage, pH balance, conductivity, and temperature information.

The next site surveyed was K11 located at RK 105.9 at Castile falls. The survey was conducted in a small 2m² areas at the outlet of a pipe due to being the only area with suitable habitat containing small amounts of silts mixed with small cobble. The rest of the area was composed of large bedrock, cobble, and deep water. No lamprey was found here along with any other wildlife observations. At this site there was also a screw trap fishing above the area sampled. Water quality was collected before leaving the area. The next sampled was K10 located at RK99.7 at a small camping area. The area that was sampled was a 10 m long gravel beach composed of small cobble and woody debris mixed with coarse sand. No lampreys were found and only water striders were observed in the area. The last site surveyed for the upper section of the river, and the day, was K9 at RK82.7 and was located just outside of Glenwood, WA, at Parrots Cove, a rafting inlet and public fishing/camping area. The survey area was 9 m in length and was composed of hard compact fine sand with fallen leaves littered around. Three lampreys were observed here, one missed, with a length of about 20mm, and two caught, both unknown with lengths of 25 mm and 30 mm. This was the uppermost site that lamprey were found in this year's survey.

Due to the landscape of the Klickitat River, there is a section located in a canyon below K9 that is difficult to access so the crew started from the mouth of the river and worked upstream to more accessible sites. The next site surveyed was K2 at RK1.9 and was located at a public fishing area that many people were at. The survey area was located in a large backwater area with around 200 m^2 of suitable habitat composed of a soft, silt and sand mixture with milfoil and cobble spaced around. The survey was completed in a 24 m^2 area and a total of forty-one lamprey were captured, seven pacific juveniles with lengths between 70-141 mm, and the other thirty-four were unidentified due to a lack of MS-222, and had lengths between 40-70 mm. Those that were missed were small young of the year juveniles with lengths around 10 mm long.

K3 at RK9.8 was located at a public boat launch. This area had around 300m^2 of total habitat but no all was accessible. The survey are was 30m^2 and was composed of a small layer of soft silt on top of fine sand mixed with small amounts of woody debris and other organic materials. There were also many salmon carcasses and entrails from fisherman cleaning their fish in the area. Twenty-three lampreys were captured; four identified as pacific juveniles with lengths between 85-120 mm, and rest was unidentified before being released back into the area. Twenty-six were missed and had lengths between 30-50 mm. The next site sampled was K5 at RK19.5 located outside of Klickitat behind private property on Skookum Flats. This area also had a large amount of sediment that ranged about 30m^2 but most was located in deep, swift water making it inaccessible. The area surveyed was 20 m^2 and was composed of soft silt on top of hard compacted sand mixed with an abundance of woody debris and detritus. There was also salmon carcass present as well. Twenty lampreys were captured, eighteen of which were identified as pacific juveniles and had lengths between 30-60 mm, two were unknown and a total of fifty-five lamprey were missed. Majority of the missed lamprey were small 10-20 mm young of the year larvae. The next site was K6 at RK30.6 located under a bridge upstream from Wakiacus. This area had a total of 30m^2 of sediment but only 16m^2 was surveyed due to accessibility. The sediment was composed of hard compacted sand with little to no organic material. Thirteen lamprey were captured here, two identified as Western brook lamprey with lengths of 120 mm each, and the rest were too small to identify. A total of forty-one lamprey were missed, all young of the year with lengths between 10-20 mm.

Moving upstream the next site sampled was K7 at RK52.4 located at Leidl Park in between Goldendale and Glenwood, WA. The area surveyed was located in a side channel and had 14m^2 of a sand and silt mixed with woody debris, leaves, detritus, organic material and a log with gravel and cobble spaced around. Twelve lampreys were captured here; three identified as pacific juveniles, the rest unidentifiable due to their small size. Fifty-nine lampreys were missed, all of which were small young of the year with sizes around 10-20 mm and emerged mainly around the leaves. The last site surveyed on the Klickitat River was K8 at RK69.3 and was located at the Klickitat Fish Hatchery outside of Glenwood near pond 24. This survey area was composed of 15 m² of coarse sand mixed with large amounts of cobble and woody debris that was pinned up against the rocks. There was some fine sand located along the rocks along the bank. Five lampreys were captured three identified as pacific lamprey juveniles, one Western brook lamprey, and one unidentifiable due to its small size. Five lamprey were missed at this site with lengths between 20-60mm. Water quality was also taken at all surveyed sites on the Klickitat River and the mean values of conductivity was 82.19µs, dissolved oxygen percentage was 85.7%, pH was 6.7 and water temperature was 8.9°C.

Once the main stem surveys were complete, two sites were surveyed on the Little Klickitat River which is a tributary to the Klickitat River. The first site was LK1 at RK27.3 located at the Little Klickitat Bridge in Goldendale. This area had a total area of 15 m² but only 2 m² were surveyable due to deep water and low visibility from murky water. The sample area was composed of heavy detritus mixed with silt and small amounts of cobble along a grassy bank. Seven lampreys were captured here, all of which were identified as Western brook lamprey. Seven lamprey were also missed in the area with lengths between 10-170 mm. The next site surveyed was LK2 at RK29.8 located private property outside of Goldendale off Highway 97. This area had very little sand and was composed mainly of cobble creating a Type II habitat. Fifteen lampreys were captured here, all of which were identified as Western brook lamprey, and four were eyed macrophthalmia. Seven lampreys were missed and had lengths between 40-80 mm. Water quality data were also taken at these sites on the Little Klickitat River and the mean values of conductivity was 106.5µs, dissolved oxygen percentage was 65.5 %, pH was 6.9, and water temperature was 7.9°C.

Site Summary Table

Date	Stream	Rkm	Survey Type	Total Lamprey Observed	Observed Density (Larvae/m^2)	100m Habitat Availability (m^2)	Extrapolated # of larvae / 100m	% Pacific Lamprey	% Western Brook	% Unknown	Plot Temp °C	Sed. Temp °C	Primary Hab. Type
10/15/2013	Klickitat	1.9	Full Survey	59	7.4	200	1475	100	0	88	12.1	10.9	Thin Detritus
10/15/2013	Klickitat	9.8	Full Survey	49	2.5	300	735	100	0	92	12	10.8	Sand Only
10/15/2013	Klickitat	19.5	Full Survey	75	3.8	300	1125	100	0	87	9.3	8.9	Thick Detritus
10/15/2013	Klickitat	30.6	Full Survey	54	3.4	30	101	100	0	96	10	9.8	Sand Only
10/15/2013	Klickitat	52.4	Full Survey	71	5.1	30	152	0	100	96	10	9.8	Sand Only
10/16/2013	Klickitat	69.3	Full Survey	10	0.7	15	10	75	25	60	7.5	7.6	Sand Only
10/14/2013	Klickitat	82.7	Full Survey	3	0.3	10	3	-	-	100	5.6	6.6	Sand Only
10/14/2013	Klickitat	99.7	Full Survey	-	-	10	-	-	-	-	6.4	6.3	Sand Only
10/14/2013	Klickitat	105.9	Spot Check	-	-	2	-	-	-	-	7.4	7.4	Thin Detritus
10/14/2013	Klickitat	118.3	Full Survey	-	-	30	-	-	-	-	9.2	9.1	Thin Detritus
10/16/2013	Little Klickitat	27.3	Full Survey	19	9.5	15	143	0	100	63	9.1	9.4	Thin Detritus
10/16/2013	Little Klickitat	29.8	Full Survey	22	5.5	30	165	0	100	50	-	-	Thin Detritus
Overall Mean:			**12 Sites**	**40**	**4.2**	**81**	**434**	**59**	**41**	**81**	**9.0**	**8.8**	**-**

Water Quality Table

Site # (river km)	Date	Rk	Conductivity (µs)	Dissolved Oxygen (mg/L)	pH	Plot Temp
K2 (1.9)	10-15-13	1.9	170.8	95.3	6.47	12.7
K3 (9.8)	10-15-13	9.8	79.80	95.3	6.44	11.3
K5 (19.5)	10-15-13	19.5	79.19	97.4	6.50	9.4
K6 (30.6)	10-15-13	30.6	76.80	92.1	6.75	9.9
K7 (52.4)	10-15-13	52.4	75.61	94.1	7.24	9.1
K8 (69.3)	10-16-13	69.3	71.46	90.0	7.70	7.5
K9 (82.7)	10-15-13	82.7	68.98	72.2	6.79	4.7
K10 (99.7)	10-14-13	99.7	71.40	80.6	6.34	6.9
K11 (105.9)	10-14-13	105.9	64.28	83.2	6.76	7.4
K12 (118.3)	10-14-13	118.3	63.57	56.2	6.68	10.3
LK1 (27.3)	10-16-13	27.3	109.4	49.3	7.12	8.9
LK2 (29.8)	10-16-13	29.8	103.7	82.0	6.58	6.9

Lamprey Table

Site # (river km)	Date	Total Caught	Total Missed	Western Brook	Pacific	Unknown	Total Observed
K2 (1.9)	10-15-13	41	18	0	7	34	59
K3 (9.8)	10-15-13	23	26	0	4	19	49
K5 (19.5)	10-15-13	20	55	0	18	2	75
K6 (30.6)	10-15-13	13	41	2	0	11	54
K7 (52.4)	10-15-13	12	59	0	3	9	71
K8 (69.3)	10-16-13	5	5	1	3	1	10
K9 (82.7)	10-15-13	2	1	0	0	3	3
K10 (99.7)	10-14-13	0	0	0	0	0	0
K11 (105.9)	10-14-13	0	0	0	0	0	0
K12 (118.3)	10-14-13	0	0	0	0	0	0
LK1 (27.3)	10-16-13	7	7	7	0	0	14
LK2 (29.8)	10-16-13	15	7	15	0	0	22


K2: Close up view of survey area


K2: Looking upstream from survey area


K2: Looking downstream from survey area


K2: Close up view of sediment showing a mixture of silt and sand


K2: Close up view of two captured Pacific lamprey larva tails

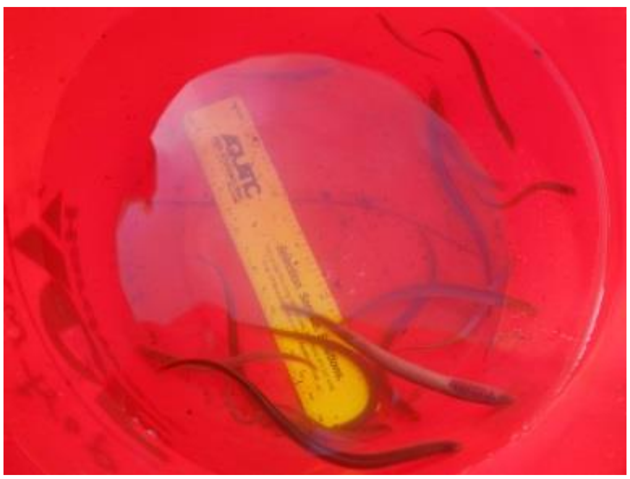

K2: Overview of captured lamprey


K3: Close up view of sediment


K3: View of surveyed area


K3: Looking downstream of survey area showing salmon carcasses


K3: Electroshocking near salmon carcass


K3: Overview of captured lamprey


K3: Close up view of a Pacific juvenile tail


K5: Looking upstream of sample area


K5: view of sample area with salmon carcass


K5: View of sample area showing all organic material

K5: Overview of captured lamprey


K6: Close up of sediment


K6: close up of sample area composed of compacted sand


K6: Looking upstream from sample area


K6: Close up of a Pacific lamprey juvenile tail

K6: Overview of captured lamprey


K7: Looking upstream of survey area


K7: Overview of survey area


K7: Close up view of sediment composed of clay, silt and sand

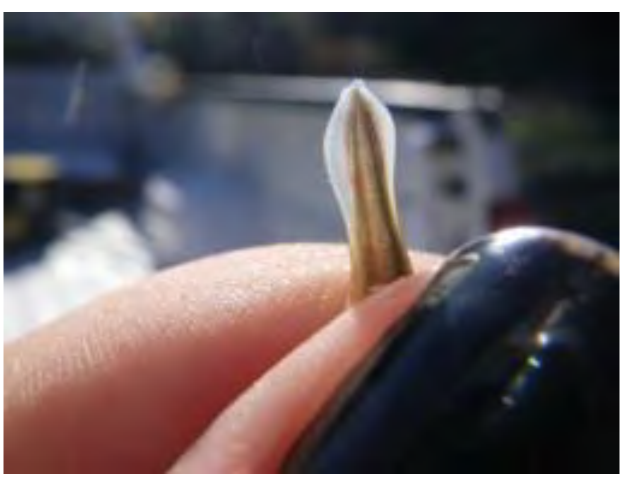

K7: Overview of captured lamprey


K8: View of survey area


K8: Close up view of coarse sand


K8: view of open mouth of a capture Western brook macrophthalmia


K8: Close up view of a captured Western brook macrophthalmia


K8: Close up view of a captured Western brook macrophthalmia tail


K9: looking downstream at the survey area


K9: Close up view of fine sand


K9: view of survey area


K9: Overview of captured lamprey


K9: Close up of unidentified juvenile lamprey


K10: Close up of sediment composed of silt and fine sand


K10: Looing downstream from survey area


K10: Looking upstream from survey area


K11: Looking upstream from survey area of the screw trap


K11: View of survey are near pipe


K11: Close up of survey area


K11: Overview of area


K11: Close up of sediment


K12: Looking downstream from survey area in side channel


K12: Looking at survey area while electroshocking


K12: Close up of survey area showing cobble and gravel


K12: Close up of survey area showing detritus and organic material

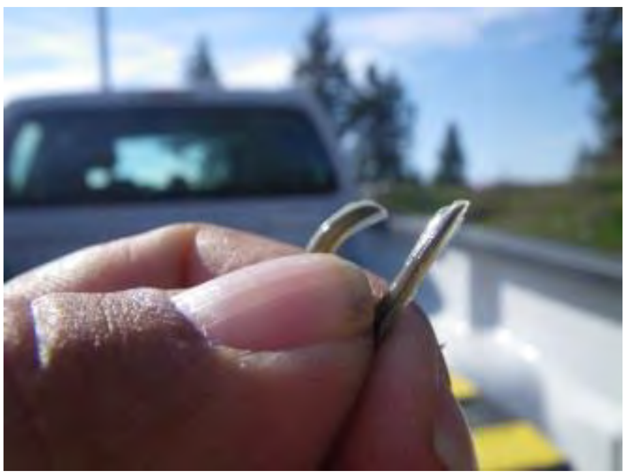

K12: Close up of sediment


LK1: Looking downstream from survey area

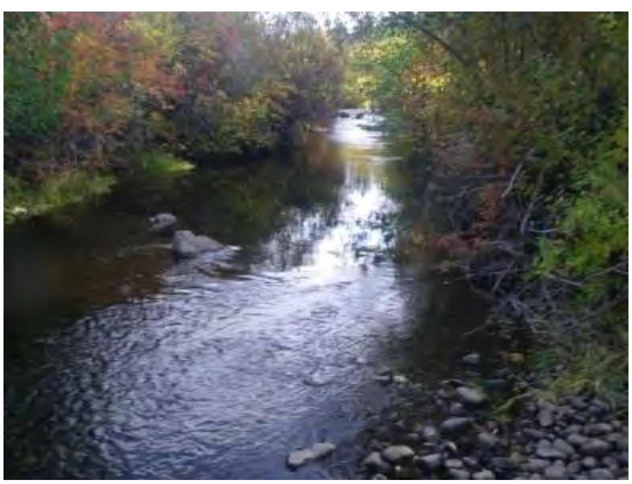

LK1: Close up of river bottom showing organic material


LK1: View of electroshocking in survey area

LK1: Overview of captured lamprey



LK1: Close up of western brook lamprey tails



LK2: Looking upstream from survey area

LK2: Electroshocking in Type II habitat

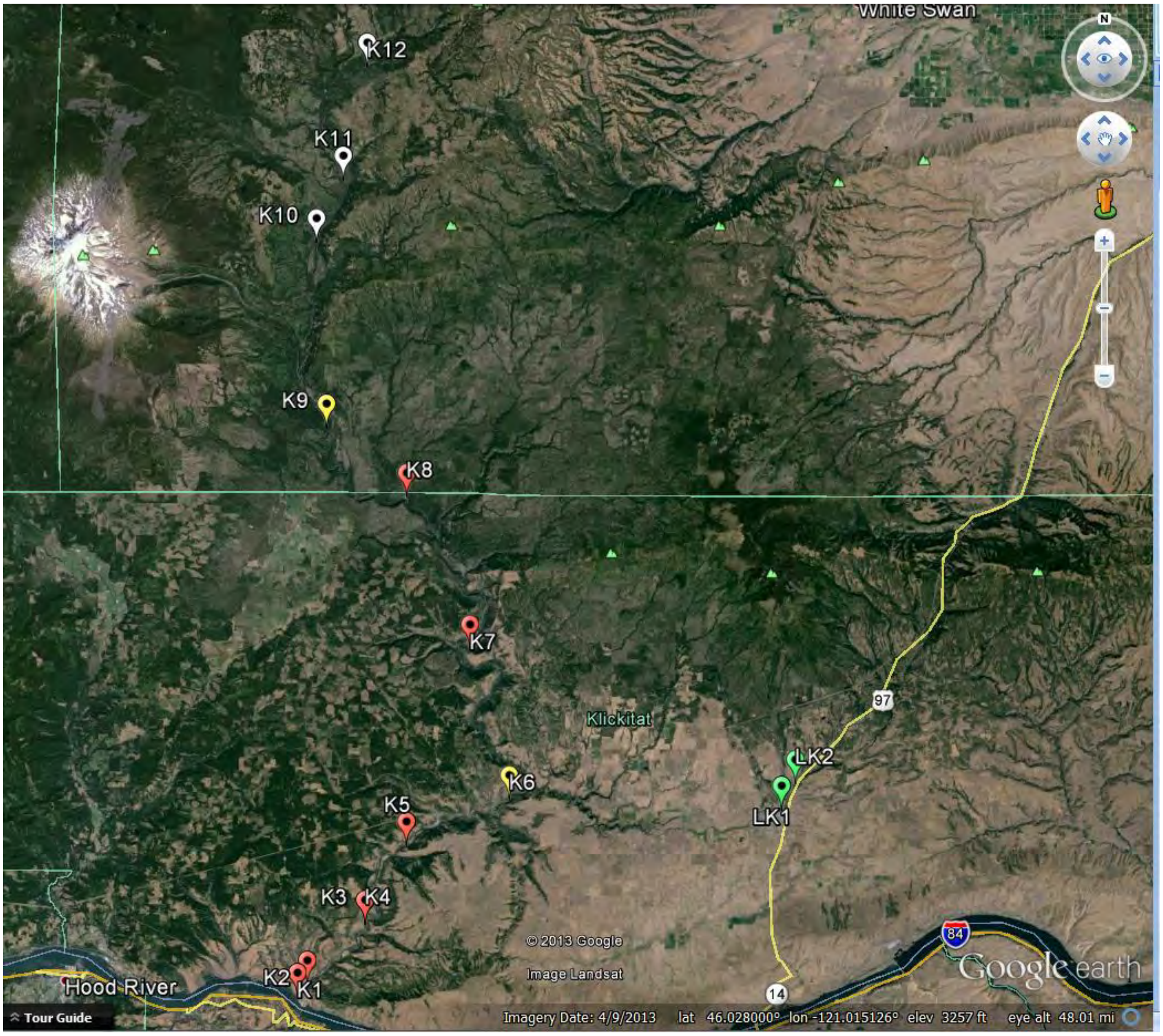
LK2: Close up view of a Western brook lamprey macrophthalmia head

LK2: Close up of a Western brook lamprey macrophthalmia tail

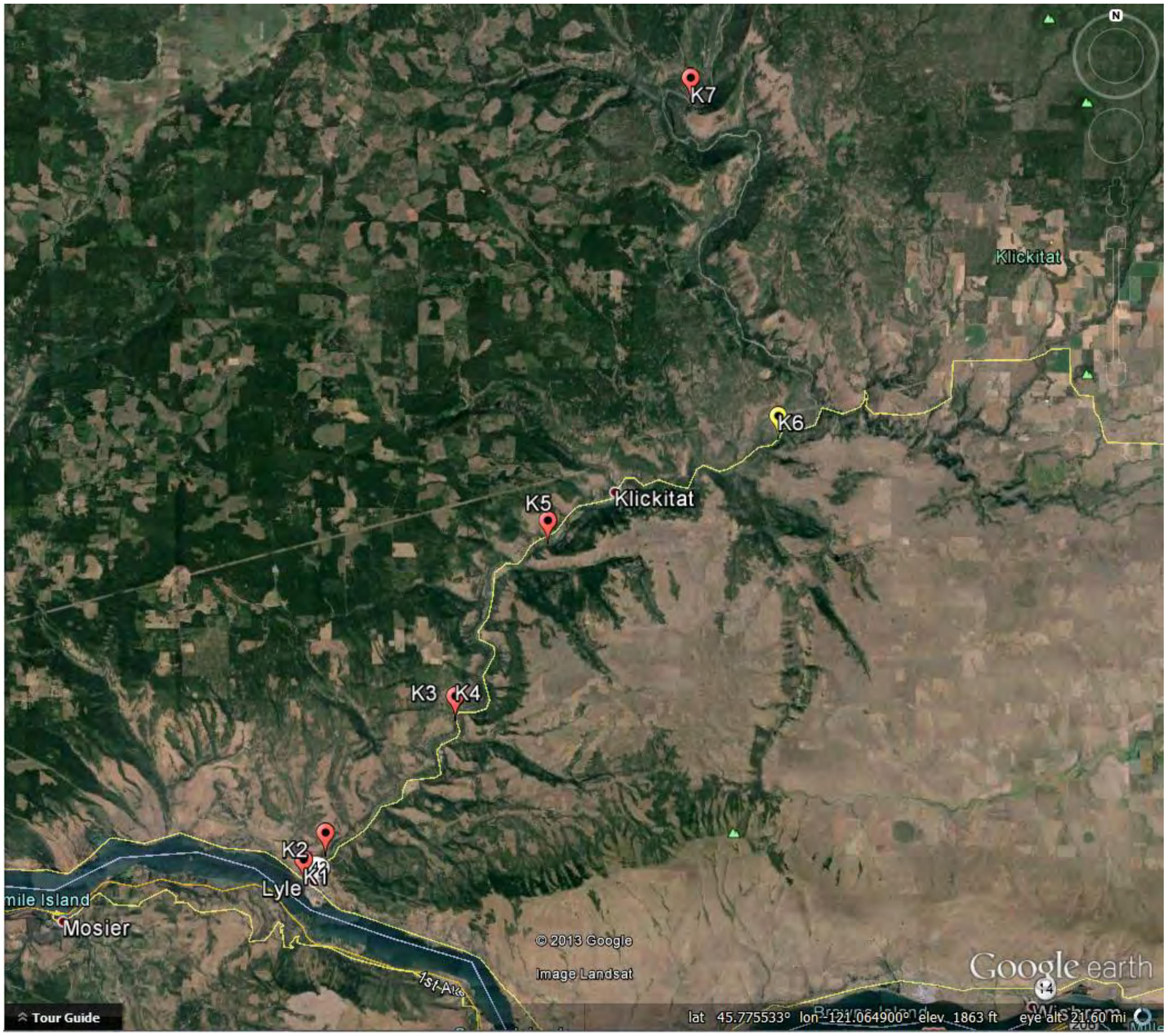
LK2: Close up view of a Western brook lamprey macrophthalmia and an ammocoete

LK2: View of a captured lamprey

LK2: Overview of captured lamprey



Overview of Klickitat River and the Little Klickitat River sites



Overview of the Lower Klickitat sites

Overview of the Upper Klickitat sites

K1: At the mouth of the Klickitat River in Lyle, WA
RK 0.6

K2: Next to public fishing area off of Hwy 142 outside
RK 1.9

K3: At public boat launch off of Hwy 142
RK 9.8

K5: Outside of Klickitat, WA, behind private property on Skookum Flats
RK 19.5

K6: Under bridge upstream from Wakiacus Bridge
RK 30.6

K7: At Leidl Park outside of Glenwood, WA
RK 52.4

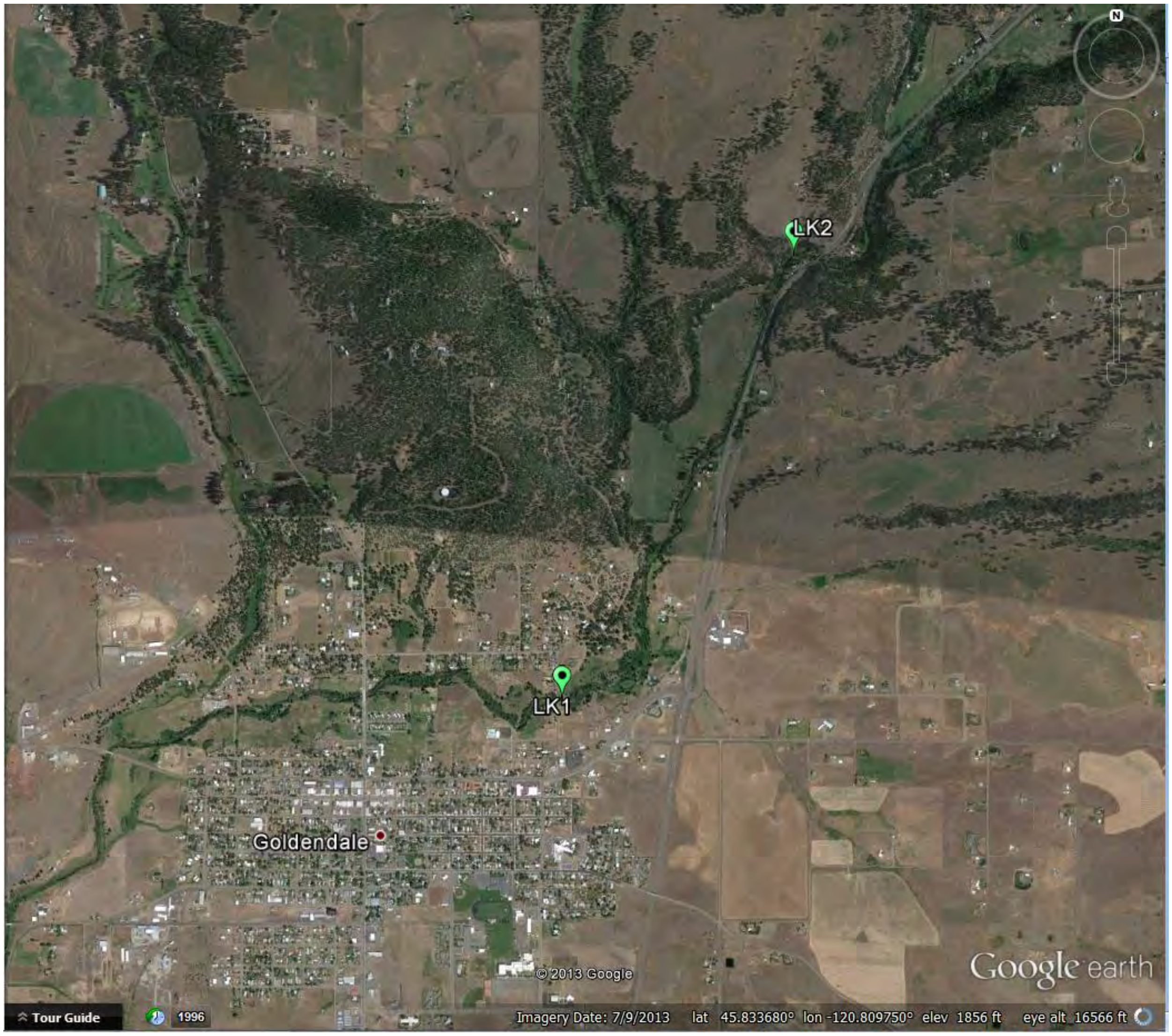
K8: At the Klickitat Salmon Hatchery next to pond 24, outside Glenwood, WA
RK 69.3

K9: At Parrots Cove boat launch outside Glenwood, WA on Yakama Reservation
RK 82.7

K10: At boat launch off of BIA Rd 140 on Yakama Reservation
RK 99.7

K11: At Castille Falls on Yakama Reservation
RK 105.9

K12: Above Castille Falls at truck turnaround on Yakama Reservation
RK 118.3



Overview of the Little Klickitat River

LK1: Above the Little Klickitat bridge in Goldendale
RK 27.3

LK2: On private property outside of Goldendale off Hwy 97
RK 29.8

2013 White Salmon Larval Lamprey Habitat Surveys

Yakama Nation FRMP, Pacific Lamprey Project
Dave'y Lumley and Ralph Lampman

Survey Conducted between 9/24/13 and 9/26/13
By Dave'y Lumley and Patrick Luke

Overall Findings:

We surveyed for larval/juvenile lamprey in the White Salmon River and one of its tributaries, Trout Lake Creek, in available Type I and Type II habitat using an Abp-2-electrofisher designed for larval lamprey sampling. First, all sites were scouted out to evaluate all survey conditions. Not all sites we visited had habitat that could be sampled. For example, all sites on Rattlesnake Creek had very low flow, stagnant water conditions with predominantly medium to large size gravel substrate composition, rendering them unsurveyable.

Eight sites were visited in White Salmon River, two of which were not surveyable due to lack of suitable habitat. Starting at the mouth of the river, we surveyed multiple sites in the lower section of the river up to the where the Condit dam removal site. The area that surrounds where the Condit dam used to stand, in 2011, has been influenced by the removal. For example, as the water level dropped in Northwestern Park, large deposits of mixed sediments and organic material appeared to have collected in the lower portion of the river and at the mouth of the river (creating a new sand bar in the Columbia River).

The lowermost sampled site was located at the mouth of the river and over 100m of surveyable habitat was available containing mixed sediments, organic material, small to large woody debris, and multiple pre/post spawned salmon carcasses. Some of the sediment that had flowed downstream from the dam has collected along the banks of the river building and raising them above water level, narrowing the mouth of the river. Although this site contained good depositional areas, no lampreys were found here. Further upstream, the river flows through a canyon with high steep walls leaving the sites inaccessible. The next two sites we surveyed below the confluence of Rattlesnake Creek upstream from this canyon contained lamprey. One site was located at Northwestern Park, which is now again open after the re-vegetation closure period following the Condit Dam removal. This area has been channelized after the removal but there was a small backwater area of fine sediments and organic material that collected along the bank. At this site, nine lampreys were captured; one was identified as a Western brook lamprey while the others were not identifiable due to their small size. After photos and lengths were collected, the lampreys were release back into their habitat. The last site surveyed in the mid-section of the river was located in Husum on private property, but permission was granted to cross the property for river access. This site was in a small backwater area along large boulders where a mound of coarse sand collected with large amounts of woody debris. There was swift current, creating ripples and hence low visibility conditions, and out of the four lamprey observed, only two were captured. The two lampreys captured were both over 100mm and identified as Western brook lamprey.

Moving upstream in White Salmon River from mid to upper reaches, there were miles of inaccessible river due to the steep canyon that the river flowed through. The next surveyable site was located in Trout Lake on River Rd. This area was along a grassy bank with large deposits of organic material of pine needles, leaves, branches, and small woody debris. Visibility was low due to the rain but 11 lampreys were observed, eight of which were captured. There was one macrophthalmia with a length of 135mm and was identified as a Western brook lamprey. The other lamprey's lengths ranged from 28mm-72mm and three more were identified as Western brook lamprey while the others were unknown due to their small size. The next site was WS6 and was located just upstream about an 1/8 mile in a small diversion next to a weir on the river. Inside the diversion there were fine sand and silt mixed with pine needles, leaves and woody debris but no lamprey were found here. The following site was WS7 and was the last site sampled on the White Salmon River. It was located on River Rd. just below a wooden covered bridge. This sample area was taken along the bank where a thin layer of silt collected on top of coarse sand with cobble interspaced. There was also fine organic matter that collected in between the rocks on top of the sediments. Out of the 10 lampreys observed, six were captured and the lengths ranged from 70mm-117mm. All six were identified as Western brook lamprey. The last site was WS9 located next to Jonah Ministries Youth building and there was no habitat to sample so only photos were taken. Water quality was taken at all surveyed sites and when averaged for the White Salmon River the average conductivity was 68.76µs, average dissolved oxygen percentage was 83.2%, average pH was 5.37, and the average temperature was 9.5°C.

Trout Lake Creek is a tributary of the White Salmon River located in Trout Lake, WA. There is not an abundance of surveyable habitat throughout Trout Lake Creek which was mostly composed of inaccessible deep pools, swift water and armored creek bottom of gravels, cobbles and boulders. Photos, temperatures, and water quality was taken to document these areas. The only site that was surveyable was located at the end of Trout Lake Road in the mid reach. This area was a marshland consisting of many small side channels braided together creating very good depositional areas of fine sand and silt layered on top of coarse sand mixed with fine deposits of organic material. There was also an abundance of aquatic vegetation (grasses) and small, medium, and large woody debris located along the banks of the creek. This entire area contained suitable Type I and Type II habitat for larval lamprey. For the survey a total amount of 85m² were sampled and 13 lampreys were observed, eight of where were captured. The lamprey that were found varied in sizes from 15mm-98mm and the largest was identified as a Western brook lamprey while the others were unidentifiable due to their small size. At the three sites on the Trout Lake Creek, the average conductivity was 54.32µs, average dissolved oxygen percentage was 74.4%, average pH was 5.87, and average temperature was 9.7°C.

During this survey trip there were depositional areas found sporadically throughout the White Salmon River and in the lower section of Trout Lake Creek and lamprey were found in both systems. The lampreys were either identified as Western brook lamprey or unknown due to their small size. Index sites, sites to be surveyed repeatedly for long-term status and trend monitoring, were chosen based on our findings from these past surveys.

Summary Table

Date	Stream	Rkm	Survey Type	Total Lamprey Observed	Observed Density (Larvae/m^2)	100m Habitat Availability (m^2)	Extrapolated # of larvae / 100m	% Pacific Lamprey	% Western Brook	% Unknown	Plot Temp °C	Sed. Temp °C	Primary Hab. Type
9/25/2013	White Salmon	0.8	Full Survey	-	-	600	-	-	-	-	10.6	10.7	Thick Detritus
9/25/2013	White Salmon	8.3	Full Survey	10	0.4	30	13	0	100	80	10.4	10.4	Sand Only
9/25/2013	White Salmon	12.9	Full Survey	4	0.1	15	2	0	100	50	9.0	9.2	Thin Detritus
9/25/2013	White Salmon	40.5	Full Survey	11	0.6	15	10	0	100	64	9.0	9.1	Only Sand
9/25/2013	White Salmon	41.0	Full Survey	-	-	30	-	-	-	-	9.0	9.0	Aq. Vegetation
9/25/2013	White Salmon	41.5	Full Survey	10	0.3	45	11	0	100	40	9.0	9.0	Thin Detritus
9/26/2013	Trout Lake	2.5	Spot Check	-	-	0	-	-	-	-	-	-	-
9/26/2013	Trout Lake	3.7	Spot Check	-	-	0	-	-	-	-	-	-	-
9/26/2013	Trout Lake	4.5	Full Survey	13	0.2	450	69	0	100	92	9.8	9.8	Thin Detritus
Overall Mean:			**9 Sites**	**10**	**0.3**	**132**	**21**	**0**	**100**	**65**	**9.5**	**9.6**	**-**

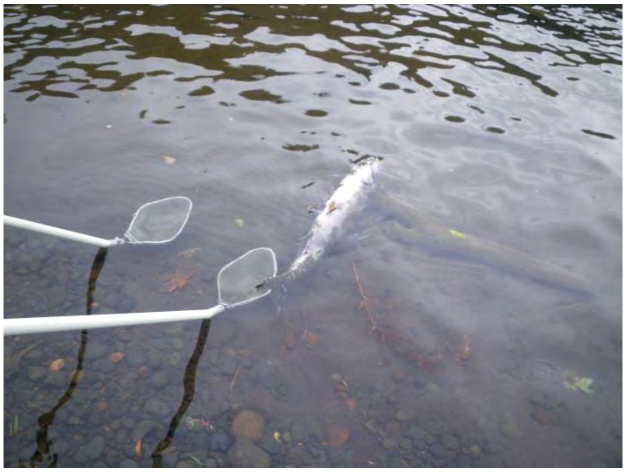
Lamprey Table

Site # (river km)	Total Caught	Total Missed	Western Brook	Pacific	Unknown	Total Observed
WS1 (0.8)	0	0	0	0	0	0
WS2 (3.7)	N/A	N/A	N/A	N/A	N/A	N/A
WS3 (8.3)	9	1	2	0	7	10
WS4 (12.9)	2	2	2	0	0	4
WS5 (40.5)	8	3	4	0	4	11
WS6 (41.0)	0	0	0	0	0	0
WS7 (41.5)	6	4	6	0	0	10
TL1 (2.5)	N/A	N/A	N/A	N/A	N/A	N/A
TL2 (3.7)	N/A	N/A	N/A	N/A	N/A	N/A
TL3 (4.5)	8	5	1	0	7	13


WS1: Close up of sample area showing woody debris and vegetation growing in and out of the water


WS1: Close up of sediment showing the mixture of silt/fine sand on top and coarse sand on bottom


WS1: Close up of one of many decomposing Chinook salmon carcasses in the sample area


WS1: Close up of electroshocking near a Chinook salmon carcass


WS1: At the 50m mark (center point of our 100m reach), looking downstream at the mouth of the White Salmon River


WS1: 50m looking upstream

WS2: Condit Dam Removal sign

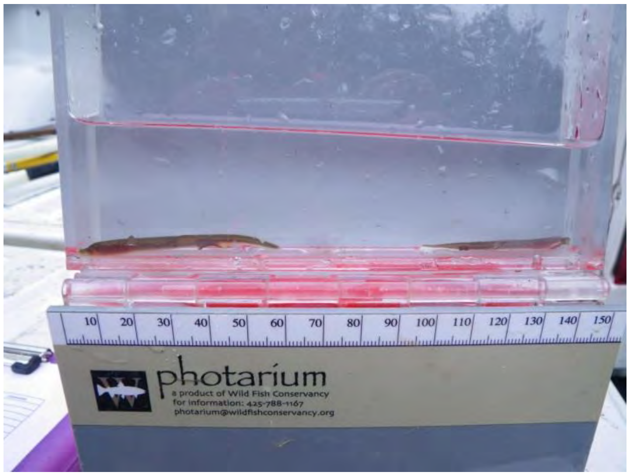

WS2: Overview of the river from the lowest point we could travel down the hill


WS2: Zoomed in photo of possible habitat across the river

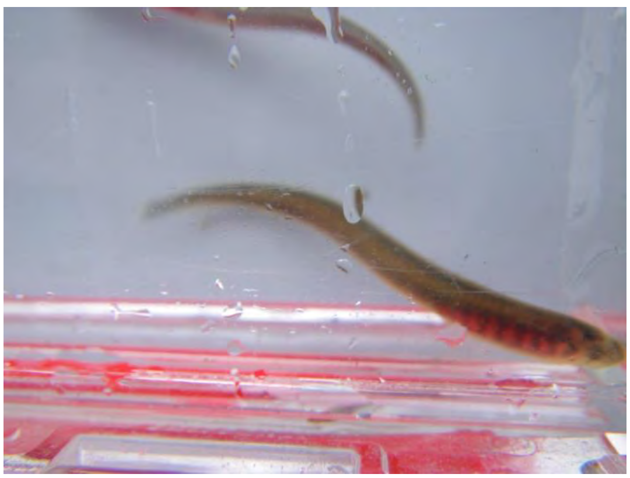

WS3: View of the open area at the Northwestern Park in the vegetated area


WS3: Patrick electroshocking in the sample area


WS3: Close up of the fine and coarse sand



WS3: View of the captured lamprey


WS3: Close up view of the captured lamprey


WS3: Close up view of the tail of a Western brook lamprey


WS4: View of sample area across the river


WS4: Patrick electroshocking in the sample area


WS4: Close up view of the coarse sand

WS4: Electroshocking in woody debris

WS4: Side view of a 121 mm Western brook lamprey

WS4: View of a 100 mm Western brook lamprey


WS5: View of sample area


WS5: Close up view of the sediment mixed with large amounts of organic matter


WS5: Close up view of a Western brook transformer head


WS5: Close up of the macrophthalmia tail


WS6: View from left bank of diversion weir


WS6: View from right bank of diversion weir and the head gate


WS6: looking downstream in the diversion from the weir


WS6: Close up of silt/clay collected in the small diversion

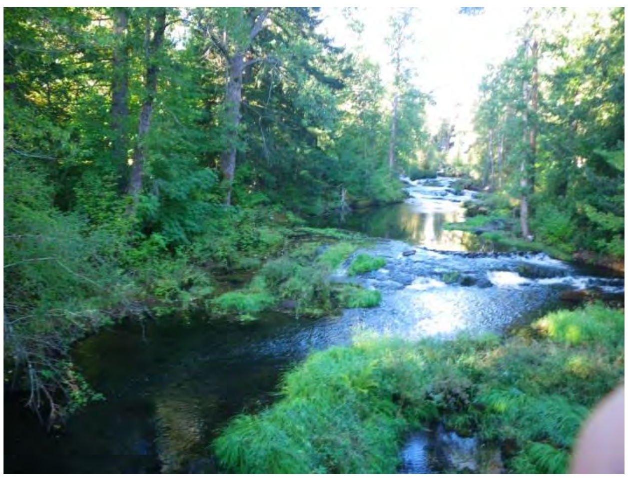

WS7: Looking upstream of the site


WS7: Close up of the coarse sand

WS7: Close up view of the lamprey that were captured


WS7: Close up of a Western brook tail with speckles on tail


WS8: View of incised channel with a deep pool and steep cutoff banks


TL1: View of survey site in Trout Lake Creek


TL2: View of survey site inTrout Lake Creek


TL2: Close up of armored creek bottom composed of gravel and cobble

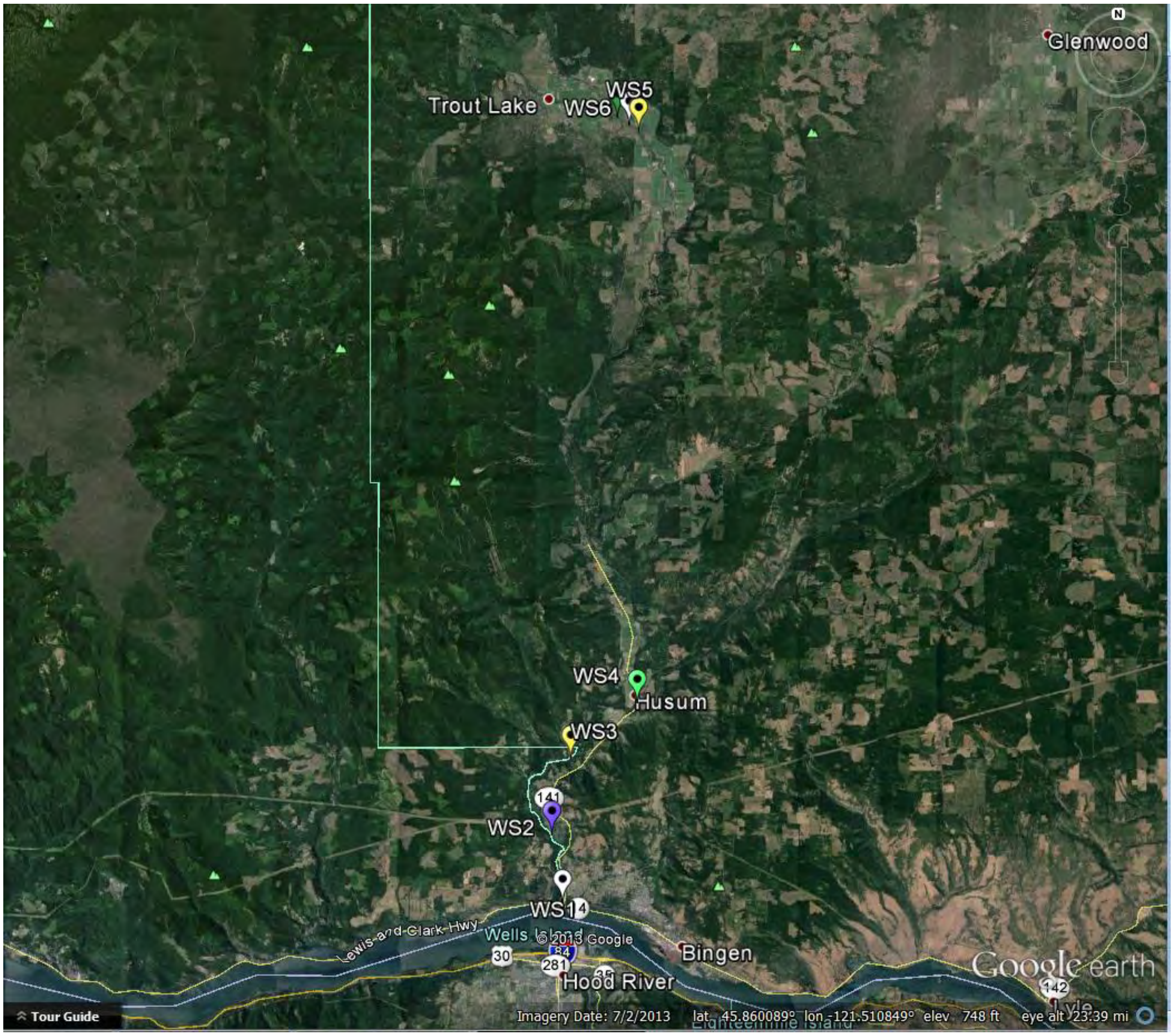

TL3: Overview of sample area looking downstream


TL3: Overview of sample area looking across the wetland

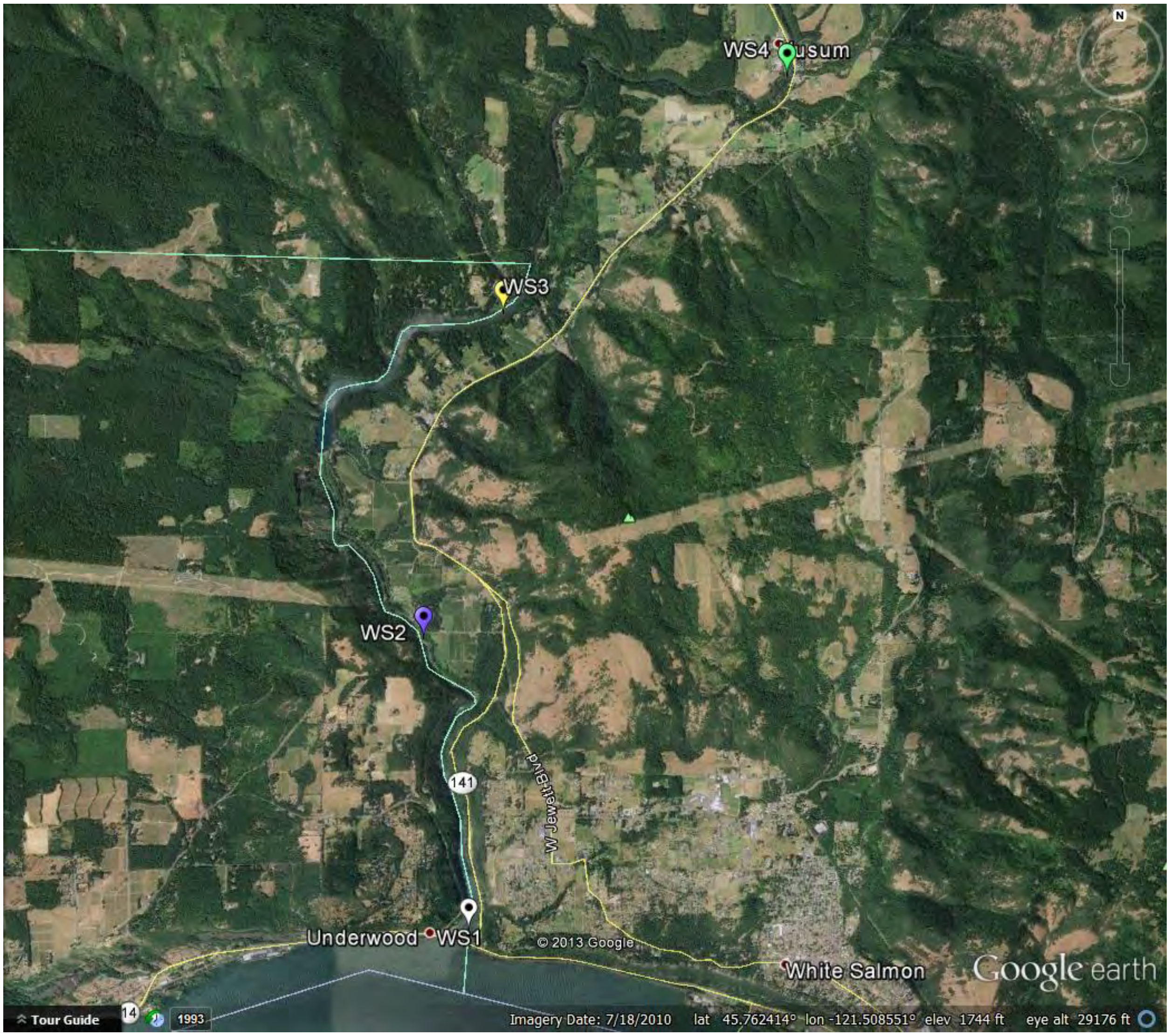

TL3: Close up of sample site showing the aquatic vegetation growing in the sandy sediment

TL3: View of the lamprey captured at this site

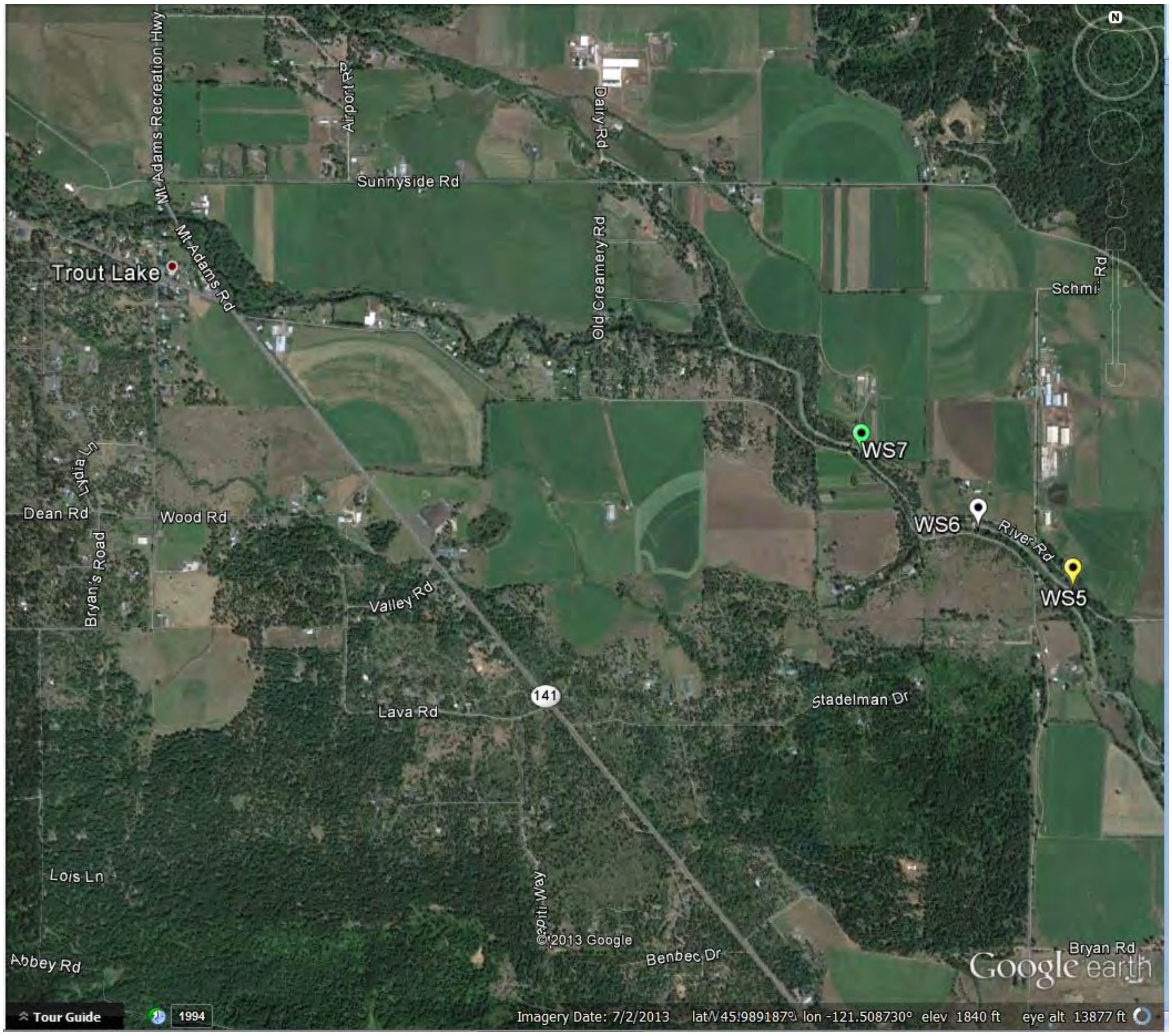

TL3: Close up of a Western brook tail (translucent fin)



Overview of White Salmon River Survey Sites



Overview of Lower White Salmon Reach



Overview of Upper White Salmon Reach

WS1: Mouth of the White Salmon River along Hwy 14 outside of Bingen, WA
RK 0.8

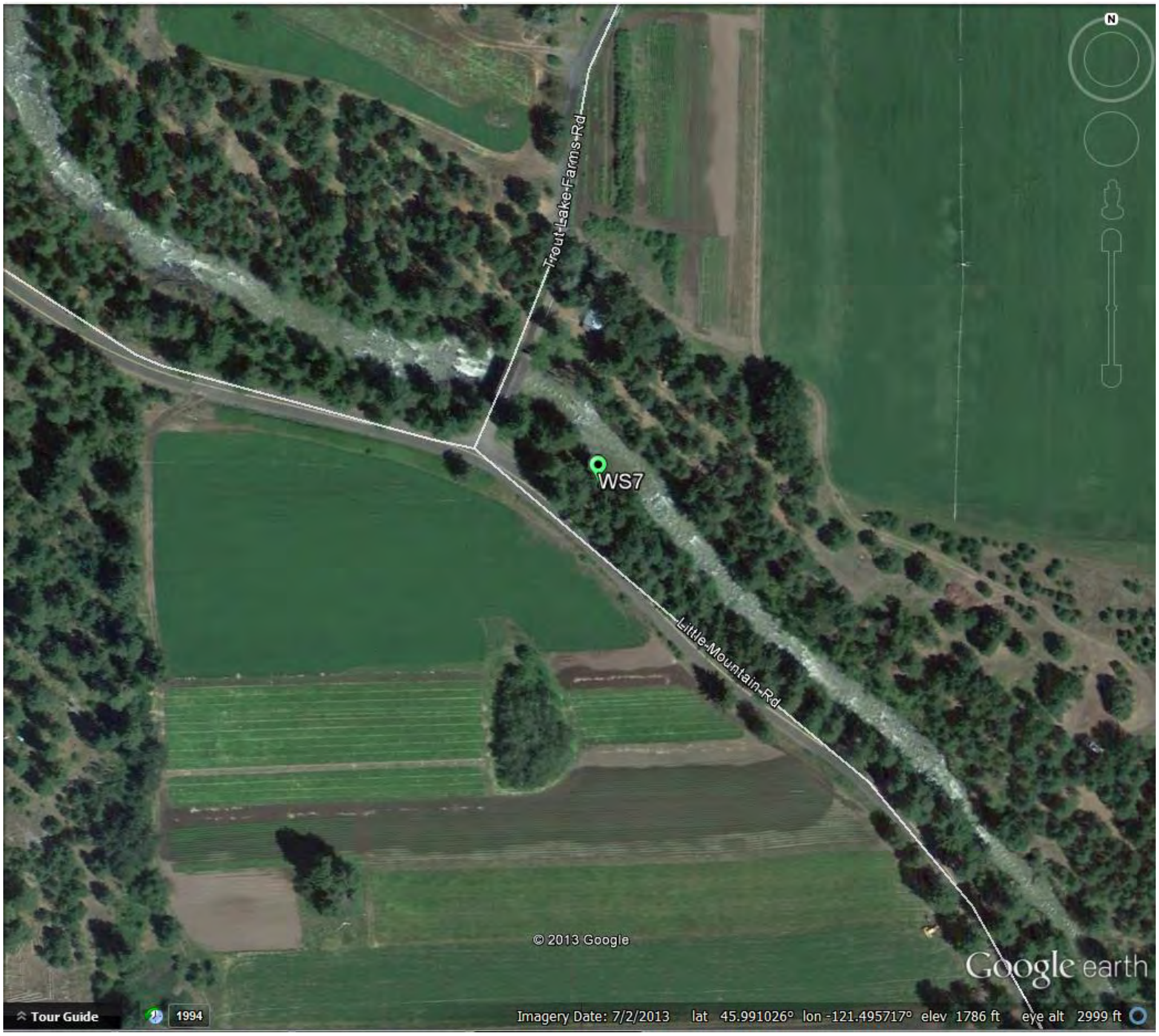
WS2: At the end of Powerhouse Rd off of Hwy 141, no survey
RK 3.7

WS3: At Northwestern Park above where the Condit Dam was removed
RK 8.3

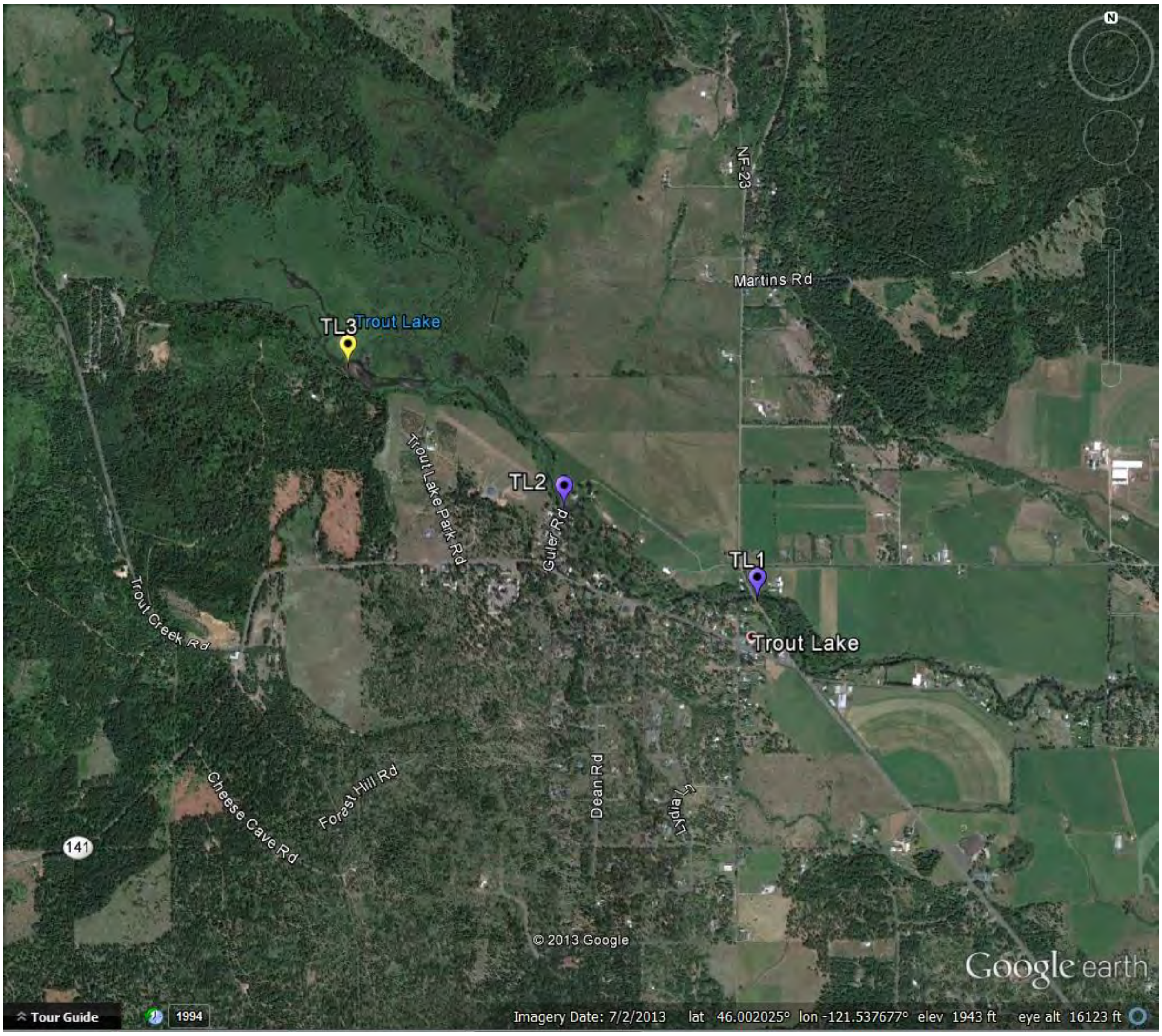
WS4: In Husum, WA, on Private Property at the end of Olson Drive
RK 12.9

WS5: In Trout Lake, WA, off River Road
RK 40.5

WS6: In Trout Lake, WA, off River Road in Diversion weir
RK 41.0



WS7: In Trout Lake, WA, off Little Mountain Road below Bridge
RK 41.5



Overview of Trout Lake, WA, Survey sites

TL1: In Trout Lake, WA, off Mt Adams Road below bridge
RK 2.5

TL2: In Trout Lake, WA, at the end of Guler Road
RK 3.7

TL3: In Trout Lake, WA, at the end of Trout Lake Park Road
RK 4.5

2013 Lower Columbia River Tributary Lamprey Collection for Mercury Concentration Study

Yakama Nation FRMP, Pacific Lamprey Project
Dave'y Lumley and Ralph Lampman

Surveys Conducted between 11-6-13 and 11-7-13
By Dave'y Lumley and Patrick Luke

Summary of Findings:

We surveyed for larval/juvenile lamprey in three of the lower Columbia River tributary mouths (Klickitat, Fifteenmile, and Wind) to collect larval/juvenile Pacific lamprey and fine sediment they rear in for a mercury concentration analysis by Pacific Northwest National Laboratory. We sampled for larval/juvenile lamprey in Type I and Type II habitat (i.e. larval preferred and acceptable habitat) using a Abp-2-electrofisher designed for larval lamprey sampling. Because the collection of lamprey was the key objective, very little habitat data was collected at these sites.

The first site of collection was located on the Lower Klickitat River at river km 0.6. This was an area that had not been previously sampled but contained an abundance of suitable habitat. At this site one Pacific lamprey and four Western brook lamprey were captured, while one larva was missed, and their length ranged from 83-133 mm. The next survey area was located on the Klickitat River at river km 9.8 (control) where a total of eight lamprey were observed and five collected for the study. The next tributary sampled was Fifteenmile Creek at river km 0.2 and 3.6 where five lampreys were collected from each sight all ranging in length from 57-126 mm. The last tributary that was sampled was the lower Wind River at river km 1.7. At this site five lampreys were collected ranging in sizes from 34-101 mm while other smaller young of the year larvae were observed but not captured. Only one site was sampled on the Wind River due to lack of accessibility and habitat in the upper portion. Once all collection was completed, all samples were sent to the Pacific Northwest National Laboratory for the mercury concentration analysis.

Table 1. Summary information for the larval lamprey sampling in Lower Columbia River and tributaries.

Stream	River km	Total Caught	Total Missed	Pacific	Western brook	Unknown	Total Observed
Lower 15 Mile	0.2	5	0	5	0	0	5
Upper 15 Mile	3.6	5	0	5	0	0	5
Lower Klickitat	0.6	5	1	1	4	1	6
Upper Klickitat	9.8	5	3	5	0	3	8
Lower Wind	1.7	5	30	0	4	1	35

Figure 1: Overview of Larval/Juvenile Collection Sites

2013 Yakama Rafting Larval Lamprey Habitat Survey

Yakama Nation FRMP, Pacific Lamprey Project
Dave'y Lumley and Ralph Lampman

Survey Conducted on 9-9-13
By Dave'y Lumley, Markeyta Pinkham, Tyler Beals, Jamie Sohappy, and Mike Porter

Summary of findings:

We surveyed for larval/juvenile lamprey in the Yakima River in available Type I and Type II habitat (i.e. larval habitat) using an Abp-2 electrofisher designed for larval lamprey sampling. The sample reach was located between river kilometers 243.8 and 247.9 on Yakima River (from Ellensburg, WA, to the Yakima Canyon) and a total of six sites were sampled. We deployed the rafts at the Irene Rhinehart boat launch and made our way downstream. The goal was to identify all suitable Type I habitat areas and conduct surveys throughout the reach in the best available ammocoete habitat.

RK247.9 was at the outlet of a small pond that flowed into the river. The survey area was located in the outlet channel and ran along the bank of the pond. This area was composed of a deep silt/clay mixture with small amounts of detritus and organic material spaced around. There was 20m² of surveyable habitat but no lampreys were found here. Other larval fish were observed in the area along with small aquatic insects. Once the site information was documented with photos, temperature readings, and other observations, the crew moved downstream.

RK247.2 was located off of a large gravel island in the middle of the main stem river. There was a small backwater area that was composed of sand and silt with high densities of woody debris spaced around. There was 14m² of surveyable habitat and two lampreys were observed but not captured so the species remains unknown. Other larval fish and insects were observed in the area as well.

RK246.9 was located at the confluence of a side channel. This area was composed of silt mixed with small amount of sand and detritus and high densities of medium-large woody debris. There was also small aquatic vegetation growing in the water. There was 18m² of surveyable habitat and one lamprey was captured and identified as a Western brook lamprey. There was fifty other lamprey observed but were only 10-15 mm in length, indicating they are likely young of the year larvae from 2013. Due to their size they would fall through the net and would hide in between the woody debris.

RK245.1 was located at the confluence of another side channel. This area was composed of a thin layer of silt on top of coarse sand mixed with thick amount of detritus and woody debris. There was 34m² of surveyable habitat and nine lampreys were captured and thirty-one were observed. Seven of the captured lampreys were identified as Western brook lamprey while the other two were unknown due to their small size. Other small fish, such as sculpin, crayfish, and aquatic insects were also observed in this area.

RK 244.2 was located at the confluence of a side channel where fine sediment had deposited. This area was composed of a mixture of silt, sand, and thick deposits of detritus and woody debris. There was 19m² of surveyable habitat and three lampreys were captured while 30 were observed. All three captured lamprey were identified as Western brook lamprey. A majority of the other observed lamprey were very small and could of possible been the offspring from 2013. Crayfish, stickleback, worms, water skippers and other aquatic insects were also observed in this area.

RK 243.8 was located at the confluence of a small side channel. This site was composed of silt, sand, small wood debris, and high densities of long aquatic grasses. There was 20m² of surveyable habitat and 17 lampreys were captured while 10 were observed. All lampreys were unknown species due to their small size. The other observed lampreys were difficult to capture because of the long aquatic grasses but two of the missed were over 100 mm. Once the site information was documented, the crew rafted down to the take out at Ringer Loop.

During this rafting trip, Type I habitat was estimated throughout this reach. The crew was unable to stop at every available habitat due to the timeframe and the current and flow of the river so only the best points were picked to conduct surveys. Habitat was also estimated using polygon features in Google Earth, delineating possible Type I habitat which can be seen in the maps below. The habitat at each survey site was color coded into two categories; yellow polygons delineate the survey area and pink polygons delineate the overall habitat area, including areas that were not surveyed. In some areas, water level was too deep to sample or was too shallow due to the time of year (dried up habitat along the bank). In addition to the surveyed habitat, the entire habitat in the rafting reach was assessed as well using Google Earth for other potential habitat. These areas are also delineated with pink polygons, indicating they are potential Type I habitat areas based off of the surveyed habitat areas and likely have similar characteristics.

Lamprey Table

Site #	Total Caught	Total Missed	Total Observed	Western Brook	Pacific	Unknown
YAK-243.8	17	10	27	0	0	17
YAK-244.2	3	30	33	3	0	0
YAK-245.1	9	31	40	7	0	2
YAK-246.9	0	50	50	0	0	0
YAK-247.2	0	2	2	0	0	0
YAK-247.9	0	0	0	0	0	0

Total Habitat Area Assessment

Total	Sq Meters
Surveyed	243.5
Available	1008.4
Potential	6889.2

Survey Site Habitat Assessment

RK	Habitat	Area (Sq Meters)	Perimeter/Length (Meters)	Mid-Point (Degrees)
YAK-247.9	Surveyed	29.8	29.6	46.9572622°, -120.5373117°
YAK-247.9	Available	180.4	106.7	46.9572713°, -120.5372248°
YAK-247.2	Surveyed	18.6	28.3	46.9518864°, -120.5372232°
YAK-247.2	Available	214.9	93.2	46.9518841°, -120.5372603°
YAK-246.9	Surveyed	12.6	21.2	46.9498585°, -120.5405289°
YAK-246.9	Surveyed	19.1	25.4	46.9500595°, -120.5402730°
YAK-246.9	Available	52.8	35.8	46.9500495°, -120.5402899°
YAK-246.9	Available	22.0	28.4	46.9498778°, -120.5405270°
YAK-245.1	Surveyed	46.4	41.6	46.9357525°, -120.5316923°
YAK-245.1	Available	152.1	98.6	46.9358067°, -120.5317252°
YAK-244.2	Surveyed	39.0	44.0	46.9318543°, -120.5238425°
YAK-244.2	Available	86.6	50.6	46.9318633°, -120.5238503°
YAK-243.8	Surveyed	78.0	61.6	46.9296313°, -120.5204147°
YAK-243.8	Available	299.5	118.8	46.9297282°, -120.5204653°

Potential Habitat Assessment

RK	Name	Area (Sq Meters)	Perimeter/Length (Meters)	Mid-Point (Degrees)
YAK-251.7	1	135.4	54.1	46.9772564°, -120.5671908°
YAK-251.4	2	57.3	52.8	46.9772125°, -120.5632771°
YAK-251.1	3	118.4	93.2	46.9768679°, -120.5603156°
YAK-251.1	4	55.5	49.5	46.9774398°, -120.5591105°
YAK-251.0	5	42.5	50.2	46.9765222°, -120.5589095°
YAK-250.7	6	63.4	43.5	46.9740678°, -120.5586721°
YAK-250.5	7	52.5	39.5	46.9720532°, -120.5588468°
YAK-250.4	8	144.6	113.5	46.9717474°, -120.5574875°
YAK-250.3	9	68.9	42.2	46.9715210°, -120.5567200°
YAK-250.0	10	45.8	45.6	46.9693081°, -120.5545210°
YAK-249.7	11	46.4	33.9	46.9665683°, -120.5536116°
YAK-249.7	12	99.5	95.4	46.9662510°, -120.5536988°
YAK-249.5	13	350.9	145.5	46.9650928°, -120.5548437°
YAK-249.1	14	268.6	114.4	46.9632548°, -120.5492119°
YAK-248.6	15	53.6	39.4	46.9607732°, -120.5441511°
YAK-248.2	16	190.8	103.5	46.9586708°, -120.5409428°
YAK-247.6	17	207.3	179.3	46.9547696°, -120.5370662°
YAK-247.6	18	165.6	54.9	46.9523754°, -120.5383823°
YAK-247.0	19	71.2	47.8	46.9508576°, -120.5389017°
YAK-246.8	20	100.0	86.2	46.9489795°, -120.5394690°
YAK-246.8	21	38.1	39.5	46.9484464°, -120.5392631°
YAK-246.6	22	23.2	20.0	46.9480438°, -120.5371595°
YAK-246.4	23	40.8	43.2	46.9461581°, -120.5344206°
YAK-246.2	24	46.5	32.8	46.9454507°, -120.5357216°
YAK-246.2	25	41.5	43.6	46.9454082°, -120.5352826°
YAK-246.2	26	112.5	87.6	46.9454322°, -120.5350831°
YAK-245.9	27	283.1	126.2	46.9422258°, -120.5349508°
YAK-245.5	28	78.2	46.7	46.9390803°, -120.5323868°
YAK-245.3	29	587.9	163.1	46.9374022°, -120.5314107°
YAK-244.9	30	255.9	135.0	46.9343016°, -120.5297945°
YAK-244.7	31	650.8	148.5	46.9321807°, -120.5294151°
YAK-244.6	32	80.0	39.7	46.9322873°, -120.5279371°
YAK-244.5	33	355.1	148.0	46.9329008°, -120.5267057°
YAK-244.1	34	278.2	108.0	46.9320802°, -120.5224546°
YAK-244.0	35	135.8	44.8	46.9315367°, -120.5214996°
YAK-244.0	36	194.9	116.5	46.9314861°, -120.5204327°
YAK-244.0	37	836.3	346.4	46.9321483°, -120.5198064°
YAK-243.8	38	266.8	69.7	46.9298205°, -120.5193588°
YAK-243.6	39	108.1	59.1	46.9283456°, -120.5202741°
YAK-243.3	40	76.1	40.7	46.9263161°, -120.5182698°
YAK-243.1	41	50.8	49.5	46.9258956°, -120.5169651°
YAK-243.1	42	8.5	15.0	46.9265085°, -120.5166287°

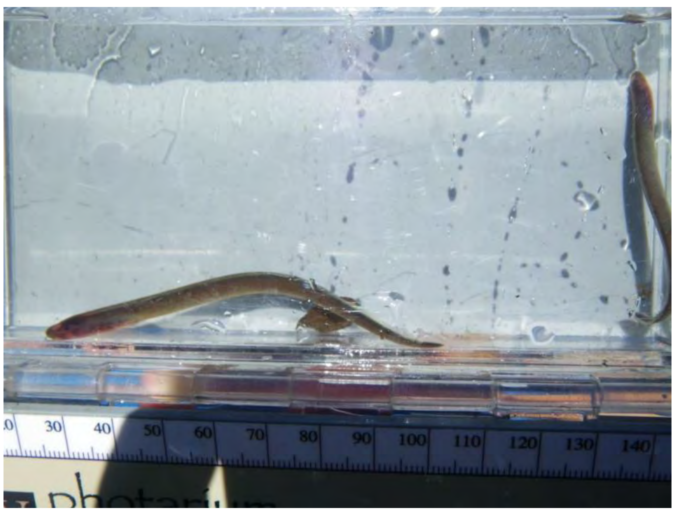
Photos:

RK243.8: Overview of the sample site in the side channel

RK243.8: Close up of the woody debris mixed in the sediment

RK243.8: Close up of the sediment which was composed of sand and silt


RK244.2: View of the survey site



RK244.2: Close up of two Western brook lamprey in the photarium


RK245.1: Overview of the high density of woody debris throughout the sample area


RK245.1: Close up of the sediment that was composed of mostly sand mixed with woody debris

RK245.1: Close up of a Western brook lamprey in the photarium


RK246.9: View of the small side channel


RK246.9: Close up of the sediment that was composed of sand mixed with small amounts of silt


RK246.9: Close up of a Western brook lamprey in the photarium


RK247.2: Close up of the survey site showing the high density of woody debris

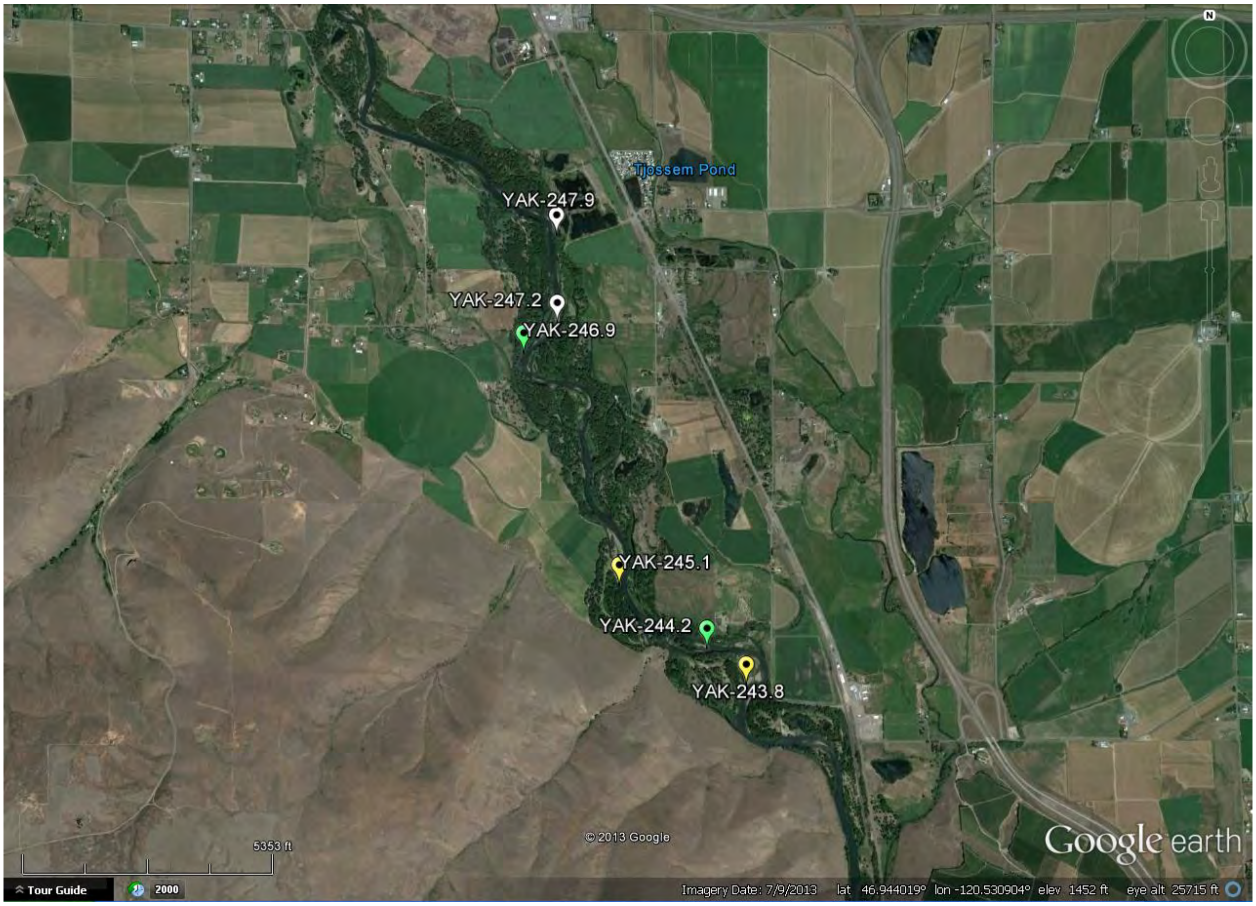

RK247.2: close up of the site showing the high density of woody debris


RK247.9: Close up of the sediment composed of sand and silt


RK247.9: Close up of the sediment after it has been squeezed to show how it holds together


RK247.9: View of the pond

Maps:



Overview of Rafting Sites above Yakima Canyon outside Ellensburg

YAK-243.8: Upstream from the Ringer Loop boat launch at confluence of a side channel

YAK-244.2: Outside private property in confluence of a side channel

YAK-245.1: At the confluence of a side channel

YAK-246.9: At the outlet to a side channel

YAK-247.2: In a small backwater area

YAK-247.9: At the mouth of a small pond below the Irene Rhinehart boat launch

Other Type I habitat within the rafting reach (from upstream to downstream):

Other Type I habitat within the rafting reach (from upstream to downstream):

Other Type I habitat within the rafting reach (from upstream to downstream):


N
535 ft
Google earth
Tour Guide
2000
Imagery Date: 7/9/2013 lat 46.952575° lon -120.537027° elev 1463 ft eye alt 3776 ft


N
537 ft
Google earth
Tour Guide
2000
Imagery Date: 7/9/2013 lat 46.947052° lon -120.536802° elev 1455 ft eye alt 3776 ft

Other Type I habitat within the rafting reach (from upstream to downstream):

Other Type I habitat within the rafting reach (from upstream to downstream):

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

2013 Annual Report
Phase 2: Sunnyside and Wapato Dams

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

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

On the cover: A radio-tagged adult Pacific lamprey released in the Yakima River during the study. Photograph by Dave Herasimtschuk and Jeremy Monroe, © Freshwater Illustrated.

The correct citation for this report is:
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Passage of Radio-tagged Adult Pacific Lamprey
at Yakima River Diversion Dams

2013 Annual Report
Phase 2: Sunnyside and Wapato Dams

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U.S. Fish and Wildlife Service, Leavenworth WA

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R10PG10402-BOR
13330-A-148-FONS

May 12, 2014

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PASSAGE OF RADIO-TAGGED ADULT PACIFIC LAMPREY
AT YAKIMA RIVER DIVERSION DAMS: 2013 ANNUAL REPORT

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

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Leavenworth, WA 98826

Abstract- The Pacific lamprey *Entosphenus tridentatus* has declined across much of its range in the Pacific Northwest, including in the Yakima River. Several irrigation diversion dams may prevent or delay the upstream migration of adults in the Yakima River but the total impact on migration and spawning is not known. This report details the second of three phases of a radio-telemetry study designed to determine residence times, passage timing and durations, passage efficiencies, and passage routes of Pacific lampreys at diversion dams on the Yakima River. Eighty adult Pacific lampreys, collected at lower Columbia River dams during summer 2012, were radio-tagged and released downstream of Sunnyside Dam and downstream of Wapato Dam on August 27, 2012 and March 20, 2013. Overall passage success of lampreys that approached a dam was 68% at Sunnyside Dam and 82% at Wapato Dam. All passage events occurred from August-September 2012 and April-June 2013. At Sunnyside Dam, lampreys used the center (66%), right (28%), and left (3%) fishways while 3% used an unknown route. At Wapato Dam, lampreys used the left (41%), center (22%), and right (20%) fishways while 17% apparently passed via the dam face. Passage times in fishways at Sunnyside Dam averaged 0.9 hours (SD = 0.9; range = 0.1 to 3.3 hours) and at Wapato Dam averaged 1.6 hours (SD = 3.7; range = 0.1 to 23.5 hours). Two tagged lampreys were entrained in the Sunnyside Canal: one resided for 59 days and the other was not detected exiting the canal. One lamprey was entrained and resided in the Wapato Canal for 53 days before moving upstream. A substantial number of tagged lampreys entered and used Roza Wasteway #2, including 20 of 49 lampreys (41%) during the fall and 4 of 11 lampreys (36%) during the spring. Minimum known residence in the wasteway ranged from 1.4 to 324 days. Twelve tagged lampreys migrated to Roza Dam and six ascended the ladder to the salmon trapping facility where they spent from 1 to 26.5 days in the holding pen before descending the ladder, resulting in 0% passage efficiency at the dam. Six of ten lampreys (60%) passed Cowiche Dam with the uppermost detection at rkm 53 of the Naches River. Dam passage efficiencies were seasonally inverted at Phase 2 study dams relative to Phase 1 study dams: passage of fall-released fish was substantially higher than for spring-released fish at Sunnyside (96% fall, 33% spring) and Wapato (95% fall, 55% spring) compared to Wanawish (53% fall, 71% spring) and Prosser (50% fall, 45% spring). Seasonal effects at Yakima River diversion dams have the potential to exacerbate cumulative passage throughout the system. Reduced fall passage at the lower river dams (Wannawish and Prosser) may decrease the number of lampreys available to pass the upper river dams (Sunnyside and Wapato) in the fall when passage success at these facilities is highest.

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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 65 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).

Mainstem Columbia River hydroelectric dams cause major delays and difficulties for the upstream migration of Pacific lampreys; telemetry studies of Pacific lamprey movements documented that less than 50% of tagged fish successfully passed upstream through the fishways (Moser et al. 2002a, Moser et al. 2002b, 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.

To better understand migrations dynamics, we began a multiyear study in 2011 investigating Pacific lamprey passage at diversion dams in the Yakima River basin. 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, passage duration, 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.

Results from Phase 1 of this study at Wanawish and Prosser dams indicated overall passage efficiencies of 62% and 48%, respectively, with lower passage rates during the fall (Johnsen et al., 2013). Only 7% of the lampreys released downstream of Wanawish Dam were documented passing Wapato Dam, the fourth dam on the Yakima River.

This annual report presents the results of Phase 2 of our study at Sunnyside and Wapato dams for the 2012 migratory year, from September 27, 2012 through August 31, 2013.

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. Unlike many anadromous fishes, Pacific lampreys do not appear to home to their natal streams (Hatch and Whiteaker 2009, Spice et al. 2012), 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 differ on whether Pacific lampreys are panmictic (Goodman et al. 2008, Docker 2010, Spice et al. 2012).

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 that migration timing in the Yakima River differs from other Columbia River tributaries.

This shift 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. Elevated spring passage numbers at Prosser Dam suggest that 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.

To evaluate seasonal effects on Yakima River lamprey migration, we designed our study to test passage at the dams during both the fall and spring. 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. This design was intended 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 (USBOR), makes the Yakima River Basin one of the most intensely irrigated areas in the United States. 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). 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).

Irrigation water is distributed throughout the network via rivers, creeks, and man-made canals. Irrigation diversion dams include Wanawish, Prosser, Sunnyside, Wapato, Roza, Town, and Easton on the Yakima River and Cowiche and Wapatox on the Naches River (Figure 1).

Fixed Stations

Fixed radio telemetry stations were set up at six diversion dams and at the outfall of a power plant return flow canal (Figure 2). The standard layout at a diversion dam consisted of long-range aerial antennas that monitored downstream of the dam, the face of the dam, and upstream of the dam. Short-range underwater antennas monitored pools at the entrance, middle, and exit of each fishway. Short-range, hanging, coaxial antennas were deployed above the waterline at at the intesections of the fishways and dam face where flow conditions or debris loads would have damaged underwater equipment. Aerial antennas were four element Yagi-type. Underwater and hanging antennas were constructed of coaxial cable with 100 mm of the inner wire bared at the end. Aerial antennas were mounted on masts; underwater antennas were suspended on chains; and hanging antennas were zip-tied to rails and posts.

Data logging telemetry receivers, (Lotek SRX-400A, Lotek SRX-600), equipped with an antenna switching unit (Lotek ASP 8), were housed in a metal box at each station (Lotek Wireless, Newmarket, Ontario). When available, AC power 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 and as the primary power source at stations with no available AC power.

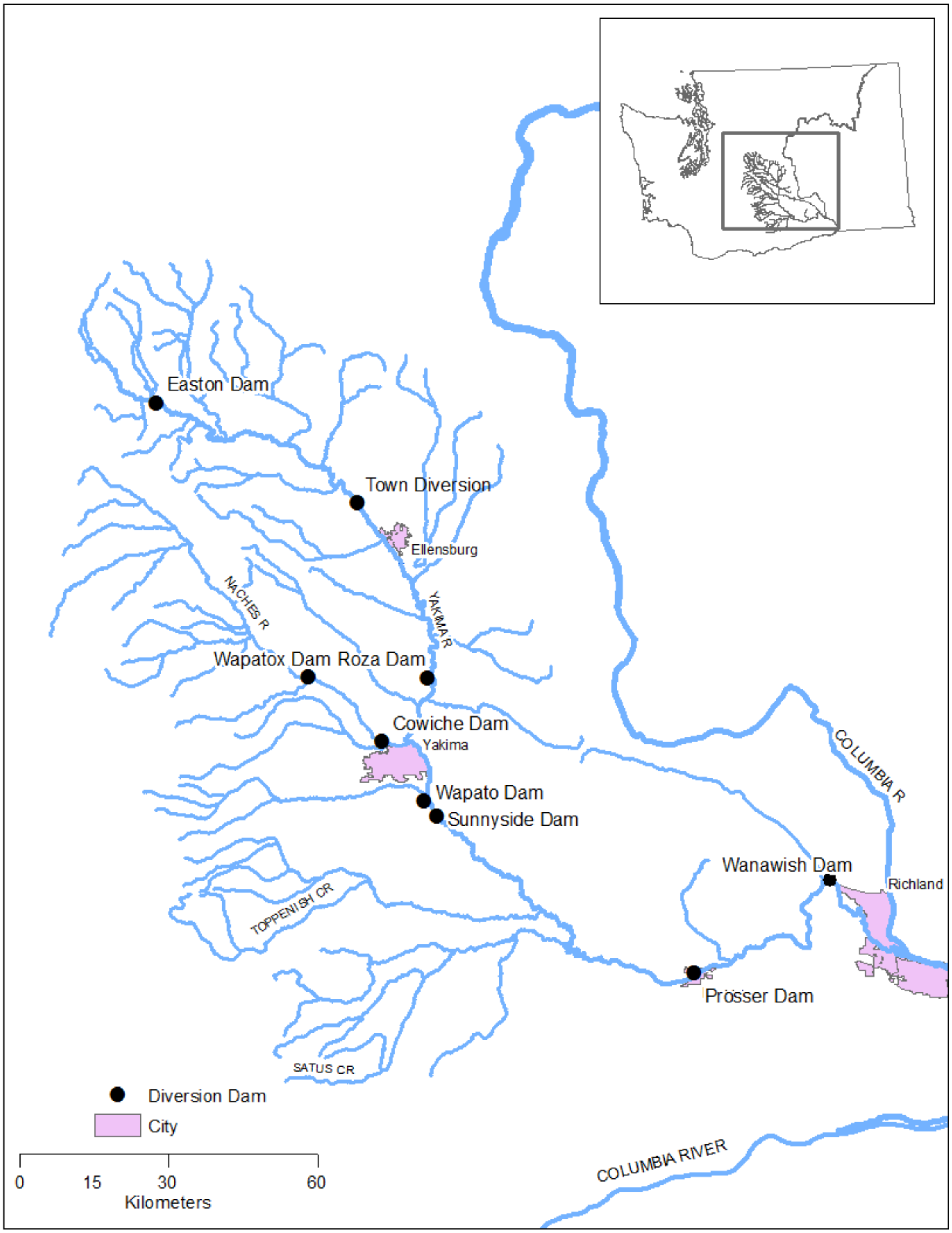

Figure 1. Map of the Yakima River watershed, showing the locations of the major diversion dams.

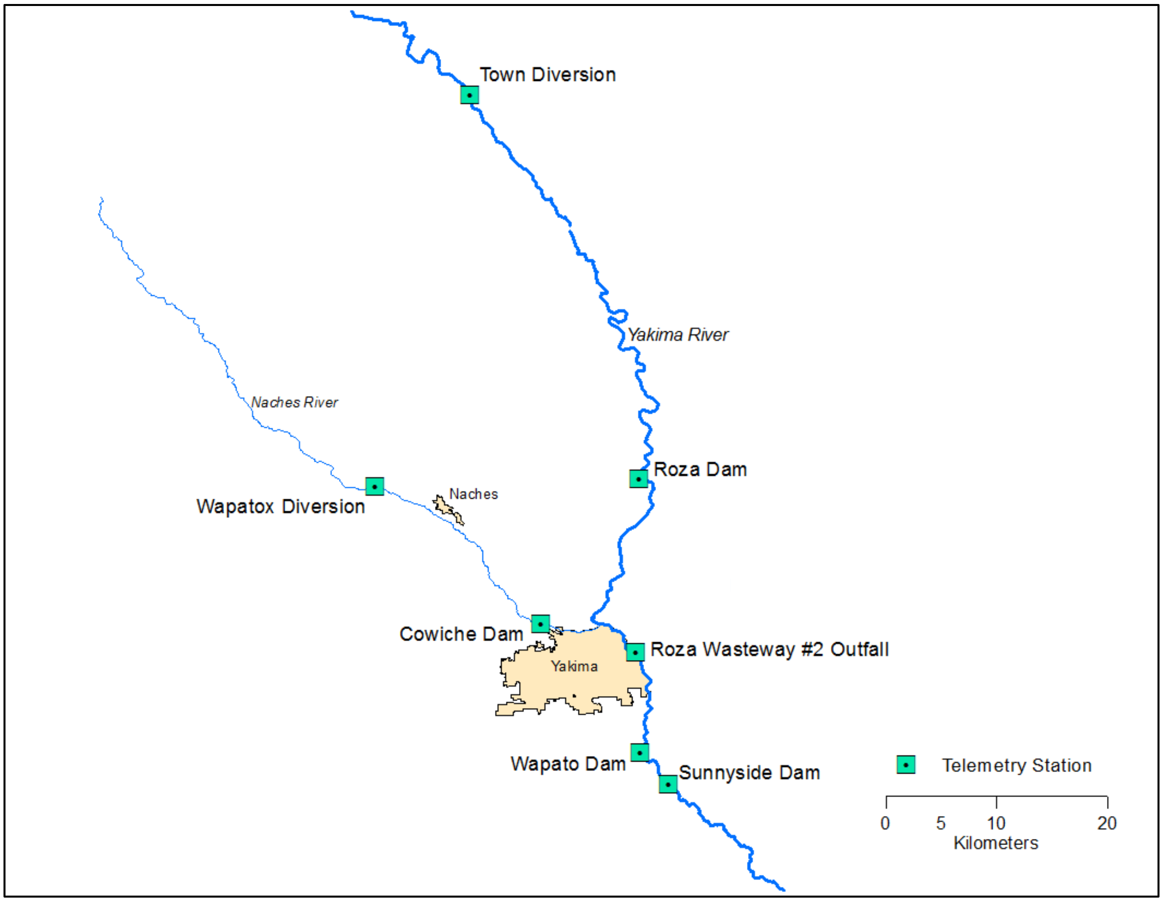

Figure 2. Map of the middle Yakima River basin showing the locations of fixed telemetry stations during 2012 and 2013.

The following illustrations of each dam and fishway were generated in Google SketchUp (version 8.016846) and are based on engineering drawings and construction blueprints obtained from the U.S. Bureau of Reclamation and on aerial photos. These illustrations depict the general layout of the fishways and thus omit screening and operational details.

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 vertical slot ladders, one on each bank and one near the center of the dam (Figure 3). 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 was equipped with one upstream aerial antenna and two downstream aerial antennas (combined as one unit, Figure 3). Underwater antennas were located in the entrance, center, and exit pools of the river left fish ladder. Hanging antennas monitored the sluiceway and the corner where the structure meets the face of the dam.

The center island fishway was equipped with a total of four aerial antennas: two antennas (combined as one unit) monitored downstream and two antennas monitored upstream on either side of the fishway (Figure 3). Underwater antennas were located in both entrance pools and a middle pool of the center fish ladder. Hanging antennas were placed in the corners of the island and the face of the dam.

The right bank fishway was equipped with three aerial antennas: one downstream, one across the face of the dam, and one upstream (Figure 3). Underwater antennas were located in the entrance, middle, and exit pools of the river right fish ladder. One hanging antenna monitored where the right bank structure and the face of the dam meet.

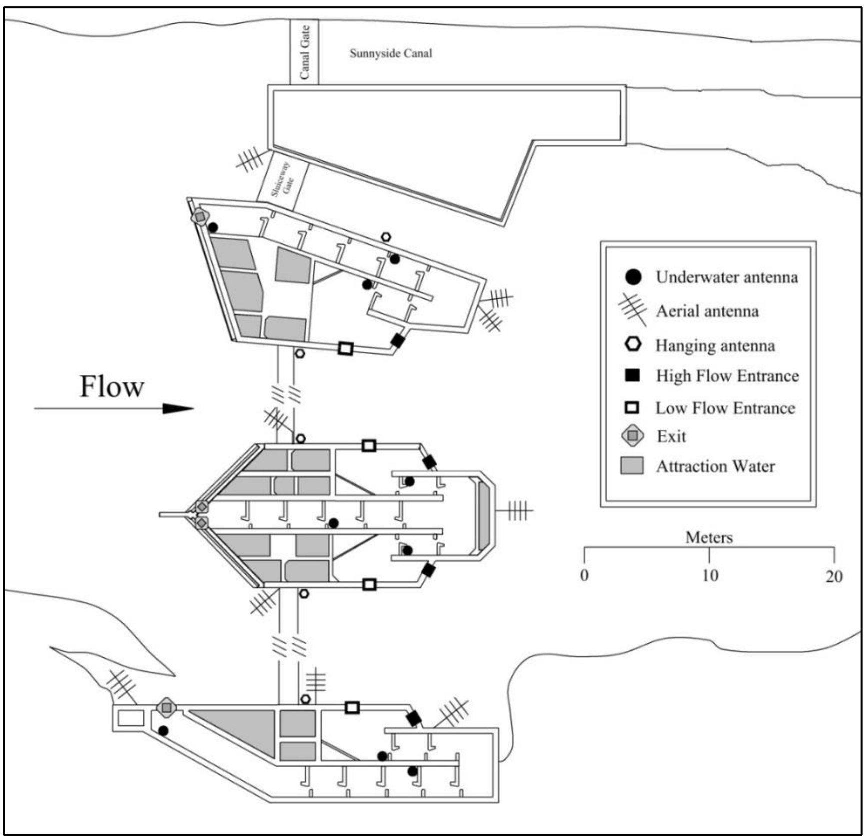

Figure 3. Locations of telemetry antennas on the river right, center and left bank fishways at Sunnyside Dam, 2012 to 2013.

Wapato Dam

Wapato Dam (rkm 171.5) consists of two separate structures in two channels connected by a natural island. The west channel has one fishway located on a center island structure with a diversion canal on the right bank. The east channel has fishways on both the center island structure 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 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 4).

The right bank fishway was equipped with three aerial antennas: one facing downstream, one facing upstream, and one facing 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 meet (Figure 4).

The west channel fishway was equipped with four aerial antennas: one oriented downstream, one oriented upstream, and two oriented 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 5).

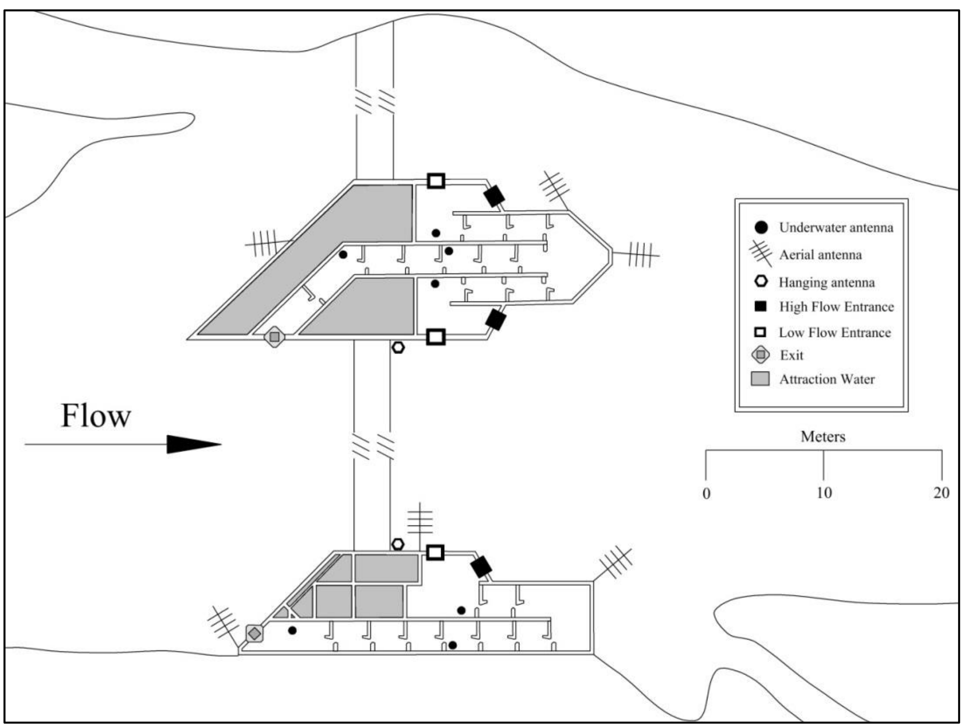

Figure 4. Locations of telemetry antennas on east channel fishways of Wapato Dam during 2012 and 2013.

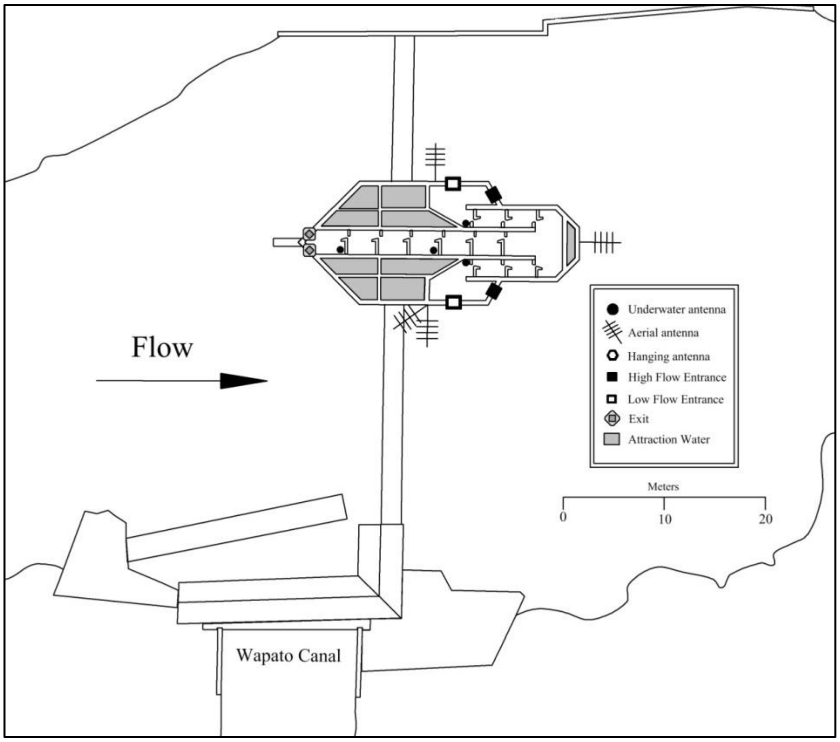

Figure 5. Locations of telemetry antennas on the west channel fishway at Wapato Dam during 2012 and 2013.

Roza Wasteway #2

The Roza Canal conveys water for both irrigation and hydropower. In 1959, the USBOR constructed the 12,937 kilowatt Roza Power Plant on a spur of the main diversion canal located approximately three miles northeast of the city of Yakima, WA. The Roza Power Plant return flow, known as Roza Wasteway #2, extends 1.4 km south of the Power Plant, and then rejoins the mainstem Yakima River at rkm 182 (Figure 6, Figure 18). The outfall of the Roza Wasteway #2 into the Yakima River is screened to exclude adult salmon.

The Roza Outfall radio telemetry station was located at the outfall fish screens. This station was equipped with a single aerial antenna facing upstream into the mainsteam Yakima River, and was AC powered. This station was run jointly with the Yakama Nation Fisheries Program.

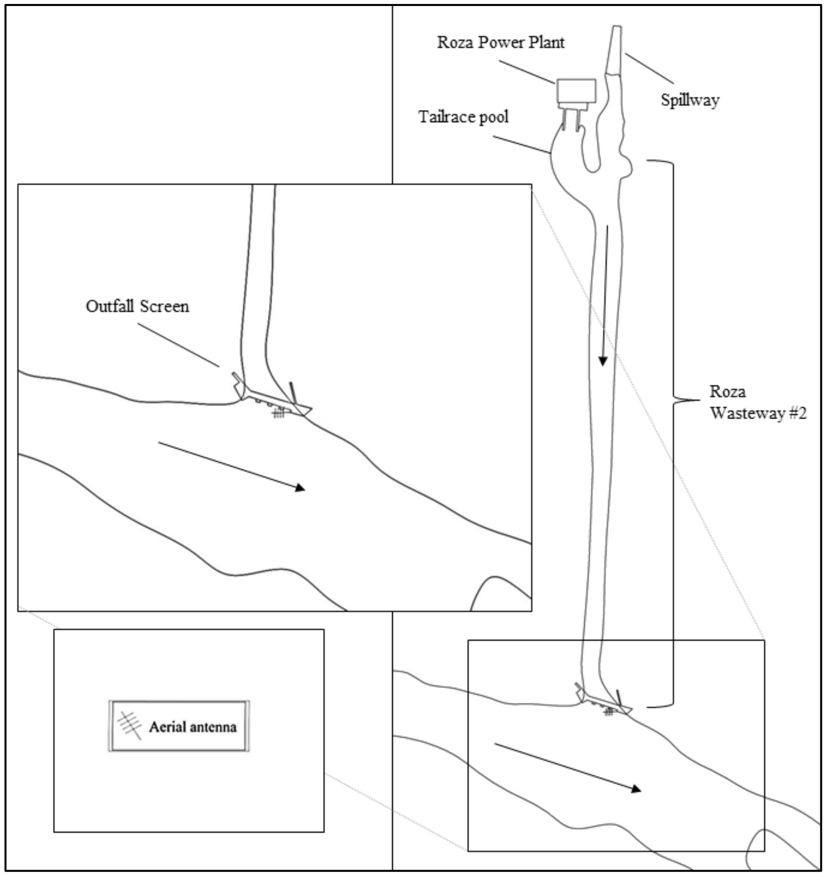

Figure 6. Location of the telemetry station at the outfall of Roza Wasteway #2 during 2012 and 2013.

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. For Phase 2 of this study, the left side of the dam was initially equipped with three aerial antennas: one downstream, one across the face of the dam, and one upstream. Three additional underwater antennas were installed in the fishway on February 26, 2013 (Figure 7). These new antennas were added in order to improve passage monitoring after several of the fall-release lampreys passed Cowiche Dam via unknown routes.

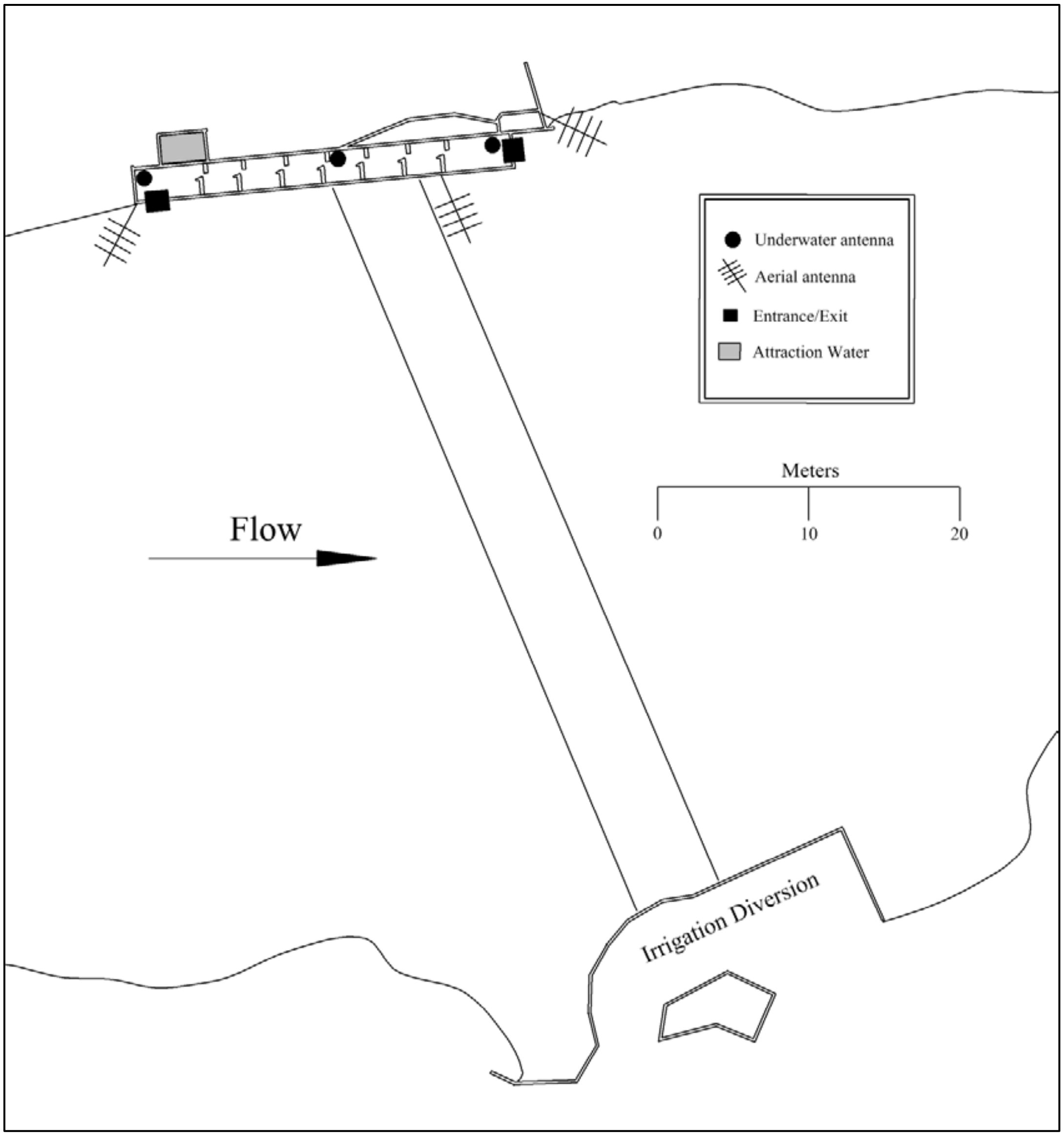

Figure 7. Locations of telemetry antennas at Cowiche Dam during 2012 and 2013.

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 Roza Dam fishway is comprised of several structures, including a fishway entrance on river right, a fishway entrance on river left, a gallery passage connecting the right and left entrances, two notched pool and weir fish ladders on river left (high and low flow ladders), a gallery passage connecting the high flow ladder to the fish processing facility, and the fish processing facility (Figure 8).

During Phase 2 of this project, three telemetry stations (SRX 600) were deployed at Roza Dam (Figure 8). The river right station was equipped with three antennas, a downstream aerial, a hanger at the river right fishway entrance, and an underwater antenna located partway between the fishway entrance and the cross-dam gallery. The river left station was initially equipped with four antennas, one downstream aerial, and underwater antennas at the river left fishway entrance, halfway up the high flow ladder, and at the ladder exit. Partway through the season, an additional underwater antenna was added halfway up the low water ladder to account for flow and maintenance conditions. The Roza fish facility station was equipped with two antennas: an underwater antenna located in the upper gallery at the entrance to the fish passage facility and an upstream aerial antenna monitoring the forebay. Roza Dam telemetry stations were plugged into AC power and did not include solar backup systems.

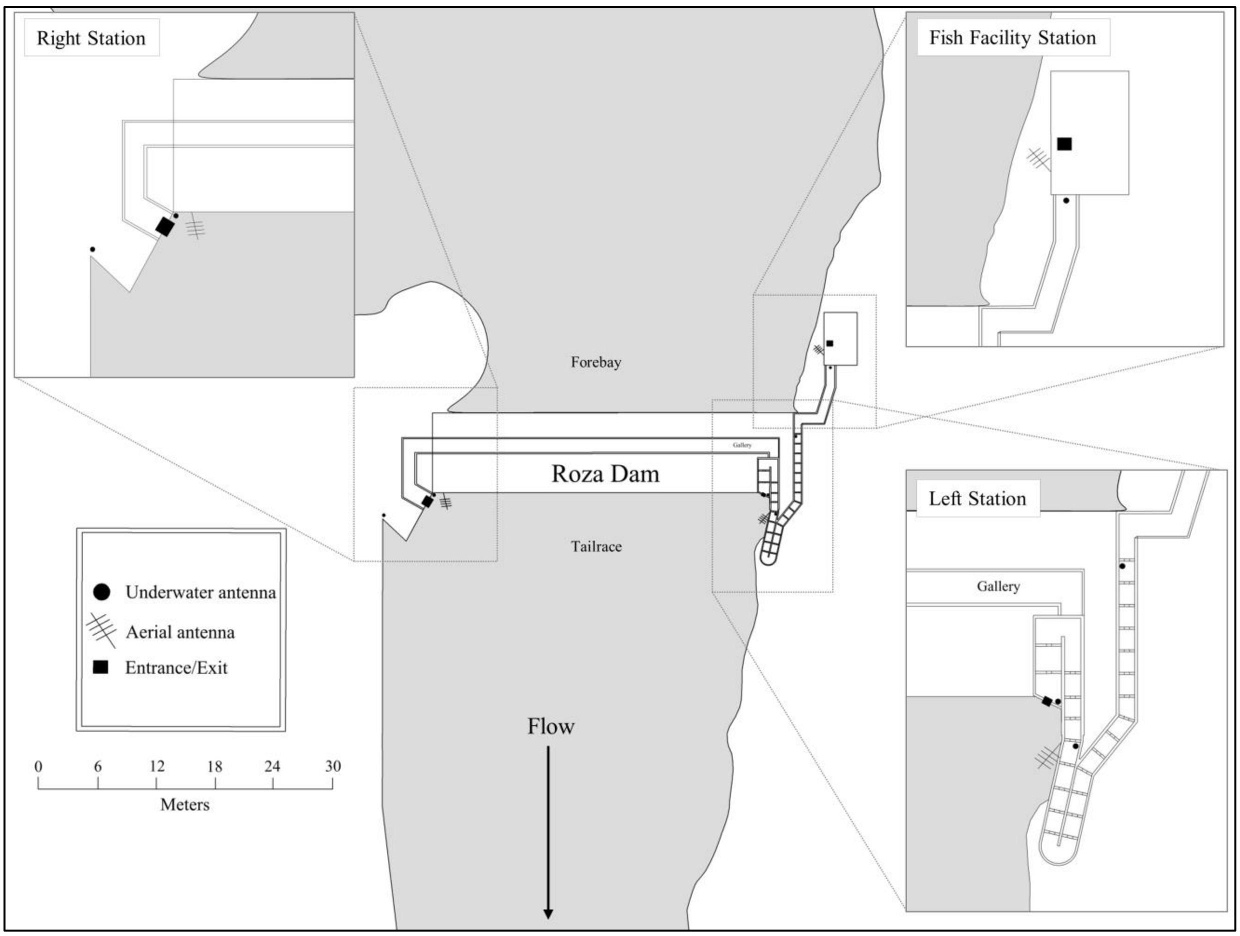

Figure 8. Locations of telemetry antennas at Roza Dam during 2012 and 2013.

Town Diversion

This gate station was Set up on April 5, 2013, at the Town Diversion of the Ellensburg Water Company. The Town Diversion site consisted of a single downstream aerial antenna and the receiver was plugged into AC power in the operations building.

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 any antenna at a fixed telemetry station. *Below dam residence* was calculated as the elapsed time between the first downstream detection at the dam and either the first detection of entry into the fishway during a passage event, or the last detection before a fish moved downstream out of range of the receivers. *Fishway passage* was calculated as the elapsed time between the first fishway entrance detection and the last fishway exit detection during a passage event. In the event that an exit antenna detection was missing, the final corner face detection was substituted. *Dam passage efficiency* was defined as the number of lampreys that successfully passed the dam at least once divided by the number of lampreys that approached the dam (i.e., passage through a dam was only scored one time for each fish). *Above dam residence* was defined as the difference between the last fishway exit detection and the last upstream aerial antenna detection at the dam. *Roza Wasteway Canal Residence Time* was calculated as the sum of time elapsed between mobile tracking detections within the canal (representative of fish that stayed in the canal) or between mobile tracking detections in the canal and the first detection at Roza Outfall (representative of fish that left the canal).

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 and August 2012. 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 where they were help until tagging. 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. (2002a) and Nelson et al. (2007). Tools and transmitters were chemically disinfected with Benz-All®. Each lamprey was anesthetized in a bath of 80 mg/l 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 mg/l 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 lateral to 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 was inserted into the incision. Lotek NTC-6-2 transmitters (9 x 30 mm, 4.3 g, 441 d battery life) were

implanted in fall release lampreys, and Lotek NTC-4-2L transmitters (8 x 18 mm, 2.1 g, 162 d battery life) were implanted into spring release lampreys. The incision was then closed with 3 to 4 braided absorbable sutures. Following tagging, the lamprey was immediately placed in a recovery bucket containing three gallons of aerated well water and transferred to the holding tanks.

Release

Release dates were selected to mimic the seasonal Pacific lamprey movements in the Yakima River system. Release sites were located downstream of Sunnyside Dam, between Sunnyside and Wapato dams, and upstream of Wapato Dam. Release sites were chosen by accessibility and relative close proximity to each dam. Individual lamprey were allocated to a release treatment by removing them from the holding tank at random. The code of each fish was then recorded prior to release.

Tracking

Fixed telemetry stations operated continuously and 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 conducted opportunistically to determine precise locations at the dams as well as approximate locations between the dams. Mobile tracking was conducted by foot, and truck.

Temperature

Stream temperatures were monitored at, Sunnyside, Wapato, Roza, and Cowiche 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 cubic feet per second (ft^3/s).

Velocity

Velocity data were not collected systematically in Phase 2. While Phase 1 velocity data indicated that high velocities occurred at Yakima River fishways, standardizing velocity sampling methods to collect quantitatively robust results proved to be beyond the scope of this study.

Results

Tagging

Tagging and release occurred in the fall 2012 and the spring 2013. For the fall releases, 45 adult Pacific lampreys were radio tagged August 2-3, 2012 (Table 1). Weights ranged from 367 to 886 g (mean 486 g), and total lengths from 675 to 768 mm (mean 675 mm, Figure 9). Girths ranged from 104 to 130 mm (mean 114 mm, Figure 10), and inter-dorsal base length ranged from 22 to 40 mm (mean 34 mm, Figure 11).

For the spring releases, 45 lampreys were tagged on February 20-22, 2013 (Table 2). Weights ranged from 258 to 550 g (mean 349 g), and lengths ranged from 530 to 695 mm (mean 585 mm). Girths ranged between 90 and 120 mm (mean 102 mm), and inter-dorsal base lengths ranged from 14 to 38 mm (mean 23 mm) (Figures 9 and 10).

Holding

Fish were held a minimum of three weeks after tagging before release. On March 15, 2013, one of the holding tanks overflowed, and 19 tagged lampreys escaped. Nine of the escaped fish were recovered by Yakama Nation Fisheries Program staff and lived, the other 10 were mortalities. The nine survivors were monitored for the remainder of the holding period (five days) and were released along with the remainder of the spring study fish. No evidence of an "escapee" effect on passage was observed, and data from these fish were included in all relevant calculations/analyses.

Releases

Fall release- A total of 45 tagged lampreys were released on August 27, 2012. Five were released from the head of the island 0.15 km upstream of Wapato Dam; 15 were released 2.6 km downstream of Wapato Dam (and 1.8 km upstream of Sunnyside Dam) on the left bank, and 25 were released 1.4 km downstream of Sunnyside Dam in the middle of the channel (Figure 12).

Spring release- A total of 35 Pacific lampreys were released on March 20, 2013 at the same locations used in the fall. Thirteen lampreys were released at the site between Wapato and Sunnyside dams, and 22 lampreys were released below Sunnyside Dam. No tagged lampreys were released above Wapato Dam because fewer tagged lampreys were available due to the mortalities incurred during holding.

Table 1. Morphometric data and release location of radio-tagged adult Pacific lampreys released in the Yakima River on August 27, 2012. Release locations are denoted as: AWD (above Wapato Dam), BWD (Below Wapato Dam), and Below Sunnyside Dam (BSD).

Code	Total Length (mm)	Weight (g)	Girth (mm)	Dorsal Base Length (mm)	Release Location
11	692	522	125	30	AWD
17	700	527	120	34	AWD
19	695	480	115	31	AWD
28	685	--	109	35	AWD
48	690	502	116	30	AWD
5	675	530	120	40	BWD
6	647	420	107	32	BWD
7	675	482	117	40	BWD
10	690	553	120	40	BWD
18	737	886	130	33	BWD
22	692	--	118	40	BWD
24	652	--	115	32	BWD
29	720	--	113	38	BWD
30	662	--	115	40	BWD
34	702	544	115	36	BWD
37	672	456	113	32	BWD
39	710	575	124	40	BWD
43	700	455	105	35	BWD
44	656	380	106	34	BWD
46	690	501	114	30	BWD
4	640	491	115	35	BSD
8	635	370	106	35	BSD
9	647	425	113	31	BSD
12	648	425	112	27	BSD
13	615	380	107	30	BSD
14	635	367	104	33	BSD
15	670	759	118	40	BSD
16	627	399	107	30	BSD
20	720	--	124	35	BSD
21	652	--	110	32	BSD
23	620	--	105	30	BSD
25	675	--	115	37	BSD
26	665	--	116	40	BSD
27	680	--	115	40	BSD
31	675	--	108	30	BSD
32	768	--	128	40	BSD
33	672	--	110	37	BSD
35	682	469	113	33	BSD
36	714	537	118	34	BSD
38	688	463	116	33	BSD
40	680	491	124	30	BSD
41	680	417	107	24	BSD
42	630	387	108	32	BSD
45	684	448	107	36	BSD
47	642	428	110	22	BSD

Table 2. Morphometric data and release location of radio-tagged adult Pacific lampreys released in the Yakima River on March 20, 2013. Release locations are denoted as: AWD (above Wapato Dam), BWD (Below Wapato Dam), Below Sunnyside Dam (BSD), and E/M (escaped/mortality)

Code	Total Length (mm)	Weight (g)	Girth (mm)	Dorsal Base Length (mm)	Release Location
52	572	295	96	27	BSD
53	545	305	100	16	BSD
54	560	302	99	24	BSD
55	580	359	107	26	BSD
56	655	--	116	38	BSD
57	635	--	109	33	BSD
58	662	--	109	29	BSD
59	583	--	95	25	BSD
60	605	372	102	20	BSD
65	582	348	99	19	BSD
68	542	296	95	30	BSD
72	610	329	97	31	BSD
75	695	550	120	35	BSD
76	602	381	105	27	BSD
79	587	342	100	27	BSD
80	565	386	111	18	BSD
82	610	422	112	28	BSD
83	560	310	95	22	BSD
85	610	450	113	20	BSD
89	545	302	103	16	BSD
90	600	388	107	20	BSD
93[a]	588	318	98	21	BSD
50	585	338	102	21	BWD
51	535	302	98	23	BWD
61	582	316	100	24	BWD
69	567	335	101	18	BWD
70	580	334	92	18	BWD
71	558	296	95	20	BWD
77	541	321	100	20	BWD
78	580	382	101	20	BWD
84	610	427	113	28	BWD
86	610	424	108	25	BWD
88	575	300	95	21	BWD
91	585	359	101	14	BWD
92	619	384	105	17	BWD
62	553	281	98	18	E/M
63	535	258	93	17	E/M
64	532	--	95	18	E/M
66	592	303	90	19	E/M
67	530	292	95	18	E/M
74	672	486	113	31	E/M
81	563	324	100	25	E/M
87	582	369	103	25	E/M
49	590	356	102	26	E/M
73	561	307	94	25	E/M

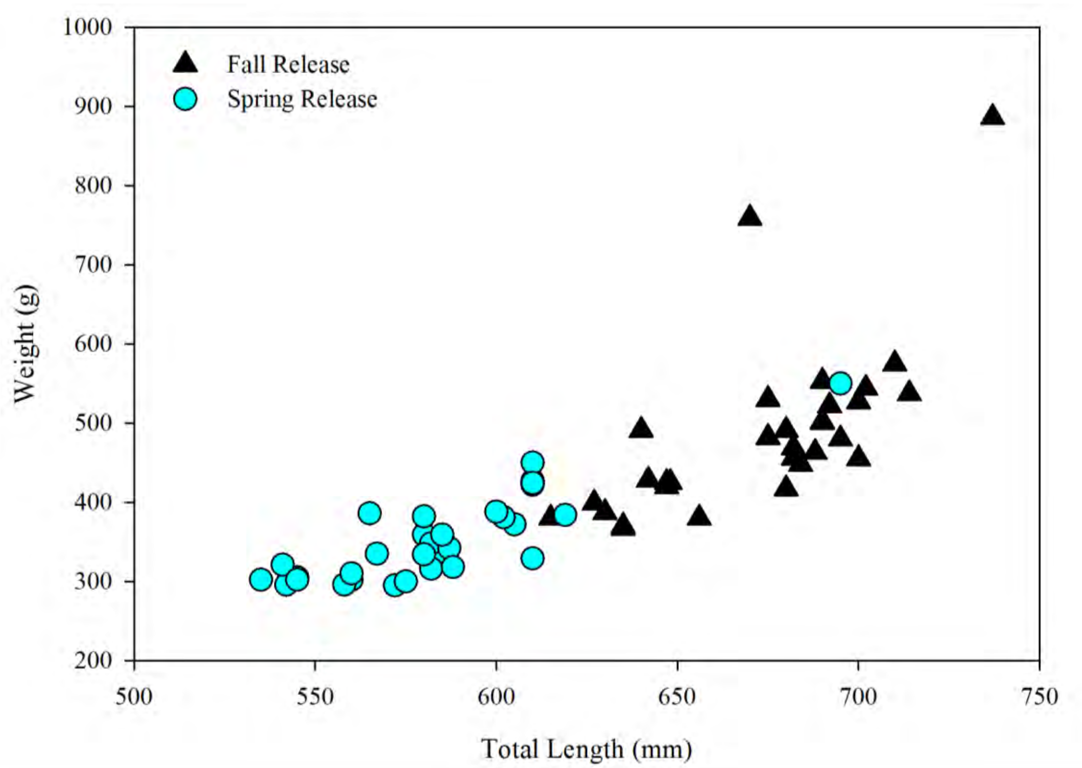

Figure 9. Weight versus total length of radio-tagged Pacific lampreys released into the Yakima River on September 27, 2012 and March 20, 2013.

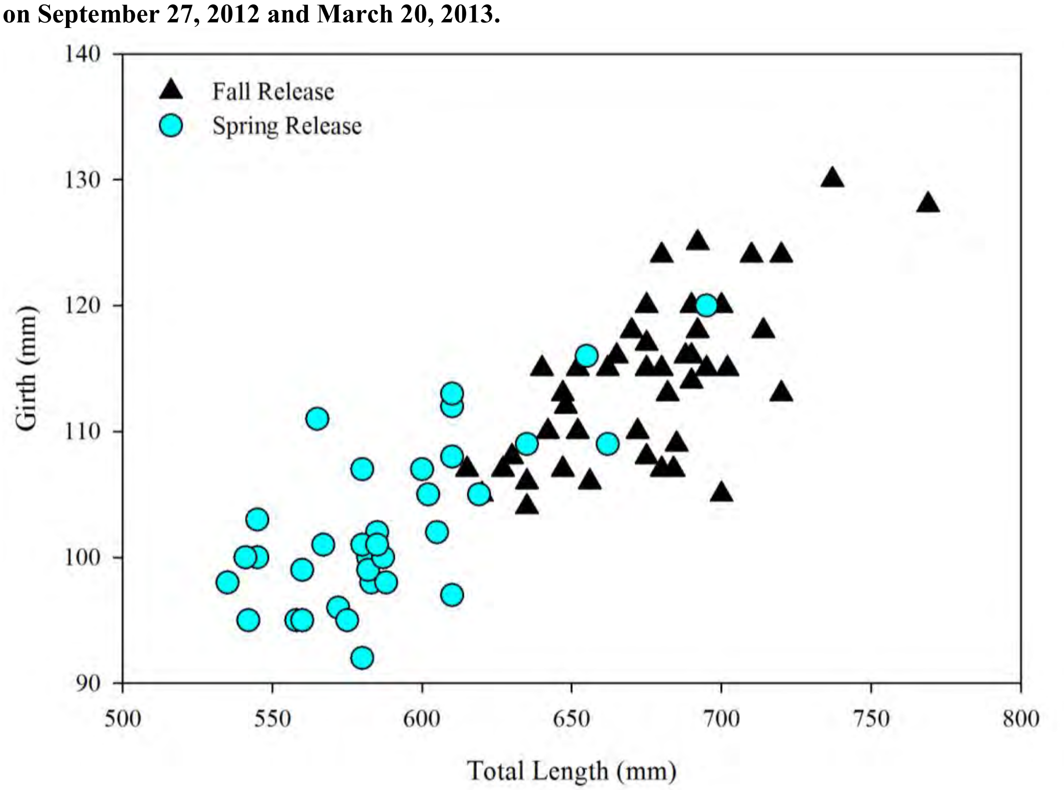

Figure 10. Girth versus total length of radio-tagged Pacific lampreys released into the Yakima River on September 27, 2012 and March 3, 2013.

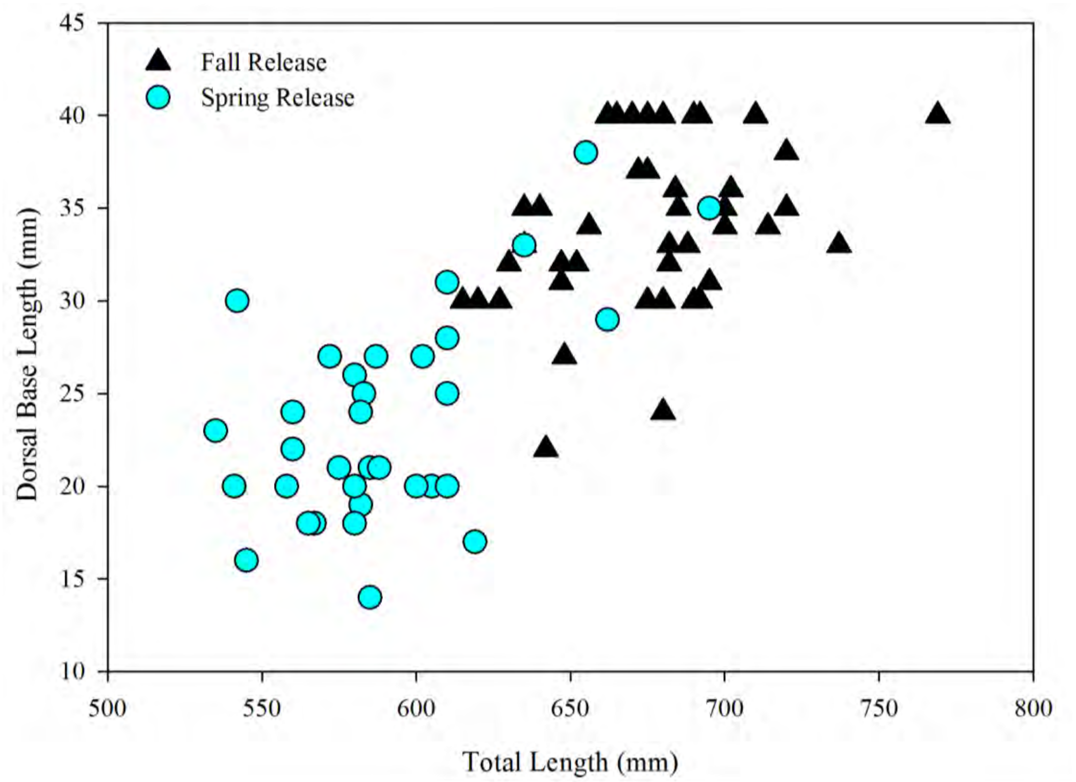

Figure 11. Inter-dorsal base length versus total length of radio-tagged Pacific lampreys released into the Yakima River on September 27, 2012 and March 3, 2013.

Figure 12. Release locations of radio-tagged adult Pacific lampreys in the vicinity of Sunnyside and Wapato dams on August 27, 2012 and March 20, 2013.

Movements

A total of 76 (95%) Pacific lampreys moved upstream from their release sites. Two moved downstream from their release sites and two never moved. Both of the stationary tags were assumed to be shed tags or mortalities. First approaches of a dam were made between August 27, 2012 and July 19, 2013. A total of four lampreys (codes 5, 18, 26, and 27) resided at the dams through the winter. The movements of radio-tagged lampreys at each dam are described in the following sections.

Sunnyside Dam

First approach of fall release- Twenty-five tagged lampreys were released downstream of Sunnyside Dam on August 27, 2012 and all 25 approached the dam on the day of release (Table 3). In addition, one tagged lamprey (code 19) released above Wapato Dam moved downriver past both Wapato and Sunnyside Dams, and approached Sunnyside Dam from downstream on May 8, 2013.

First approach of spring release- Tagged lampreys were released downstream of Sunnyside Dam on March 20, 2013 (n = 22). Twenty-one of these fish were detected approaching the dam. Detections of first approach of individuals at the dam ranged from March 20 to April 7, 2013.

Below dam residence- Residence times were calculated for all lampreys that were released below, and approached Sunnyside Dam. Below dam residence times ranged from 30 seconds to over 363 days (Table 3). Fish that successfully passed the dam exhibited shorter below dam residence times than those that did not, and lampreys that passed in the fall exhibited shorter residence times that those that passed in the spring (Table 4). One lamprey (code 19) was released above Wapato dam on August 27, 2012 and moved downstream over Wapato Dam on August 28, 2012. By April 8, 2013, this lamprey moved downstream over Sunnyside Dam. It later approached Sunnyside Dam, and passed upstream on May 8, 2013. This lamprey was excluded from the residence time analysis because it was not a part of the original treatment group released below Sunnyside Dam.

Two lampreys overwintered at the dam, one downstream (code 27) and one upstream (code 26) of the structure. Although it entered the ladders at Sunnyside right and Sunnyside left, code 27 did not pass the dam and was detected in the vicinity of the dam for over a year. During this time it is likely that the tag was either shed or the fish died. Code 26 passed the dam by September 30, 2012 but remained above Sunnyside until March 14, 2013 when is resumed upstream migration and was detected at Wapato five days later.

Both lampreys that overwintered below Sunnyside Dam were likely inactive for some period during the winter. However, during the overwinter period they stayed within range of the telemetry station and were detected (whether there were actively moving or not) on multiple antennas simultaneously. With continuous detections on multiple antennas over a period of months, we were unable to determine when lamprey became inactive, and the onset and duration of overwintering behavior is unknown.

Table 3. Sunnyside Dam approach and residence data: first and last detection dates and below dam residence times of adult radio-tagged Pacific lampreys released in fall 2012 and spring 2013.

Code	1st Detection Date	Last Detection Date	Days	Pass Dam?
20	08/27/12 15:05	08/27/12 21:33	0.27	Yes
33	08/27/12 15:05	08/29/12 02:22	1.47	Yes
13	08/27/12 16:06	08/27/12 21:08	0.21	Yes
41	08/27/12 16:18	08/27/12 16:47	0.02	Yes
8	08/27/12 16:25	08/27/12 20:46	0.18	Yes
40	08/27/12 16:35	08/29/12 01:21	1.37	Yes
23	08/27/12 16:39	08/30/12 00:40	2.33	Yes

Table 3 Continued

Code	1st Detection Date	Last Detection Date	Days	Pass Dam?
36	08/27/12 20:21	09/04/12 20:47	8.02	Yes
9	08/27/12 20:30	08/31/12 01:23	3.20	Yes
12	08/27/12 20:31	08/27/12 21:10	0.03	Yes
27	08/27/12 20:43	08/25/13 16:56	362.84	No
4	08/27/12 20:45	08/31/12 00:49	3.17	Yes
14	08/27/12 20:52	08/27/12 21:03	0.01	Yes
31	08/27/12 20:58	08/27/12 20:59	0.00	Yes
47	08/27/12 21:07	08/31/12 21:48	4.03	Yes
42	08/27/12 21:08	08/28/12 04:24	0.30	Yes
32	08/27/12 21:12	09/04/12 00:42	7.15	Yes
15	08/27/12 21:15	08/27/12 22:30	0.05	Yes
45	08/27/12 21:15	08/31/12 04:27	3.30	Yes
38	08/27/12 21:18	08/27/12 21:49	0.02	Yes
35	08/27/12 21:19	08/27/12 21:52	0.02	Yes
25	08/27/12 21:24	08/27/12 21:55	0.02	Yes
21	08/27/12 21:35	08/27/12 22:06	0.02	Yes
26	08/27/12 21:41	08/30/12 18:49	2.88	Yes
16	08/27/12 22:01	08/28/12 03:02	0.21	Yes
80	03/20/13 12:21	08/21/13 07:38	153.80	No
55	03/20/13 12:21	04/02/13 20:48	13.35	Yes
75	03/20/13 15:21	04/02/13 01:10	12.41	Yes
83	03/20/13 15:42	05/24/13 21:10	65.23	No
58	03/20/13 16:02	06/19/13 09:57	90.75	No
59	03/20/13 16:38	07/16/13 01:43	117.38	No
52	03/20/13 16:45	05/08/13 22:16	49.23	Yes
65	03/20/13 20:16	05/12/13 05:50	52.40	No
79	03/20/13 21:09	05/20/13 00:18	60.13	Yes
82	03/20/13 21:27	07/07/13 04:53	108.31	No
89	03/20/13 21:31	05/06/13 16:43	46.80	No
93	03/20/13 21:33	--	--	Yes
72	03/20/13 21:50	06/07/13 09:53	78.50	No
56	03/20/13 22:07	07/25/13 04:42	126.27	No
85	03/20/13 23:09	05/06/13 01:55	46.12	Yes
90	03/21/13 02:05	05/15/13 22:20	55.84	No
54	03/21/13 08:36	04/25/13 22:58	35.60	No
57	03/30/13 20:41	06/02/13 23:21	64.11	No
60	04/01/13 01:04	05/21/13 17:38	50.69	No
76	04/02/13 22:40	04/20/13 03:37	17.21	Yes
68	04/07/13 14:55	08/08/13 19:14	123.18	No

Table 4. Below dam residence summary for radio-tagged Pacific lampreys released below Sunnyside Dam in fall 2012 and spring 2013.

Release	Passage success	*n*	Duration (days)	Mean (days)	Median (days)	SD (days)
Fall	Yes	24	0.00 - 8.02	1.59	0.24	2.28
	No	1	362.84	362.84	362.84	--
Spring	Yes	7	12.41 – 60.13	33.07	31.66	21.12
	No	15	35.59 - 153.80	86.34	78.50	26.89

Dam passage efficiency and Fishway passage - Forty-seven tagged lampreys approached Sunnyside Dam, and 32 of these successfully passed upstream, resulting in an overall dam passage efficiency of 68% (Table 5). Twenty-six fall-release lampreys approached the dam, and 25 of these passed (96%). Twenty-two of the fall-release lampreys passed in August 2013, within 4.5 days of release. Two fall-release lampreys passed in early September 2012, and one passed in May 2013 after falling back over both Sunnyside and Wapato dams.

Dam passage efficiency was not as high for the spring release lampreys, as 21 approached the dam only seven passed (33%). Spring-release lampreys did not initiate passage as rapidly as the fall-release; successful passage events began on April 2 (13 days after release), and continued through July 2013.

Lampreys used the right (28%), center (66%), and left (3%) fishways to pass Sunnyside Dam. The remaining 3% of passage events occurred via unknown routes, where lampreys may have climbed the dam face or moved through a ladder when receivers were not operational.

All Sunnyside Dam ladder passage events occurred in less than 3.5 h (Table 5). Mean passage times were similar across seasons (fall: 1.07 hr, spring: 1.00 hr), and locations (right: 0.97 hr, center: 1.11 hr). The left fishway passed a single lamprey in 0.55 hr. Passage times were not calculated for the fish that passed via an unknown route.

Table 5. Sunnyside Dam passage data: passage routes, dates of entry, exit, and total time in fish ladder, and daily mean water temperature for radio-tagged adult Pacific lampreys from August 2012 to August 2013.

Code	Release Site/Period	Passage Route	Entered Ladder	Exited Ladder	Time in Ladder (hr)	Temp °C
41	BSD/Fall	C. Ladder	08/27/12 16:47	08/27/12 17:19	0.53	18.0
8	BSD/Fall	C. Ladder	08/27/12 20:46	08/27/12 22:42	1.93	18.0
31	BSD/Fall	C. Ladder	08/27/12 20:59	08/27/12 21:58	0.98	18.0
14	BSD/Fall	C. Ladder	08/27/12 21:03	08/28/12 00:10	3.12	18.0
13	BSD/Fall	C. Ladder	08/27/12 21:08	08/27/12 23:57	2.81	18.0
12	BSD/Fall	R. Ladder	08/27/12 21:10	08/27/12 22:01	0.84	18.0
20	BSD/Fall	C. Ladder	08/27/12 21:33	08/27/12 22:31	0.97	18.0
38	BSD/Fall	R. Ladder	08/27/12 21:49	08/27/12 22:06	0.29	18.0
35	BSD/Fall	C. Ladder	08/27/12 21:52	08/28/12 00:20	2.47	18.0
25	BSD/Fall	C. Ladder	08/27/12 21:55	08/27/12 22:21	0.43	18.0
21	BSD/Fall	C. Ladder	08/27/12 22:06	08/27/12 22:43	0.61	18.0
15	BSD/Fall	C. Ladder	08/27/12 22:30	08/27/12 23:05	0.59	18.0
16	BSD/Fall	C. Ladder	08/28/12 03:02	08/28/12 03:18	0.27	18.2
42	BSD/Fall	C. Ladder	08/28/12 04:24	08/28/12 05:11	0.77	18.2
40	BSD/Fall	R. Ladder	08/29/12 01:21	08/29/12 01:53	0.54	17.5
33	BSD/Fall	C. Ladder	08/29/12 02:22	08/29/12 05:41	3.32	17.5
23	BSD/Fall	C. Ladder	08/30/12 00:40	08/30/12 01:53	1.22	17.4
26	BSD/Fall	R. Ladder	08/30/12 18:49	08/30/12 21:01	2.19	17.4
4	BSD/Fall	C. Ladder	08/31/12 00:49	08/31/12 01:12	0.39	17.8
9	BSD/Fall	C. Ladder	08/31/12 01:23	08/31/12 01:26	0.04	17.8
45	BSD/Fall	C. Ladder	08/31/12 04:27	08/31/12 04:28	0.01	17.8
47	BSD/Fall	C. Ladder	08/31/12 21:48	08/31/12 22:51	1.06	17.8
32	BSD/Fall	C. Ladder	09/04/12 00:42	09/04/12 00:46	0.06	16.9
36	BSD/Fall	C. Ladder	09/04/12 20:47	09/04/12 20:54	0.11	16.9
75	BSD/Spring	R. Ladder	04/02/13 01:10	04/02/13 02:19	1.15	10.4
55	BSD/Spring	R. Ladder	04/02/13 20:48	04/02/13 22:52	2.07	10.4
76	BSD/Spring	R. Ladder	04/20/13 03:37	04/20/13 04:18	0.68	9.8
85	BSD/Spring	C. Ladder	05/06/13 01:55	05/06/13 03:31	1.59	12.0
19	AWD/Fall	R. Ladder	05/08/13 15:00	05/08/13 15:46	0.77	12.4
52	BSD/Spring	R. Ladder	05/08/13 22:16	05/08/13 22:29	0.22	12.4
79	BSD/Spring	L. Ladder	05/20/13 00:18	05/20/13 00:51	0.55	12.8
93	BSD/Spring	Right face	--	--	--	--

Discharge- Pacific lampreys passed Sunnyside Dam at a variety of discharge levels (Figure 13). Those passing in the fall did so at relatively low flows between 655 and 965 ft^3/s. Those passing during the spring months did so at widely varying flows between 2,500 and 8,100 ft^3/s. The majority of passage events, especially in the spring, occurred during periods of increasing discharge (Figure 13).

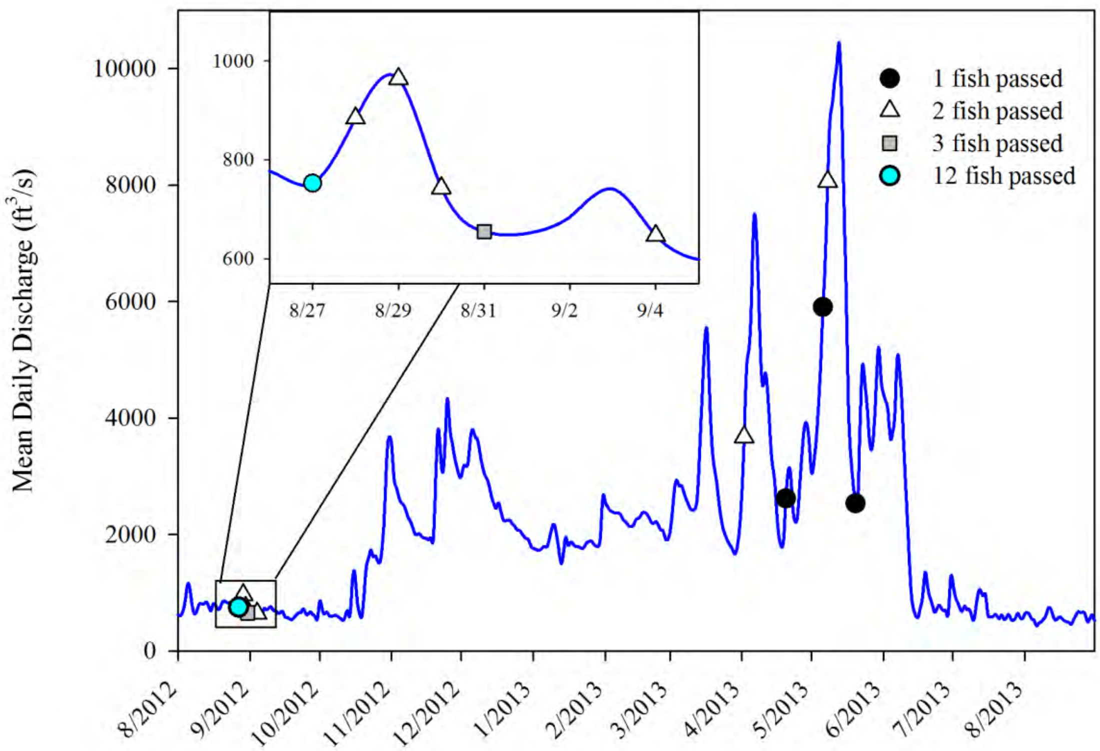

Figure 13. Mean daily discharge and passage timing of radio-tagged lampreys at Sunnyside Dam on the Yakima River, August 2012 through August 2013.

Temperature- Water temperatures of the Yakima River were recorded at Sunnyside Dam between August 1, 2012 and August 31, 2013 (Figure 14). Daily averages varied from 0 to 21 °C. Lamprey passage occurred during daily mean temperatures of 10.4 to 18.2 °C, with fall passage events occurring at warmer temperatures than spring passage events. In the fall, water temperatures rapidly declined below 16.9 °C after the last lamprey passed the dam and movements below the dam generally ceased for the remainder of the fall. In the spring, passage events resumed at temperatures greater than 9.7 °C. Spring passage events occurred at local temperature maxima, when average daily temperatures were transitioning from increasing to decreasing.

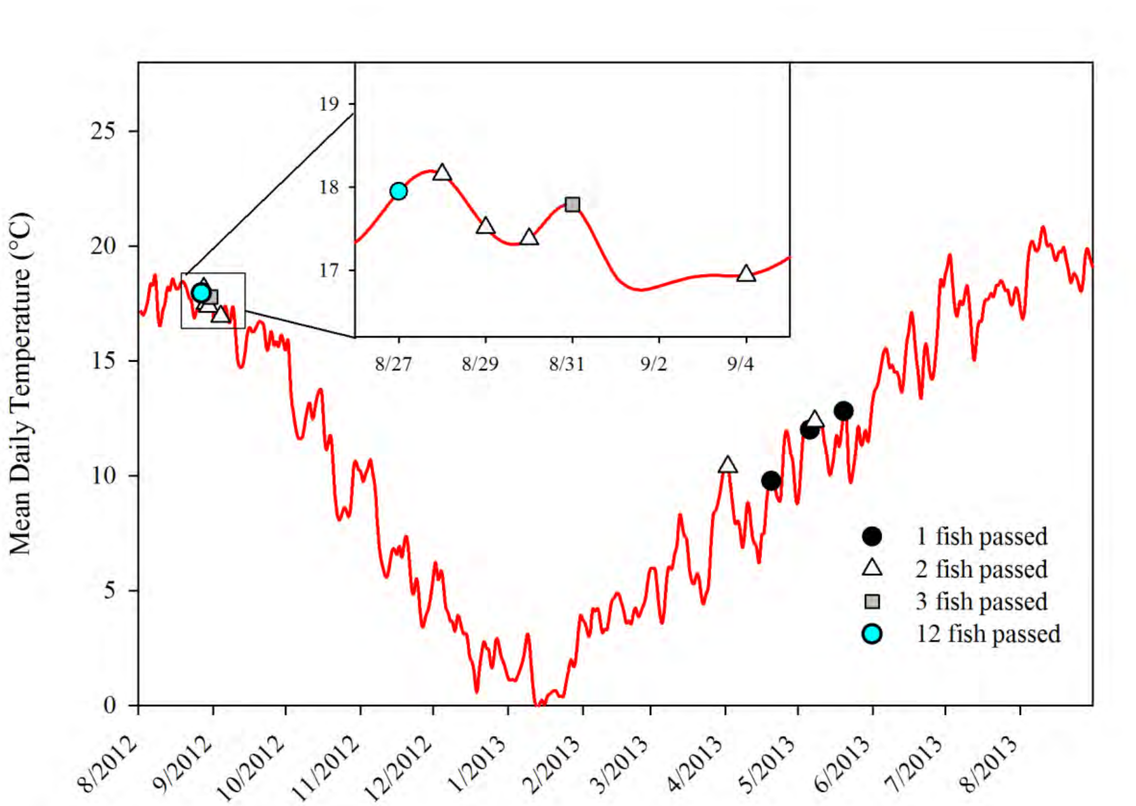

Figure 14. Mean daily water temperatures and passage timing of radio-tagged lampreys at Sunnyside Dam on the Yakima River, August 2012 through August 2013.

Above dam residence- Twenty-two of the 32 lamprey that passed Sunnyside dam moved rapidly upstream, leaving the upstream detection zone less than 1.5 h after exiting the fishways. Four of the Sunnyside lampreys exhibited an intermediate above dam residence period that lasted from 0.7 to 6.4 d. These four were detected on both the upstream aerial antennas at Sunnyside and the downstream and face antennas at Wapato, indicating that they moved back and forth between the dams after passing Sunnyside. One fall-release fish passed the Sunnyside ladder and overwintered in range of the upstream antenna array, resulting in an above dam residence time of 196.0 days.

*Sunnyside Diversion Canal residence-*Two tagged lampreys resided in the Sunnyside Canal upstream of the fish screen structure. One lamprey (code 79) was released downstream of the dam and one (code 18) was released upstream of the dam. Code 79 passed through the left fish ladder on May 20, 2013 and became entrained in the irrigation canal, and was located 30 meters downstream of the canal headgate on June 7 and 11, 2013. Code 79 resided in the canal for at least 41 to 59 d. It was last detected on the Sunnyside Dam antenna array on July 18, 2013, before it moved upstream and was detected on the Wapato Dam array on the following day. Code 18 was released between Sunnyside Dam and Wapato Dam at 15:46 on August 27, 2012 and almost immediately moved downstream as it was detected approaching Sunnyside Dam at 19:03 later that day. Although it was detected upstream of the dam until August 28, 2012 at 12:07, it is unclear from the detection history whether the lamprey passed over the dam or entered the canal at that time. Truck-based tracking conducted in April and May 2013 indicated code 18 was in the Yakima River downstream of the dam but that conclusion was based on coarse signal vector direction and not foot-based tracking. It was recorded on the downstream antenna arrays but it was determined on June 7, 2013 that the fish was at the trash rack in the canal. Code 18 was not tracked in any of the ladders so if it had passed upstream of the dam the route was unknown. The most likely scenario of canal entrainment is that code 18 entered the canal as it moved downstream from its release location. It is also possible it entered the canal at the screening structure through the fish bypass system of primary and secondary return pipes. Code 18 was still in the canal when the tag battery expired on August 18, 2013.

Wapato Dam

First approach of fall release- On August 27, 2012, 15 tagged lampreys were released downstream of Wapato Dam and 12 of these eventually approached the dam (Table 6). First approaches at Wapato Dam occurred on the night of the release, when eight tagged lampreys moved upstream to the dam. Four more lampreys approached the dam over the next 10 days, with all fish having approached by September 7, 2012. The three fish that did not approach moved downstream over Sunnyside Dam: one tag was recovered downstream of the Sunnyside left station, one fish was detected in the Sunnyside Diversion Canal (code 18, see *Sunnyside Diversion Canal residence*), and one resided below Sunnyside Dam for several months.

First approach of spring release- On March 20, 2013, 13 tagged lampreys were released downstream of Wapato Dam and 12 of these fish were eventually detected approaching the dam (Table 6). Initial approaches in the spring occurred from March 21 to April 3, 2013, and no fish approached the dam on the evening following release. The one fish that did not approach Wapato Dam remained at the release site downstream of the dam, where it was detected through July 2013. It is likely that this was a shed tag or mortality.

Below dam residence- Lampreys that successfully passed the dam exhibited shorter below dam residence times than those that did not, and fish that passed in the fall exhibited shorter residence times than those that passed in the spring (Table 7). Residence time below Wapato Dam ranged from less than 2 h to more than 154 days (Table 6).

Table 6. Wapato Dam approach and residence data: first and last detection dates and total number of days that adult radio-tagged Pacific lampreys resided below Wapato dam before initiating a successful passage event or moving downstream, August 2012 through August 2013.

Code	1st Detection Date	Last Detection Date	Days	Pass Dam?
44	08/27/12 21:44	08/29/12 00:24	1.1	Yes
29	08/27/12 21:51	08/27/12 23:48	0.1	Yes
46	08/27/12 21:55	08/28/12 00:50	0.1	Yes
6	08/27/12 22:06	08/28/12 02:22	0.2	Yes
39	08/27/12 22:21	08/28/12 01:59	0.2	Yes
43	08/27/12 22:39	08/28/12 04:45	0.3	Yes
7[a]	08/27/12 23:00	--	--	Yes
24	08/28/12 00:55	08/31/12 01:26	3.0	Yes
30	08/28/12 21:32	08/29/12 00:18	0.1	Yes
37	08/31/12 22:41	09/01/12 01:57	0.1	Yes
10	09/05/12 21:40	--	--	Yes
22	09/07/12 22:03	09/10/12 00:51	2.1	Yes
78	03/21/13 00:27	05/16/13 23:21	57.0	No
84	03/21/13 02:23	08/22/13 22:46	154.8	No
77	03/26/13 21:55	03/31/13 22:54	5.0	Yes
88	03/31/13 22:35	04/01/13 21:21	0.9	Yes
61	04/01/13 21:56	04/02/13 22:01	1.0	Yes
91	04/01/13 22:19	06/03/13 13:41	62.6	No
50	04/01/13 23:13	08/11/13 22:47	132.0	No
86	04/02/13 22:47	04/26/13 21:26	23.9	Yes
69	04/02/13 23:48	04/03/13 04:14	0.2	Yes
70[a]	04/03/13 04:40	04/03/13 22:01	0.7	Yes
92	05/07/13 02:23	06/11/13 03:31	35.0	No
71	05/08/13 21:16	06/06/13 16:30	28.8	No

[a] Fish passed Wapato, fellback over the dam, and passed a second time. Only the first passage is included here.

Table 7. Below dam residence summary for radio-tagged Pacific lampreys at released downstream of Wapato Dam from August 2012 - August 2013.

Release	Passage success	*n*	Duration (days)	Mean (days)	Median (days)	SD (days)
Fall	Yes	12	0.08 - 3.02	0.73	0.16	1.04
	No	0	--	--	--	--
Spring	Yes	7	0.18 – 23.94	4.67	0.95	8.57
	No	6	28.80 – 154.85	78.38	59.80	52.47

Dam passage efficiency and Fishway passage - Of the 55 Pacific lampreys that approached Wapato Dam (including fish that were released below Sunnyside and above Wapato dams), 45 passed upstream resulting in an overall dam passage efficiency of 82% (Table 8, Table 9, Table 10). Passage efficiency for the fall-release fish was 95%, as 37 lampreys approached the dam, and 35 passed. The first seventeen fall-release lampreys passed within 2 days of release; the next 17 fish passed within 14 days of release, and one fish overwintered below the dam and passed on May 8, 2013, 254 days after release.

As with Sunnyside Dam, Wapato passage efficiency was reduced for the spring-release group. Of the 18 spring-release lampreys that approached the dam, 10 passed successfully, resulting in a spring passage efficiency of 55%. One fish (code 70) passed two times. Spring-release group passage events took place in April (n = 8), May (n = 2), and June (n = 1) of 2013.

Of the lampreys passing Wapato Dam, 27 were released below Sunnyside Dam, while 18 were released below Wapato Dam (Table 8, Table 9, and Table 10). Lampreys used the left (41%), center (22%), and right (20%) fishways, and the dam face (17%) to pass Wapato Dam (Table 8, Table 9, and Table 10).

The duration of Wapato Dam passage events ranged from 0.1 – 23.5 hours. (Table 8). All but one passage event lasted less than four hours, and 50% lasted less than one hour. The lone 23.5 hour passage event occurred overnight. Mean passage times were longer in the spring (3.3 hours) than fall (1.0 hours). Passage times also varied with location, mean passage time at the river right ladder (3.5 hours) took longer than at the left (1.26 hours) or center (0.55 hours) ladders. Passage times were not calculated for fish passing via unknown routes.

Table 8. Wapato Dam fishway data: dates of entry and exit, total time in the fish ladder, and mean daily water temperature at passage for radio-tagged adult Pacific lampreys released downstream of Wapato Dam, August 2012 through August 2013.

Code	Release Site/Period	Fishway	Entered Ladder	Exited Ladder	Time in Ladder (hr)	Temp °C
29	BWD/Fall	L. Ladder	08/27/12 23:48	08/28/12 00:17	0.49	17.9
46	BWD/Fall	L. Ladder	08/28/12 00:50	08/28/12 02:30	1.67	18.1
39	BWD/Fall	L. Ladder	08/28/12 01:59	08/28/12 05:15	3.26	18.1
6	BWD/Fall	C. Ladder	08/28/12 02:22	08/28/12 02:30	0.14	18.1
43	BWD/Fall	L. Ladder	08/28/12 04:45	08/28/12 05:21	0.60	18.1
30	BWD/Fall	C. Ladder	08/29/12 00:18	08/29/12 00:41	0.39	17.4
44	BWD/Fall	L. Ladder	08/29/12 00:24	08/29/12 01:22	0.96	17.4
24	BWD/Fall	R. Ladder	08/31/12 01:26	08/31/12 02:12	0.77	17.7
37	BWD/Fall	L. Ladder	09/01/12 01:57	09/01/12 03:20	1.39	16.8
22	BWD/Fall	C. Ladder	09/10/12 00:51	09/10/12 01:01	0.17	16.4
77	BWD/Spring	R. Ladder	03/31/13 22:54	04/01/13 22:23	23.49	--

Table 8 Continued

Code	Release Site/Period	Fishway	Entered Ladder	Exited Ladder	Time in Ladder (hr)	Temp °C
88	BWD/Spring	C. Ladder	04/01/13 21:21	04/01/13 22:24	1.06	--
61	BWD/Spring	R. Ladder	04/02/13 22:01	04/02/13 23:32	1.51	--
69	BWD/Spring	C. Ladder	04/03/13 04:14	04/03/13 05:49	1.59	--
70[a]	BWD/Spring	L. Ladder	04/03/13 22:01	04/03/13 22:47	0.76	--
70[a]	BWD/Spring	C. Ladder	04/04/13 00:47	04/04/13 01:38	0.85	--
86	BWD/Spring	C. Ladder	04/26/13 21:26	04/26/13 21:49	0.39	11.9

[a] Fish passed the dam twice, both passage times reported here.

Table 9. Wapato Dam fishway data: dates of entry and exit, total time in the fish ladder, and mean daily water temperature at passage for radio-tagged adult Pacific lampreys released downstream of Sunnyside Dam, August 2012 through August 2013.

Code	Release Site/Period	Fishway	Entered Ladder	Exited Ladder	Time in Ladder (hr)	Temp °C
38	BSD/Fall	L. Ladder	08/28/12 02:07	08/28/12 02:57	0.85	18.1
8	BSD/Fall	R. Ladder	08/28/12 02:29	08/28/12 03:10	0.68	18.1
41	BSD/Fall	L. Ladder	08/28/12 03:01	08/28/12 03:07	0.10	18.1
12	BSD/Fall	R. Ladder	08/28/12 03:17	08/28/12 03:51	0.57	18.1
21	BSD/Fall	L. Ladder	08/28/12 03:51	08/28/12 04:48	0.94	18.1
14	BSD/Fall	L. Ladder	08/28/12 05:07	08/28/12 06:00	0.88	18.1
35	BSD/Fall	L. Ladder	08/28/12 21:46	08/28/12 22:23	0.62	18.1
25	BSD/Fall	L. Ladder	08/29/12 00:35	08/29/12 01:15	0.67	17.4
20	BSD/Fall	C. Ladder	08/29/12 01:03	08/29/12 01:25	0.37	17.4
23	BSD/Fall	L. Ladder	08/31/12 04:56	08/31/12 06:53	1.95	17.7
45	BSD/Fall	L. Ladder	09/01/12 02:17	09/01/12 05:56	3.66	16.8
4	BSD/Fall	R. Ladder	09/02/12 00:57	09/02/12 01:21	0.40	16.8
31	BSD/Fall	C. Ladder	09/03/12 00:42	09/03/12 00:52	0.16	16.9
9	BSD/Fall	L. Ladder	09/03/12 01:22	09/03/12 02:53	1.52	16.9
47	BSD/Fall	L. Ladder	09/03/12 03:09	09/03/12 04:40	1.53	16.9
32	BSD/Fall	L. Ladder	09/05/12 22:59	09/06/12 00:44	1.75	17.1
36	BSD/Fall	L. Ladder	09/06/12 23:20	09/07/12 00:08	0.79	17.2
33	BSD/Fall	C. Ladder	09/07/12 23:44	09/07/12 23:50	0.10	16.8
75	BSD/Spring	R. Ladder	04/18/13 20:18	04/18/13 23:15	2.95	8.8
93	BSD/Spring	R. Ladder	05/08/13 00:25	05/08/13 00:37	0.20	12.3
85	BSD/Spring	R. Ladder	06/05/13 02:01	06/05/13 02:40	0.66	15.0

Dam face passage- Eight tagged lampreys were not detected entering a fishway and instead passed Wapato Dam by climbing the face of the dam (Table 10). Seven of these lampreys were fall releases, including five from below Sunnyside Dam where they had passed in the ladders. Five lampreys climbed Wapato Dam in the west channel, including four that used the right face between the fishway and the right bank and one that climbed the left face between the fishway and the island. Three lampreys climbed Wapato Dam in the east channel and all used the right face between the fishways. Based on interpretation of antenna detections and signal strength, most lampreys passed on their first attempt and took only 1-4 h to climb (Table 10). Code 15, which had overwintered at the dam, was not successful until its fifth attempt in the spring, when it took 11 h to climb and finally pass. Tagged lamprey that passed on the dam face did so on similar dates and under similar temperature and flow conditions as those using the ladder.

Table 10. Wapato Dam face passage data: route selection, timing, and duration of passage for radio-tagged adult Pacific lampreys, August 2012 through August 2013.

Code	Release Location/Period	River Channel	Dam Face	Start Climb	Finish Climb	Climb Time (hr:mm)
7	BWD/Fall	East	Right	08/27/12 23:00	08/28/12 03:23	4:23
42	BSD/Fall	East	Right	09/03/12 20:11	09/03/12 23:23	3:12
40	BSD/Fall	West	Right	09/04/12 21:49	09/04/12 23:03	1:14
13	BSD/Fall	East	Right	09/05/12 20:30	09/05/12 21:34	1:04
16	BSD/Fall	West	Right	09/05/12 21:00	09/05/12 23:12	2:12
10	BWD/Fall	West	Right	09/09/12 19:00	09/09/12 22:53	3:53
15	BSD/Fall	West	Left	05/08/13 02:06	05/08/13 13:08	11:02
52	BSD/Spring	West	Right	05/09/13 21:31	05/10/13 01:07	3:36

Wapato Diversion Canal residence- One tagged lamprey was entrained in the Wapato Canal. Code 15 was released downstream of Sunnyside Dam on August 27, 2012. It passed that dam, arrived at Wapato Dam on October 16, 2012 and was located in the west channel downstream of the right bank fishway on October 18, 2012. It was recorded downstream of the dam through the winter and spring until May 8, 2013, when it was detected on the left aerial antenna climbing the left face of the dam between the fishway and the island. Antenna detections indicate code 15 moved across the river above the dam and became entrained in the Wapato Canal. It resided just downstream of the trash rack for 53 days, from May 8 until June 30, 2013, when it exited the canal as indicated by the last detection on the upstream aerial antenna. On July 5, 2013, code 15 was detected in the Roza Canal Wasteway Outfall at the powerhouse pool.

Discharge- Pacific lampreys passed Wapato Dam at a variety of discharge levels (Figure 15). Those passing in the fall did so at relatively low flows between 600 and 965 ft^3/s. Those passing during the spring months did so at widely varying flows between 2,500 and 8,100ft^3/s. The majority of passage events, especially in the spring, occurred during periods of increasing discharge.

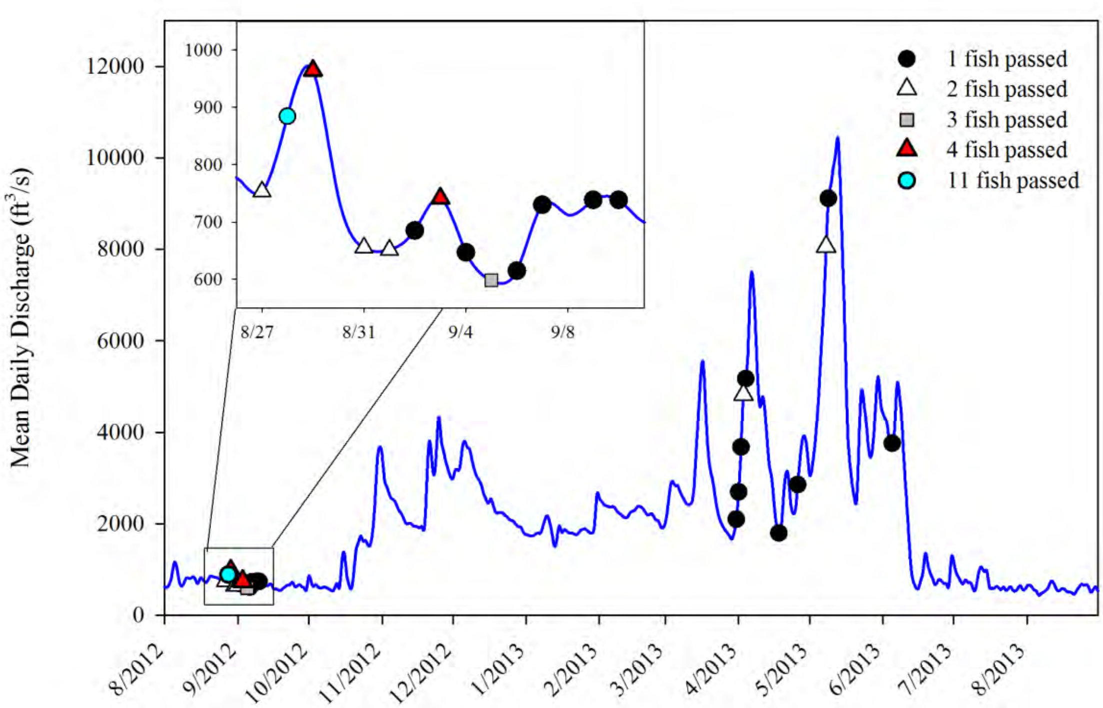

Figure 15. Mean daily discharge and passage timing of radio-tagged lampreys at Wapato Dam on the Yakima River, August 2012 through August 2013.

Temperature- Water temperatures of the Yakima River were recorded at Wapato Dam between August 1, 2012 and January 20, 2013, and between April 8, 2013 and August 31, 2013 (Figure 16). In late March and early April 2013, six tagged lampreys passed Wapato Dam, and temperature data from Sunnyside dam has been substituted to understand their movements with relation to water temperature.

Throughout Phase 2, mean daily water temperatures varied from 3.1 to 20.5 °C. Lamprey passage occurred during mean daily water temperatures of 8.7 to 18.1 °C, with fall passage events occurring at warmer temperatures than spring passage events (Figure 16). In the fall, water temperatures rapidly declined to less than 16 °C after the last lamprey passed the dam and movements below the dam generally ceased for the remainder of the fall.

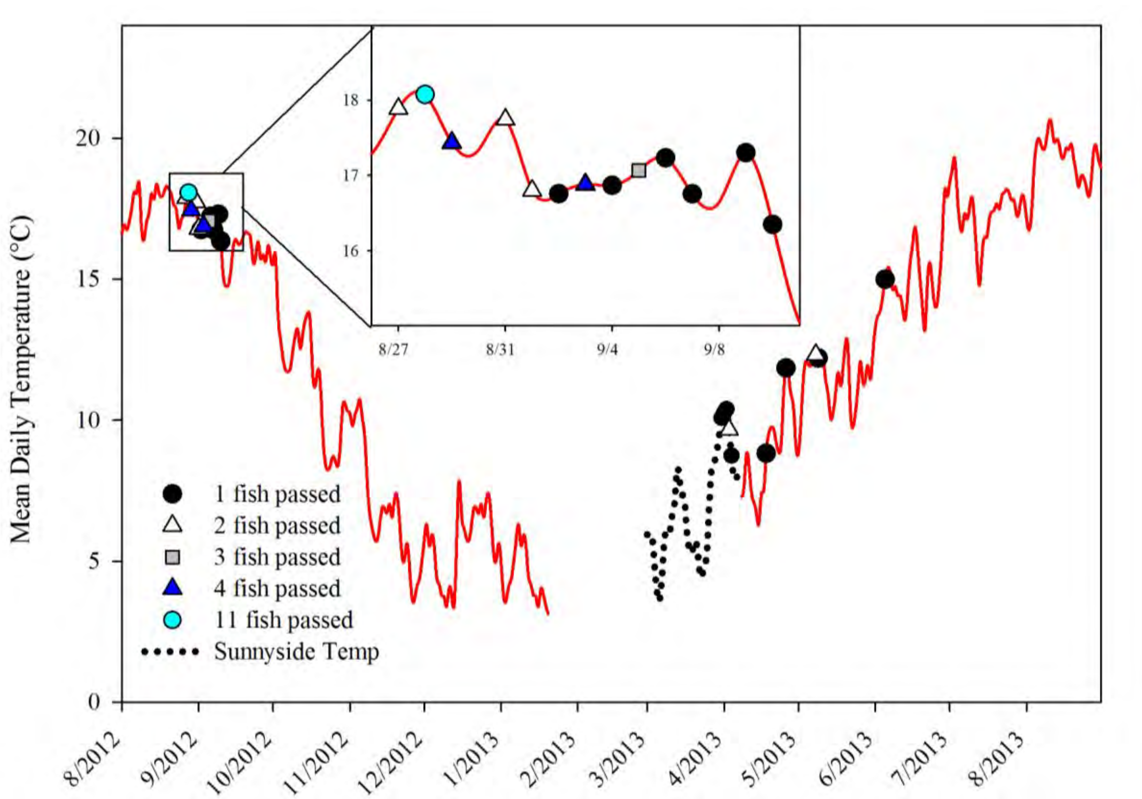

Figure 16. Mean daily water temperatures and passage timing of radio-tagged lampreys at Wapato Dam on the Yakima River, August 2012 through August 2013. Wapato Temperature data from January 20 – April 8, 2013 are not available; Sunnyside Dam temperature data were substituted from March 1 – April 7, 2013.

Above dam residence- For lampreys that passed using fishways, the time spent above Wapato Dam ranged from 2.8 minutes to 5.8 days. Most fished moved quickly upstream and 26 of 35 lampreys resided for less than one hour before moving out of detection range. Two exceptions were observed. Code 70 passed the dam on April 3, 2013, fell back over it, and passed the dam a second time on the following day. As described above, code 15 entered the Wapato Diversion Canal, where it resided for 53 days before moving upstream.

Roza Wasteway #2

A substantial number of tagged lampreys entered and used the Roza Wasteway #2 (see Figure 17). During the fall migration, 20 of the 49 tagged lampreys that passed Wapato Dam (or that were released above and remained above the dam) entered the Wasteway through the salmon exclusion screening (Table 11). During the spring release, 4 of the 11 tagged lampreys that passed Wapato Dam entered the Wasteway. Most entered within 2 weeks of passing Wapato Dam although two fall-release fish waited until spring (tag 42) or summer (tag 15). Four lampreys (tags 4, 23, 30, 44) moved between the Wastway outfall and the river several times. Minimum known residence in the Roza Wasteway #2 ranged from 1.4 to 324 days; three lampreys spent less than 7 days and seven lampreys spent more than 300 days in the Wasteway (Table 11).

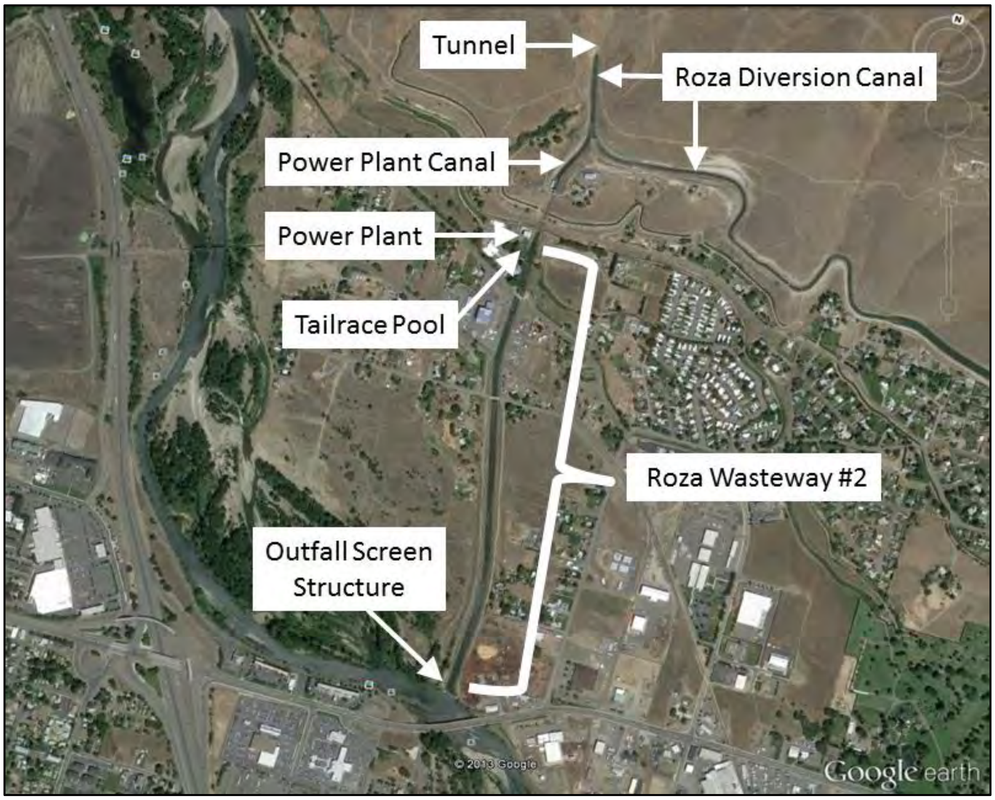

Figure 17. Aerial photograph showing the Roza Diversion Canal emerging from the tunnel, the Roza Power Plant Canal diverging from the main canal, and the locations of the Roza Power Plant, Tailrace Pool, Roza Wasteway #2, and Wasteway Outfall.

Table 11. Roza Wasteway #2 entry and residence data for radio-tagged adult Pacific lampreys, August 2012 through August 2013.

Tag ID	Release Site	Release Date	1st Date Roza Outfall	Last Date Roza Outfall	Total Time at Outfall (days)	Minimum Residence (days)	Exit?	1st Date Upstream Dam
4	BSD	08/27/12	09/12/12	05/09/13	238.8	26.0	yes	--
7	BWD	08/27/12	09/12/12	07/26/13	316.5	317.0	no	--
8	BSD	08/27/12	04/25/13	05/28/13	33.5	33.5	yes	--
9	BSD	08/27/12	09/03/12	12/20/12	107.1	106.0	yes	--
11	AWD	08/27/12	09/12/12	07/26/13	317.0	317.0	no	--
15	BSD	08/27/12	07/05/13	08/19/13	45.1	44.6	unk	--
17	AWD	08/27/12	09/05/12	07/05/13	303.0	303.0	no	--
20	BSD	08/27/12	09/18/12	05/24/13	248.7	248.2	yes	--
23	BSD	08/27/12	09/05/12	10/28/12	53.1	12.8	yes	09/15/12[a]

Table 11 Continued

Tag ID	Release Site	Release Date	1st Date Roza Outfall	Last Date Roza Outfall	Total Time at Outfall (days)	Minimum Residence (days)	Exit?	1st Date Upstream Dam
24	BWD	08/27/12	09/12/12	09/14/12	2.1	1.6	yes	--
25	BSD	08/27/12	09/12/12	07/11/13	302.0	302.0	no	--
30	BWD	08/27/12	09/05/12	07/26/13	324.0	188.0	no	--
31	BSD	08/27/12	09/12/12	09/12/12	7	7	yes	02/27/13[b]
38	BSD	08/27/12	09/18/12	05/28/13	252.9	252.9	yes	--
39	BWD	08/27/12	09/05/12	09/15/12	11.0	10.5	yes	05/20/13[a]
42	BSD	08/27/12	04/25/13	05/05/13	10.1	9.6	yes	--
43	BWD	08/27/12	09/12/12	09/13/12	1.9	1.4	yes	09/16/12[a]
44	BWD	08/27/12	09/28/12	05/20/13	234.2	34.3	yes	--
45	BSD	08/27/12	09/05/12	07/26/13	324.0	324.0	no	--
46	BWD	08/27/12	09/05/12	07/26/13	324.0	324.0	no	--
61	BWD	03/20/13	04/08/13	05/31/13	53.0	52.5	yes	--
75	BSD	03/20/13	04/25/13	06/19/13	55.0	36.5	unk	--
85	BSD	03/20/13	06/19/13	07/26/13	37.0	33.5	unk	--
88	BWD	03/20/13	04/17/13	04/17/13	--	unk	unk	--

[a] Cowiche Dam
[b] Roza Dam

During mobile tracking the majority of lampreys were detected in the power plant tailrace pool (Figure 17 and Figure 18) and a few were distributed downstream in the Wasteway to the outfall screens (Figure 17). The number of lampreys recorded at the power plant tailrace pool in the spring of 2013 ranged from five tags on April 1, to 11 tags on April 25 and May 9. Thirteen of the tagged lamprey eventually exited the Wasteway; seven were last detected within the Watseway, and exit status of four is unknown. A total of nine lampreys were present during the presumed spawning period (mid-June to late July, 2013), including two that first entered the Wasteway at that time. Several lampreys moved downstream after exiting and only four lampreys were subsequently detected at upstream stations- three at Cowiche Dam and one at Roza Dam (Table 11).

Several features may influence lamprey behavior at the site. The Yakima River thalweg is on the same side of the river as the Wasteway due to the gravel bar that spans most of the river channel (Figure 19). At lower flows this gravel bar also appears to guide lampreys directly to the Roza Wasteway #2 Outfall (Figure 20). The spacing of bars in the screen structure is designed to exclude adult salmon but adult lampreys are not deterred (Figure 21). The Roza Canal was dewatered and the Wasteway shut off from late October to late November during 2012, but water still flowed from subsurface sources in the outfall canal and the lampreys apparently survived until diversion water flowed again on November 24.

Figure 18. The Roza Power Plant showing the tailrace pool where 7 tagged adult Pacific lampreys were present when Roza Wateway #2 was shut off for annual maintenance during November, 2012.

Figure 19. Aerial photo showing the gravel bar and thalweg of the Yakima River at the Roza Wasteway #2 confluence.

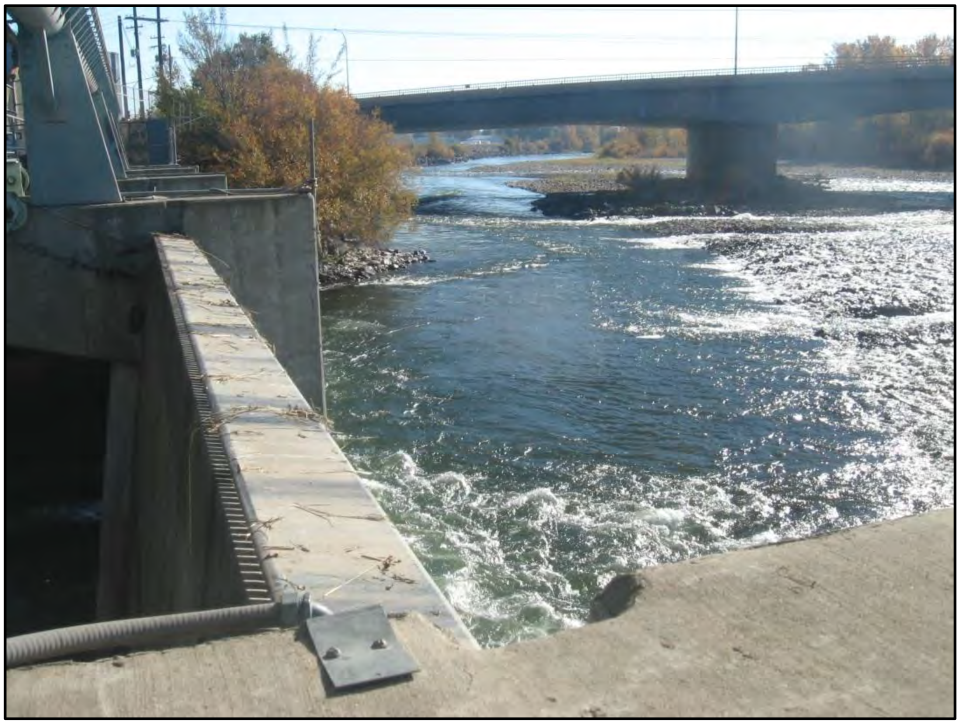

Figure 20. The Yakima River thalweg and gravel bar located downstream of the Roza Wasteway #2 outfall screen structure.

Figure 21. The Roza Wasteway #2 outfall screen structure at the Yakima River confluence, with the gravel bar visible beyond screen.

Roza Dam

Fishway passage-Twelve study lampreys approached Roza Dam between September 1, 2012 and May 9, 2013. Eleven of these were detected at fishway entrances, and eight were detected at interior fishway antennas (Table 12). Most of the lampreys (11 of 12) that reached Roza Dam were released in the fall. Eight of 11 fall release fish approached in the fall within 12 days of release, and four approached in the spring after overwintering downstream. Lampreys that approached Roza were released below both Wapato (n = 4) and Sunnyside (n = 8) dams.

Table 12. Roza Dam approach and passage summary for radio-tagged adult Pacific lampreys, August 2012 through August 2013.

Fish ID	Release Site/Time	First Roza Detection	Roza Highpoint	Pass?
29	BWD/Fall	08/28/12 11:29	Fish facility holding pen	No
41	BSD/Fall	08/31/12 23:35	Downstream of dam	No
6	BWD/Fall	09/01/12 00:08	Right fishway entrance	No
35	BSD/Fall	09/02/12 23:43	Fish facility holding pen	No
12	BSD/Fall	09/03/12 22:42	Fish facility holding pen	No
21	BSD/Fall	09/06/12 01:01	Fish facility holding pen	No
14	BSD/Fall	09/06/12 02:11	Fish facility holding pen	No
40	BSD/Fall	09/08/12 02:45	Fish facility holding pen	Yes[a]
32	BSD/Fall	03/14/13 19:58	Right and left fishway entrances	No
22	BWD/Fall	04/03/13 00:28	Right fishway interior	No
86	BWD/Spring	05/09/13 00:35	High water ladder exit	No
47	BSD/Fall	05/11/13 17:10	Right and left fishway entrances	No

[a] One untagged lamprey was released from the holding pen intro the forebay, and we assume this was the study fish that shed tag code 40 which was later recovered in the fish facility.

Salmon facility holding pen- Of the 12 tagged lampreys that approached Roza Dam, six ascended the fish ladder and were detected in the salmon trapping facility (Table 12). All were from the fall release group, with five release downstream of Sunnyside Dam and one released downstream of Wapato Dam. During mobile tracking on September 8, 2012, four lampreys were detected in the holding pen. Because Roza Dam was initially wired as a simple gate station with only one downstream antenna, additional antennas were then set up to monitor the fish ladder and fish processing facility.

Based on the mobile and antenna detections, the lampreys ascended the ladder and entered the holding pen within 1 to 6 days after first approaching the dam. Three lampreys (codes 12, 14, 21) spent 1 day, one (code 35) spent 12.5 days, and one (code 29) spent 26.5 days in the facility. Code 40 was detected in the pen for 40 days, but when the tank was emptied on October 24, 2012, the transmitter was recovered. An untagged lamprey was passed upstream by the trapping crew during the previous week and was assumed to be code 40.

Cowiche Dam
Dam passage efficiency and Fishway passage - Ten lampreys approached Cowiche dam, between September 5, 2012 and June 6, 2013 (Table 13). Of these, six passed resulting in a dam passage efficiency of 60%. Passage routes at Cowiche were mostly unknown, as fishway monitoring antennas were installed on February 26, 2013 after the fall release lampreys had passed. The one lamprey (code 52) passed in the spring used the left fishway.

Table 13. Cowiche Dam approach and passage data for radio-tagged adult Pacific lampreys, August 2012 through August 2013.

Fish ID	Release Site/Time	First Cowiche Detection	Pass?	Ladder	Passage Date
28	AWD/Fall	09/05/12 21:30	Yes	Unknown	09/05/12
37	BWD/Fall	09/08/12 04:03	Yes	Unknown	09/08/12
16	BSD/Fall	09/09/12 02:38	Yes	Unknown	09/09/12
33	BSD/Fall	09/11/12 01:53	Yes	Unknown	09/13/12
24	BWD/Fall	09/15/12 19:22	Yes	Unknown	09/15/12
43	BWD/Fall	09/16/12 06:58	No	--	--
10	BWD/Fall	09/21/12 03:48	No	--	--
39	BWD/Fall	05/20/13 02:43	No	--	--
52	BSD/Spring	06/08/13 07:52	Yes	L. Ladder	06/10/13
47	BSD/Fall	09/12/13 18:47	No	--	--

Five of the six lampreys that passed remained above Cowiche Dam and continued migrating up the Naches River. Code 28 passed the dam and initially moved up the Naches River before reversing course and moving downstream back over Cowiche Dam and out to the confluence with the Yakima River. Two lampreys (codes 10 and 43) overwintered below the dam.

Last Known and Uppermost Detections

Last Known Detections
It is unclear if the last known detections represent the final locations of study lampreys. These detections may represent several scenarios including:

1) Tag retained: Indicates location of lamprey carcasses (mortality or predation)
2) Tag retained: Indicates location where transmitter battery failed, and lamprey movements continued but were not detected.
3) Tag shed: Indicates location where transmitter was expelled, and lamprey movements continued but were not detected.

Determining the last known detection type was beyond the scope of this study. One tag, with code 40 was recovered from the Roza Dam fish facility, and a single untagged lamprey (assumed to have shed this tag) was released into the dam forebay, but the circumstances around the remaining last detections are unknown.

The last known detection locations of radio-tagged lampreys through August 1, 2013 are summarized in Table 14. Seventy study lampreys were last detected in the Yakima River drainage, whereas 10 were last located in the Naches River system. Most codes remained in the mainstem Yakima River below Sunnyside and Wapato dams, or in the reach below Roza Dam. However, several lampreys were last detected in off-channel locations including the Roza Wasteway Canal (n = 11) and the Sunnyside Diversion Canal (n = 1), suggesting these structures may pose an entrainment risk for migratory adult lamprey (Table 14). Last detections of tagged lampreys in the Naches River system were located both upstream (n = 5) and downstream (n = 5) of Cowiche Dam (Table 14).

Table 14. Summary of last known detection locations (dam or reach) of radio-tagged Pacific lampreys released in Yakima River during fall 2011 and spring 2012.

Reach	Number final detections
Below Sunnyside Dam	20
Sunnyside Diversion Canal	1
Between Sunnyside and Wapato dams	17
Between Wapato Dam and Roza Outfall	8
In the Roza Wasteway Canal	11
Between Roza Outfall and Roza Dam	12
Above Roza Dam	1
Between the Naches confluence and Cowiche Dam	5
Above Cowiche Dam	5

Uppermost Detections: Naches River

The six radio-tagged lampreys that passed Cowiche Dam were detected from the Cowiche Dam headpond (rkm 6.5) to the town of Cliffdell (rkm 53). The uppermost detection locations of these lampreys are shown in Figure 22. Three lampreys passed an additional diversion dam, Wapatox Dam (rkm 28). Four of the six lampreys that passed Cowiche Dam were ultimately documented moving back downstream before being detected for the final time.

Naches River habitat above Cowiche Dam includes extensive networks of gravel bar and cobble islands, side channels, oxbows and backwaters. Apart from the Tieton River (rkm 29), most of the Naches River tributaries are steep, cold water streams. It is not clear how radio-tagged lampreys were using Naches River and its tributaries, but high quality spawning and rearing habitats are available in the mainstem river, and possibly in the side tributaries as well.

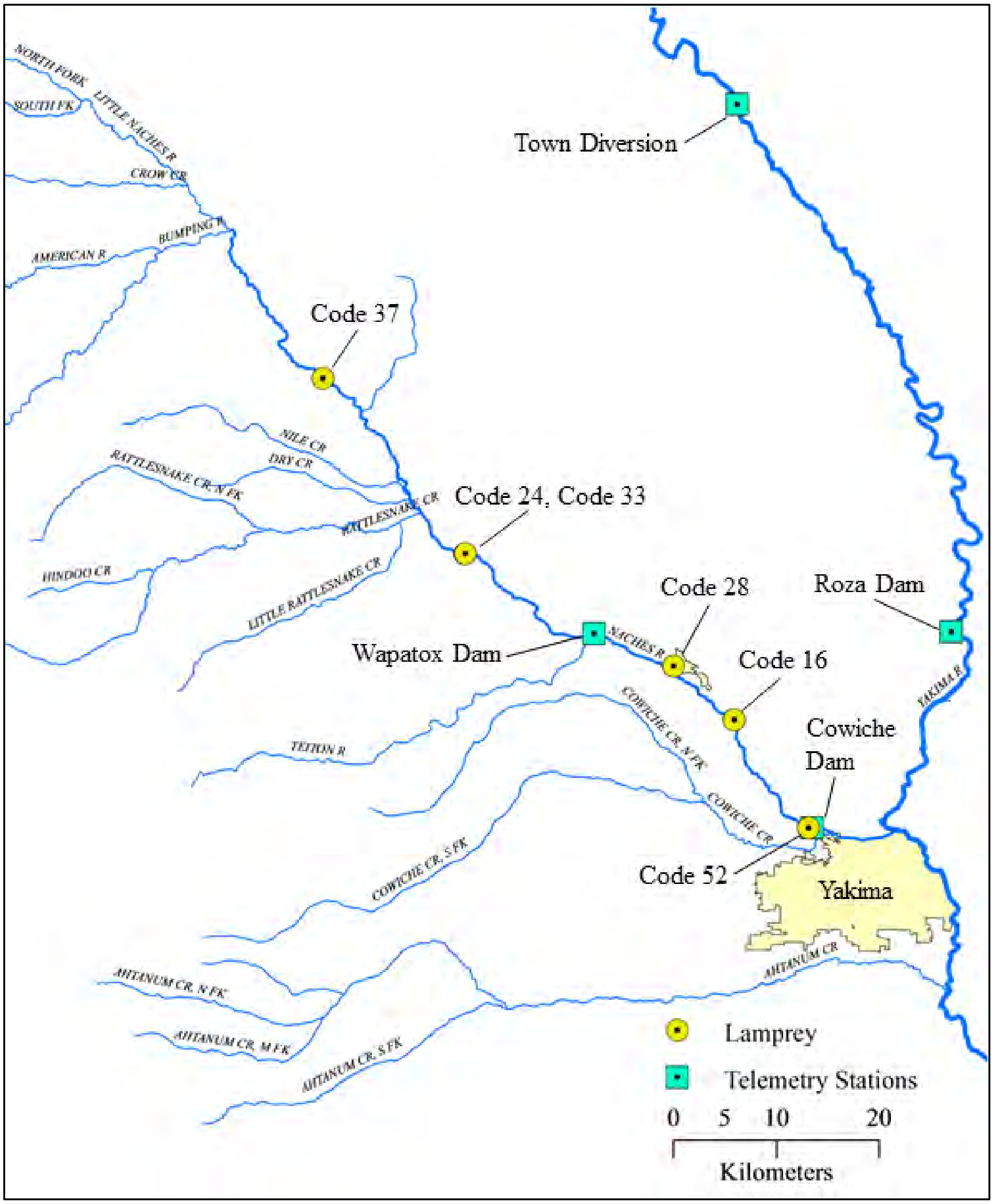

Figure 22. Last known locations of radio-tagged Pacific lampreys in the Naches River from August 2012 to August 2013.

Multiple Dam Passage

With the exception of Wapato Dam in the fall, the numbers of radio-tagged lampreys passing multiple dams was small (Table 15). Of the 47 lampreys released downstream of Sunnyside Dam, only three (6%) passed three successive diversion dams (including Cowiche Dam); two lampreys from the fall and one from the spring release group. Although one lamprey passed Roza Dam, this fish was removed from the holding pen by the fish facility staff, and therefore has been excluded from passage calculations.

Lampreys having passed at least one dam had overall passage success rates (# pass / # approach) of 90% at Wapato Dam, 56% at Cowiche Dam, and 0% at Roza Dam. Passage success at multiple dams was highest for lampreys passing Wapato Dam in the fall. Lampreys released below Sunnyside dam that approached Wapato Dam in the fall passed with 100% success. Multiple dam passage success at Wapato Dam was less spring, decreasing to 57%. This reduction in springtime dam passage efficiency at Wapato Dam was also observed for lamprey released below Wapato Dam but above Sunnyside Dam (100% in fall to 50% in spring) suggesting that passage conditions were better in the fall for both groups).

Table 15. 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**	**SUN Fall**	**SUN Spring**	**WAP Fall**	**WAP Spring**	**ROZ Fall**	**ROZ Spring**	**COW Fall**	**COW Spring**
BSD/Fall	25	24		22	1	1[a]		2	
BSD/Spring	22		7		4				1
BWD/Fall	15			12				2	
BWD/Spring	13				6[b]				
AWD/Fall	5		1					1	
Totals	***80***	***24***	***8***	***34***	***11***	***1***		***5***	***1***

[a] One untagged lamprey was released from the holding pen intro the forebay, and we assume this was the study fish that shed tag code 40 which was later recovered in the fish facility.
[b] Code 70 passed Wapato twice, but only one passage event is included here.

Discussion

Phase 2 of our telemetry study was completed during the 2012 migration season. A total of 80 adult Pacific lampreys were radio-tagged and released at Sunnyside and Wapato dams. Nearly all the tagged lampreys moved upstream and actively attempted to pass the diversions.

Passage Efficiencies

Overall passage efficiencies at Wapato Dam (82%) and Sunnyside Dam (68%) were higher than the overall passage efficiencies recorded during Phase 1 at Wanawish Dam (62%) and Prosser Dam (48%) (Johnsen et al. 2013). Seasonal dam passage efficiencies were inverted during Phase 2, relative to Phase 1. Dam passage efficiencies for fall-release fish were substantially higher than spring-release fish at Sunnyside (96% fall, 33% spring) and Wapato (95% fall, 55% spring), but not at Wanawish (53% fall, 71%

spring) or Prosser (50% fall, 45% spring). These local and seasonal differences present additional challenges to upstream migrations: in the fall, fewer lampreys are able to pass the lower dams to take advantage of the seasonal high passage efficiencies at the upstream dams; conversely, in the spring more lampreys are able to pass the lower dams but they are then confronted with low passage efficiencies at the dams upstream.

The dam passage efficiency at Wapato Dam was supplemented by tagged lampreys passing up and over the face of the dam. This "climbing" ability outside of the ladders increased overall dam passage efficiency from 67% to 82%. We were unable to pinpoint the exact locations where climbing occurred, but apparently some combination of conditions at the dam is conducive to the behavior. It may be that logs or debris hang up on the dam and create hydraulic actions that favor the climbing ability. Characteristics of the dam face such as smoothness of the concrete and flow pattern at the ladder intersections may also be a factor. Modifications such as flow deflectors on the fishway walls upstream of the dam may create calmer flow conditions for a climbing route at the face (Figures 23 and 24). Metal plating curved to fit the face of the dam below the deflector may provide a better surface for oral disk attachment to increase climbing success of the lamprey. Close inspection of the dam faces at varying flows would be instructive for designing this type of passage assistance.

Figure 23. Photograph of the right bank of Cowiche Dam showing a log hung up on crest that deflects flow and calms turbulence at the intersection of the dam face and fishway wall, resulting in conditions that may favor lamprey climbing behavior to pass a dam.

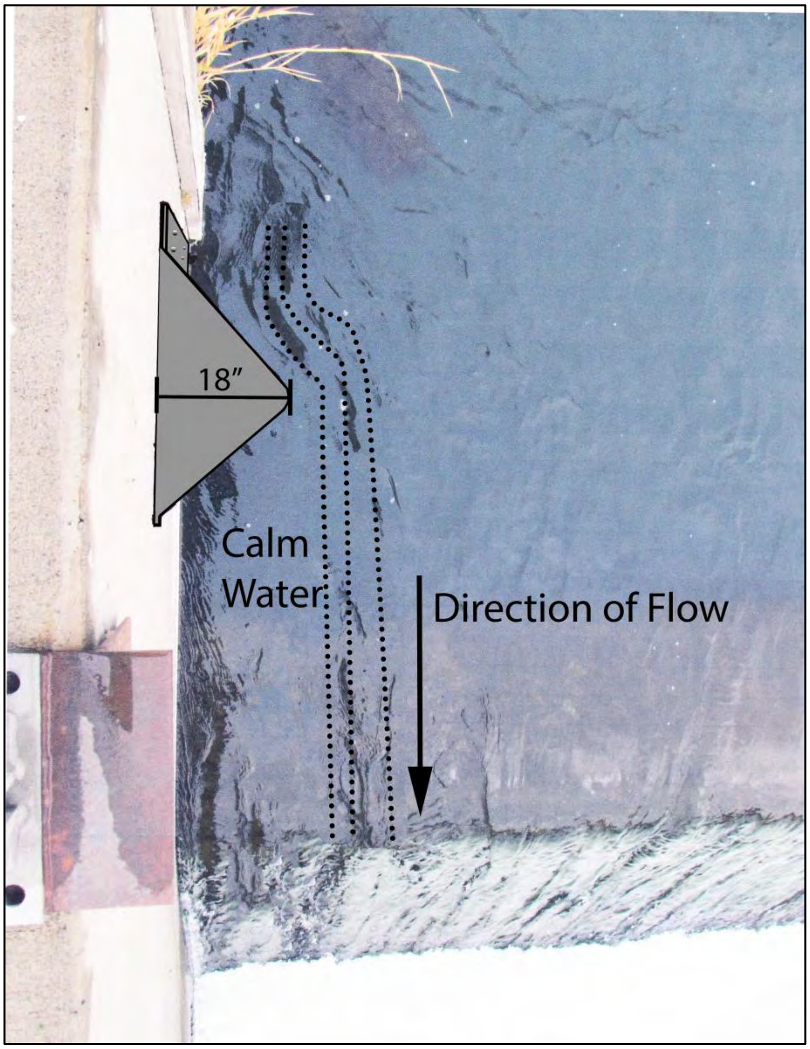

Figure 24. Photograph with concept drawing of deflector designed to create flows conducive to climbing adult lamprey at Sunnyside Dam (design created by J. Simonson of Fish Head Technology and Mark Nelson USFWS).

Entrainment in Canals

The majority of the tagged fish quickly moved upstream after passing a dam but some entrainment occurred in canals during the 2012 migration. One tagged lamprey resided in the Sunnyside Canal just upstream of the screening for 2 months before moving upstream. Another lamprey resided in the canal for a year before the battery died, but because this lamprey moved downstream from the release location upstream of Wapato Dam, the entrainment and residence is most likely a tagging effect. One lamprey resided in the Wapato Canal near the trash rack for two months before moving upstream. Only one entrainment was documented during Phase 1 at Wanawish Dam in the 2011 migratory season. Overall, entrainment in canals after passing a diversion has occurred at a relatively low frequency during our study to date.

Roza Wasteway #2
A significant number of tagged lampreys (24 of 60) entered and resided in the outfall of the Roza Wasteway #2, including 11 that overwintered at the powerhouse pool. Lampreys that overwintered in the canal for about 250 days survived and exited in May, 2013, but those that spent over 300 days were not detected leaving before the transmitter batteries died. Thus several tagged fish survived in the powerhouse pool during the November 2012 shutdown of Roza Canal, but the overall survival rate is unknown. It appears some of the lampreys may have attempted to spawn in the Wasteway while others re-entered the Yakima River and continued upstream migration to potential spawning areas.

Several factors could influence lamprey use of the Wasteway. It may be that the hydrology and morphology of the river channel and outfall simply guide lampreys into the canal and they perceive it as a natural tributary. The gravel bar at the confluence and the gravel in the canal outfall may be attractive spawning substrate. The powerhouse pool appears to provide overwinter habitat of cobble and rubble. The Wasteway water originates from Roza Dam and may be more temperate than the mainstem Yakima River during late summer, and subsurface flows may also moderate temperatures that are seasonally attractive to the lamprey.

To further evaluate lamprey entrainment and or use of Roza Wasteway #2, pot traps should be placed in the powerhouse pool to monitor use by untagged lampreys. If it is decided that the effect of the Wasteway on lamprey behavior and movement is negative, then consideration should be given to upgrading the salmon screening to exclude adult lamprey from the outfall. Alternatively, the Wasteway and vicinity could used as a migratory lamprey collection location. Traps could be constructed to capture run of the river adult lampreys for future research and potentially supplementation efforts.

Roza Dam Salmon Facility
Few if any lampreys have been reported at Roza Dam, whether in the fishway or the salmon trapping facility. Code 40 was apparently the first lamprey ever observed passing through the facility since it was constructed in 1995 (Mark Johnston, YN Fisheries, pers. comm.). About 50% of the tagged lamprey that migrated to Roza Dam during Phase 2 ascended the fish ladder and entered the facility, comparable to efficiencies at the lower Yakima River fishways. As constructed and operated, however, the fish facility is essentially a dead end for lamprey migration. The fish crowder in the trap is ineffective in moving lampreys into the fish elevator because of a gap at the bottom of the screen due to the slanted floor of the tank: lampreys simply swam under and resided behind the crowder. Observations by the trapping crew on the location and behavior of tagged lampreys in the tank resulted in a simple solution that may allow lampreys to continue upstream migration. In November 2013, during the maintenance drawdown of the forebay, the USBOR drilled a 3 inch diameter hole through the cement wall of the tank behind the crowder, providing an “escape hatch” for lamprey to swim out into the dam forebay and continue upstream migration (Mark Johnston, YN Fisheries, pers. comm.). The effectiveness of this modification will be monitored during the Phase 3 releases at Roza Dam.

Lamprey Passage Structure

Dams with low passage rates and localized lamprey holding areas are prime candidates for lamprey passage structures (LPS) (Moser et al. 2006, Moser et al. 2011). Specific locations of congregating lampreys were not found at Sunnyside or Wapato dams, so there are no obvious places to site a LPS. At Sunnyside Dam, however, the majority of the lampreys searched around the center island before entering and passing in that ladder, indicating that the downstream end of the island may be a suitable location for a LPS. The structure could be designed as a simple ramp with a rest box that returns the lamprey to the fish ladder (Figure 25) or as a larger system that returns the lamprey to the river upstream of the dam (Figure 26).

Figure 25. Photograph of the center fishway at Sunnyside Dam with concept drawing of LPS that returns lamprey into the fish ladder (J. Simonson, Fishhead Technology and Mark Nelson USFWS).

Figure 26. Photograph of center fishway at Sunnyside Dam with concept drawing of LPS that returns lamprey to river upstream of dam instead of into fish ladder as shown in Figure 25 (J. Simonson, Fishhead Technology).

Spawning

Spawning areas of Pacific lamprey in the Yakima River basin have not yet been definitively identified. No entries into Ahtanum Creek (a short distance upstream of Wapato Dam) were detected despite the availability of likely spawning areas and the presence of larval Pacific lamprey and western brook lamprey *Lampetra richardsoni* (Reid 2012; Patrick Luke, Yakama Nation, pers. comm.). During Phase 2, some tagged lampreys moved upstream as far as rkm 53 in the Naches River before overwintering. They moved back downstream in the Naches River varying distances during the following summer- behavior consistent with probable spawning-related movements that were noted during a telemetry study in the John Day River (Bayer et al. 2000). However, no tagged lamprey have been documented spawning in the Yakima River basin.

Acknowledgments

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

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Assessment of Juvenile/Larval Lamprey Entrainment in Irrigation Diversions and Canals within the Yakima Subbasin

Yakama Nation FRMP, Pacific Lamprey Project

January 15, 2014

Cover Photo: Exposed and dried ammocoete habitat (fine sediment with organic matter) within the Roza Dam reservoir on October 25, 2013 – looking downstream towards Roza Dam (left) and Roza Diversion (right). Dewatering at Roza Diversion not only affects the diversion itself, but also the reservoir area directly upstream of the dam. Surveys have not been conducted to date in this area for larval lamprey salvage.

Introduction:

The decline of Pacific Lamprey within the Columbia River Basin is well documented, with research currently underway to explore all potential threats contributing to the decline of this valuable ecological and tribal resource. Among the many causes of decline, irrigation diversions may potentially be a major threat to the species as young larval lamprey are small enough to pass through fish screens that meet the NOAA Fisheries guidelines. Juvenile survey planning and sampling within Yakima River Subbasin irrigation canals were first initiated during the dewatering period in 2010 and are ongoing for 2011, 2012 and 2013. From these surveys we have found areas behind fish screens with considerable numbers of juvenile/larval lamprey, consisting primarily of Western Brook lamprey and limited numbers of Pacific lamprey in some of the sites. From this past work it is apparent that juvenile lamprey are entrained into irrigation ditches and can move over, around or through 3/32-inch screens that are designed to keep salmonids and other fishes out of the ditches.

In 2013, one of our primary goals was to evaluate the influence that existing fish screens have on lamprey dispersal (or lack thereof) within the irrigation diversion facilities. By monitoring the distribution of lamprey above and below fish screens in light of the fish screen types and mesh sizes, we attempted to evaluate whether certain types of fish screens can effectively reduce (if not prevent) lamprey passage into the canal systems compared to others. The Yakima River Subbasin contains many dozens of irrigation diversions within the system with a wide variety of fish screen types and sizes and can therefore serve as a "natural laboratory" to better understand larval/juvenile lamprey interaction with irrigation diversions.

Methods:

In pursuit of these goals, we surveyed dewatered irrigation diversions within the Yakima River Subbasin for larval/juvenile lamprey primarily from October 16 to December 4, 2013. The order of sampling was based on the scheduled dewatering date, and we coordinated closely with the Bureau of Reclamation and Washington Department of Fish and Wildlife to schedule the larval lamprey surveys. The number of days it takes from the beginning of dewatering till the site is shallow enough (<1 m) for fish survey varies from site to site. For small facilities, the site is typically ready for fish salvage in less than a day. In large facilities, this may take one week or more as additional measures (such as extra water pumps) are needed to dewater adequately for fish surveys. Diversions were surveyed as close as possible to the time period when the site first became ready for larval/juvenile lamprey surveys, as any delay in the survey could easily lead to more loss of lamprey from desiccation and/or predation. Larval lamprey typically rear in the channel margins in fine sediment, so it is important to survey for them promptly as the fine sediment continues to dry up (even if the diversion itself is still deep and full of water). Hence, the degree to which fine substrate heaps are drying up is another important criterion to keep in mind when planning for larval lamprey surveys. When multiple diversions were dewatered at the same time, they were prioritized by their entrainment potential; in general, small diversions with less fine sediment deposition were placed at a lower priority than large diversions with more fine sediment deposition. Each diversion was separated into four locations as shown and described below (Table 1 and Figure 1):

Table 1. Definition/Description for the four locations identified within each diversion visited/surveyed

Locations	Definition/Description
Above Screens Canal	[Upstream of fish screens] The location starts at the head gate, downstream to the trash racks, if present, or the initial change in canal configuration (widening or narrowing) where it transitions into the "Above Screen" area.
Above Screens	[Upstream of fish screens] The location starts at the end of the "Above Screens Canal" area (see above), downstream to the fish bypass inlet.
Below Screens	[Downstream of fish screens] The location starts at the fish screens, downstream to the initial change in canal configuration (narrowing or widening) where it transitions into the "Below Screens Canal" area.
Below Screens Canal	[Downstream of fish screens] The location starts at the end of the "Below Screens" area (see above), downstream.

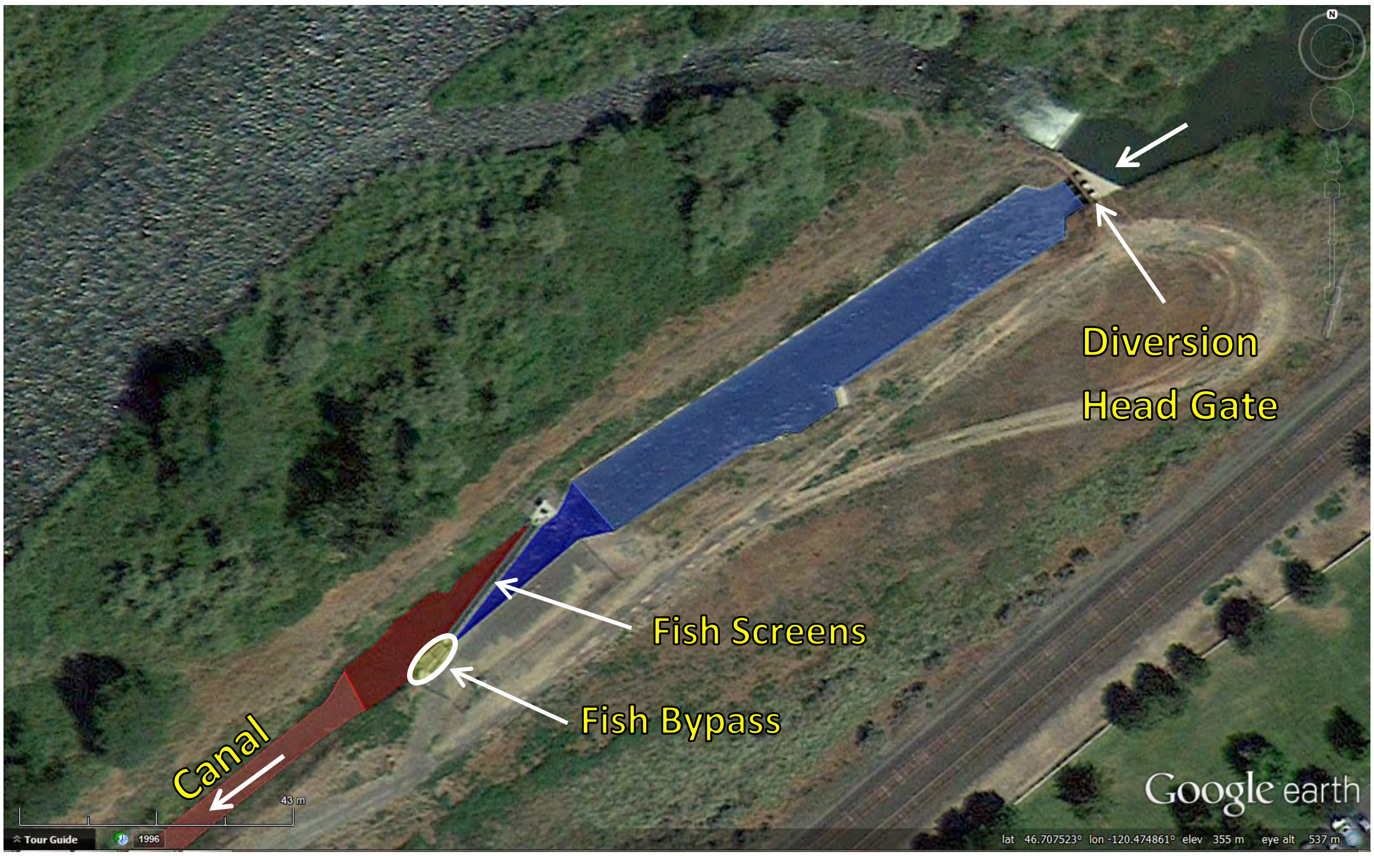


Figure 1: Overview of Selah-Moxee diversion (Yakima River) displaying defined locations for each diversion: direction of flow to the head gate, above screens canal (light blue), above screens (dark blue), fish screens, fish bypass, below screens (dark red), below screens canal (light red), and the outlet flow.

Screen types (drum or vertical), horizontal length of individual screens, screen mesh size ($^{3}/_{32}$" or $^{1}/_{8}$") and type (wire mesh or perforated), and number of individual screens were recorded at each of the visited diversion sites. The five screen types, with their respective mesh sizes and types are shown below (Figures 2, 3, 4, 5, and 6):

Taneum Diversion, Taneum Creek — New Cascade Diversion, Yakima River

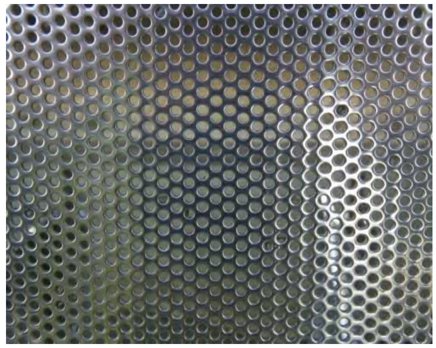
Figure 2. Representative photos of drum screen (3/32" wire cloth mesh)

Wapato Diversion, Yakima River — Town Diversion, Yakima River

Figure 3. Representative photos of drum screen with 1/8" wire cloth mesh

Taylor Diversion, Yakima River — Lower WIP Diversion, Ahtanum Creek

Figure 4. Representative photos of drum screen with 3/32" perforated mesh



Fruitvale Diversion, Cowichee Creek   Fruitvale Diversion, Cowichee Creek

Figure 5. Representative photos of vertical screen with 3/32" perforated mesh

Naches-Selah Diversion, Naches River   Naches-Selah Diversion, Naches River

Figure 6. Representative photos of vertical screen with 1.75 mm vertical mesh

We classified and mapped three types of habitat area for each visited diversion: 1) observed habitat area, 2) survey habitat area, and 3) high density habitat areas (Table 2). Taylor, Old Union, and Lower WIP diversions were not surveyed due to inadequate timing of the visits (Figure 7).

Table 2. Definition and description for the three types of habitat area measured.

Habitat Area	Definition/Description
Observed Habitat Area	All Type I / II habitat that was observed at a survey site, tallied separately by survey locations.
Survey Habitat Area	All Type I / II habitat that was surveyed, tallied separately by survey locations.
High Density Habitat Area	Surveyed area that had a noticeably higher density of larvae than other areas surveyed within that location. In a few cases, this is the only area where larvae were found. There are areas marked as high density for only ammocoetes, only transformers, and both ammocoetes and transformers.

Figure 7. A representative photo showing observed Type I and II habitat area (grey + all colors), survey habitat area (green) and a typical high density habitat area for larvae (pink) and transformers (yellow) from Taneum Diversion.

Larval lamprey surveys, aimed at capturing both ammocoetes and juvenile (transformed with eyes), were conducted at 18 of the 21 diversions visited after canal dewatering. Type I / II habitat (preferred and acceptable larval lamprey habitat, respectively) was mapped out on printed Google Earth images. The definition for Type I and Type II habitat is illustrated by Slade et al. (2003) in "Techniques and methods for estimating abundance of larval and metamorphosed sea lampreys in Great Lakes tributaries, 1995-2001":

> *"Type I habitat is located primarily in depositional zones preferred by the filter-feeding larvae, and consists primarily of a mixture of sand and fine organic matter. Type II habitat often consists of shifting sand that may contain some gravel, is utilized by some larvae for burrowing, but it is inhabited at much lower densities."*

A backpack electrofisher, Abp-2 Electrofisher, specially designed for the sampling of larval lamprey, was used to survey available habitat. In one instance, at Congdon Diversion, a Smith Root electrofisher was used due to failure of our usual equipment. A person with a net was also present and scouted for larval lamprey, netting any larvae that were missed. Specific survey location in each diversion (above screens canal, above screens, below screens, and below screens canal) was determined based on the presence or absence of available, wetted Type I / II habitat. Even if all habitat was dry, it was mapped and recorded. Not all canal habitat was surveyed or observed; if we observed habitat within close proximity to the fish screens area, we mapped it, and if the opportunity presented itself with wetted habitat and easy accessibility, a portion of the canal was surveyed. Our survey area was constrained mainly by site accessibility and time. The focus of each survey was on prime Type I habitat, usually occurring directly in front of the fish screens in accumulated organic debris, or in areas where the accumulation of fine sediment was greatest, yet still covered in water. Areas with abundant vegetation, mostly milfoil, were surveyed with preference towards patches of sediment that were not covered in vegetation to increase visibility of escaping larvae.

Missed lamprey were numerated, and, if possible, an estimated total length (in 10 mm increments) was recorded for each missed fish. If missed lamprey numbers were too numerous to keep track of (>10 in general), we estimated the number of missed larvae and classified them in an estimated general size class of small (0-50mm), medium (51-90mm), and large (91+ mm) (herein called "SML" percentage). When estimated length was not available for all missed lamprey, we used these percentages to calculate the number of missed lamprey per size class for each location within a diversion site.

At each surveyed diversion, all captured larvae were placed in a 5-gallon bucket, or large cooler. They were grouped, counted, and measured separately based on the site and location. The length, life stage and species of lamprey (if of identifiable length > 50 mm) were recorded. If the number of captured lamprey was less than 50, all fish were measured. However, to preserve survey efficiency, if the number captured was equal to or greater than 50, a subsample was taken and measured. Thirty random larvae were extracted from the captured group, measured and recorded. This subsample gave us a size class distribution for the overall number of captured lamprey. In addition to the 30 random fish, we also measured the three largest and smallest larvae to ensure the entire range of size classes was documented for each location.

When the lengths of all missed and captured fish were measured, we used a combination of both samples to represent the overall size classes for the location. However, when a large number of fish were captured (>50) and/or missed (>10), we only used the length measurements from the captured subsample to represent the overall size classes. In these cases, we compared the SML percentage of the captured and missed fish to ensure there is no substantial difference in the size classes between the two groups. If the percentage difference of the two groups was over 25% for any of the three size classes (small, medium or large), we incorporated the missed fish using the SML percentage in an attempt to better represent the overall size classes available within each location in the Appendix "Diversion Summaries."

Mapped habitat was entered and processed in Google Earth 7. Polygons covering observed habitat, survey habitat area, and high density habitat areas for both ammocoetes and transformers were created for each surveyed diversion. The observed habitat and surveyed area (m^2) was calculated via the Earth Point website (http://www.earthpoint.us/shapes.aspx). Because the calculated surface area of habitat does not account for the three dimensional quality of the larval habitat, we also made a crude estimate of the fine sediment volume for each location we surveyed. An estimated volume (m^3) of fine sediment was calculated by multiplying the observed habitat area (m^2) with one third of the maximum fine sediment depth (cm) measured for that location (geometric formula for a cone or pyramid).

Results:

Overview

A total of 21 irrigation diversions were visited in the Yakima River Subbasin, and fish screen measurements were taken at all of these sites. We surveyed three types of drum screens [3/32" wire mesh (8 sites), 1/8" wire mesh (4 sites), 3/32" perforated plate (2 sites)] and two types of vertical screens [3/32" perforated plate (3 sites) and 1.75mm vertical bar (3 sites)] (Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6). We conducted larval/juvenile lamprey sampling in 18 of these sites. The two diversion sites with 3/32" perforated drum screens [Lower WIP (Ahtanum Cr.) and Tayler (Yakima R.)] were not sampled for lamprey due to inadequate timing of the visits (arrived either too early or too late).

The total number of observed lamprey (combined totals of captured and missed larval/juvenile lamprey) from the 18 surveyed sites was 1,639 above the fish screens and 1739 below the fish screens, totaling 3,378. We captured 52.2% of these fish while the rest escaped our nets and were only observed. The Yakima River overall had the highest number of observed lamprey combined, and in particular, Wapato and Sunnyside diversions entrained the largest number of larval/juvenile lamprey (Figure 8). No lamprey were found in Kelly-Lowry (Naches R.) or Chandler Diversion (Yakima R.). The distribution of larvae above and below fish screens varied widely. In some sites larval lamprey were only captured below the screens (such as Naches-Selah, Bachelor-Hatton, and Upper WIP diversions), whereas in other sites the majority of larvae were captured below the screens (such as Sunnyside, Roza, and Fruitvale diversions).

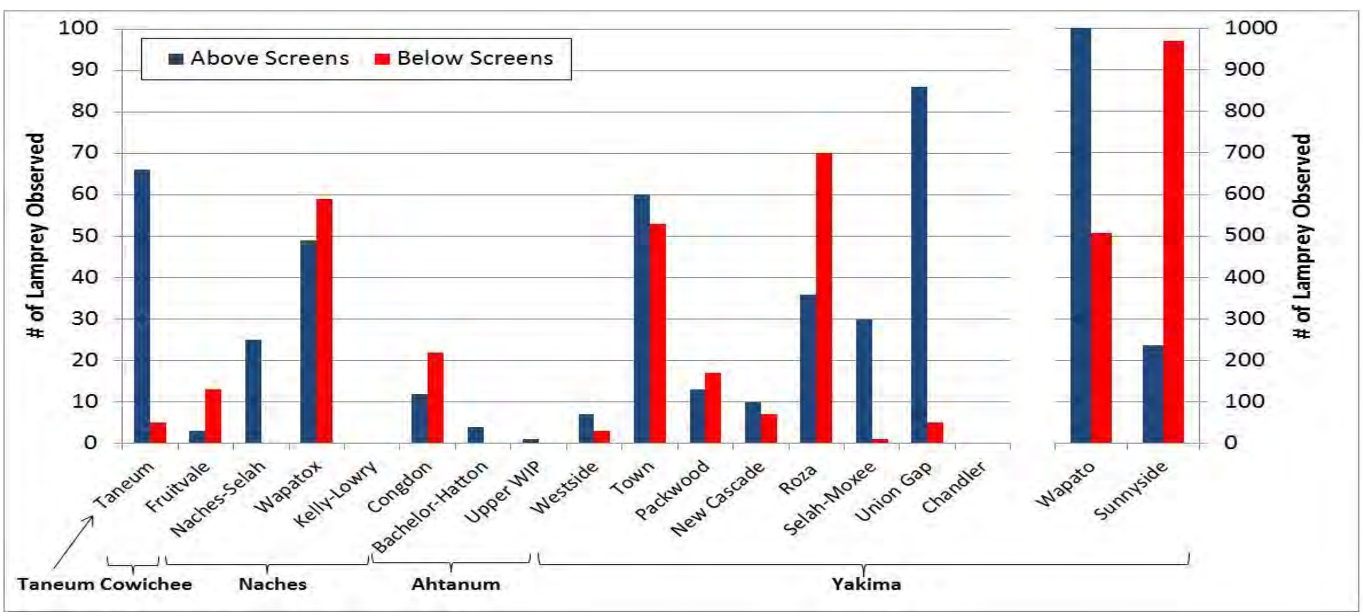


Figure 8. Total number of lamprey observed above and below fish screens for each diversion surveyed in the Yakima River Subbasin. The diversions are ordered from upstream to downstream (left to right) within their respective watersheds; bar graphs for Wapato and Sunnyside diversions, however, were placed all the way to the right next to a secondary y-axis due to their substantially higher values.

High density areas for ammocoetes were primarily found in small puddles of water over Type I habitat, wetted edges of fine sediment piles, or areas with a large amount of accumulated fine organic matter mixed with fine sediment (Figure 7). Above screens, these areas were generally located against the concrete wall along the banks directly above the fish screens, but varied considerably depending on site conditions. Below screens, high density areas again varied, but were most frequently found along the wall directly downstream of the screen or at the start of the canal further downstream. In general, areas with a higher amount of Type I habitat yielded a greater number of lamprey. See Appendix "Diversion Summaries" for detailed maps from each site.

Of the 3378 lamprey observed, 67 of them (2.0%) were transformers. Of the captured lamprey, 2.5% (44) were transformers. All the transformers we examined were Western brook lamprey (with darkly pigmented caudal ridge and a translucent tail). The majority of these transformers were found upstream of fish screens except for Packwood Diversion and a few each from Wapato and Sunnyside diversions (Figure 9). Wapato and Sunnyside diversions had the highest number of transformed lamprey overall. Except for Taeum Diversion on Taneum Creek, all transformers were found in diversions along mainstem Yakima River. Transformers were commonly found in high densities in areas among coarse organic matter, such as wood, that collected at the base of the drum screens. Transformers were also detected in high densities among other ammocoetes, primarily in areas against or near the base of drum screens above and below screen areas. See Appendix "Diversion Summaries" for detailed maps from each site.

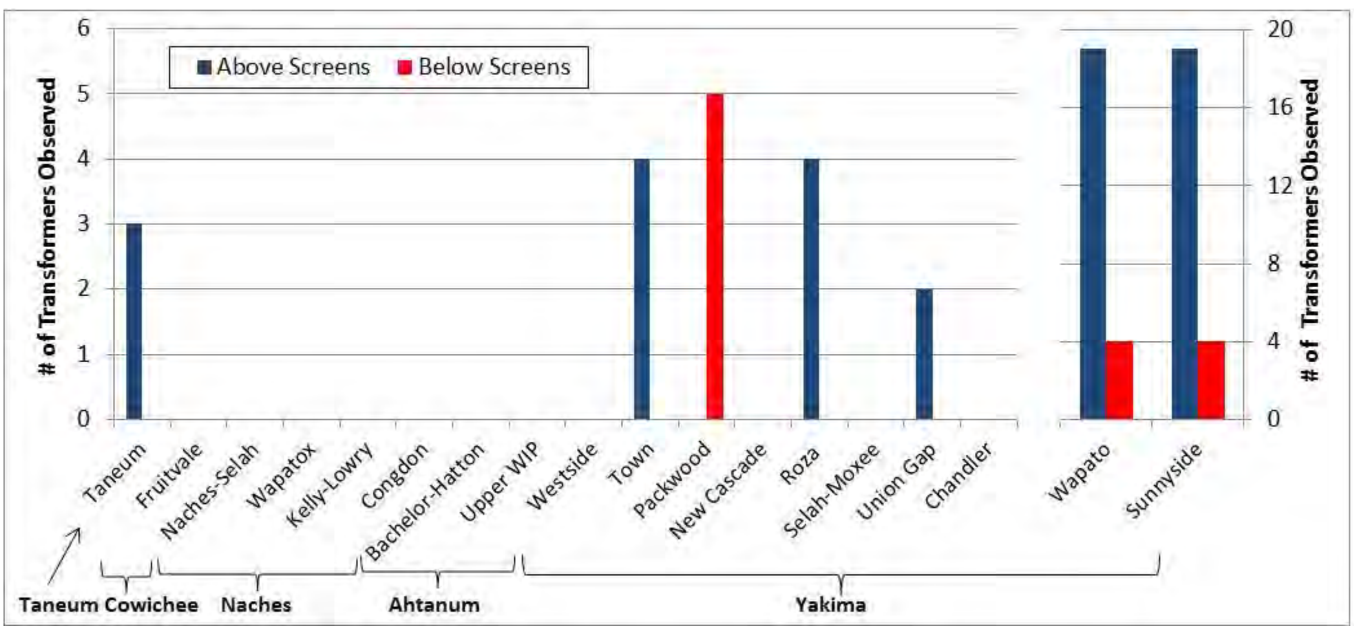


Figure 9. Total number of transformed lamprey (Western brook lamprey) observed above and below fish screens for each diversion surveyed in the Yakima River Subbasin. The diversions are ordered from upstream to downstream (left to right) within their respective watersheds; bar graphs for Wapato and Sunnyside diversions, however, were placed all the way to the right next to a secondary y-axis due to their substantially higher values.

<u>Habitat Area</u>

The total amount of observed larval habitat area (wetted and dry) from the 18 surveyed sites was 13,729 m^2 above fish screens and 18,372 m^2 below fish screens, totaling 32,102 m^2. Diversions along the mainstem Yakima River had considerably larger amounts of larval habitat compared to Naches and other tributaries of the Yakima River (Figure 10). The amount of habitat area within diversions tended to increase as you moved downstream, with Chandler Diversion (one of the lowermost diversion in the river) having the largest amount of larval habitat. The distribution of habitat area above and below fish screens varied widely. In some sites the majority of larval habitat were found upstream of the fish screens (such as in Westside, Packwood, Selah-Moxee, and Union Gap diversions) whereas in other sites a larger portion was found downstream of the fish screens (such as Roza and Sunnyside).

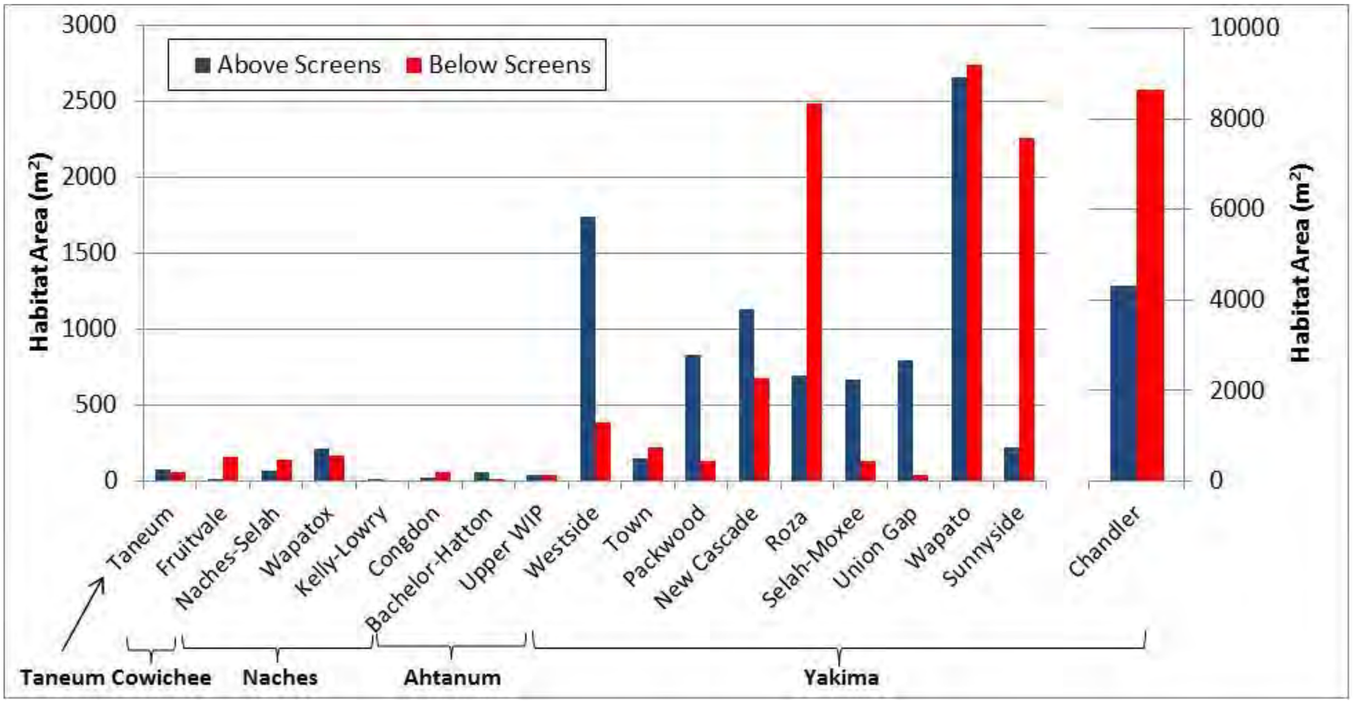


Figure 10. Total amount of observed larval habitat area above and below fish screens for each diversion surveyed in the Yakima River Subbasin. The diversions are ordered from upstream to downstream (left to right) within their respective watersheds; bar graphs for Chandler diversion, however, was placed all the way to the right next to a secondary y-axis due to their substantially higher values.

<u>Estimated Total Number of Lamprey</u>

From the 2012-2013 sampling in Wapato Diversion, we observed how the number of larvae decreased over time even when we released all fish back to where they were captured, indicating that over time the total number of larvae decreases one way or another due to desiccation, predation, and/or outmigration. In addition, electrofishing capture efficiency can vary widely, and especially in cold water conditions we may well be capturing less than half of what actually reside within the dewatered habitat. As a result, larvae we capture during electrofishing surveys in the diversions at one point in time are likely only a small subset of the total number of larvae that resided within the diversion. Based on location-specific sampling density and a crude conservative assessment of available habitat area from each location, we surmise that the total number of entrained lamprey within the Yakima River Subbasin may be as high as 14,615 (6714 lamprey above screens and 7902 lamprey below screens). This calculation suggests that we observed 23.1% of all the larval/juvenile lamprey within the diversions we visited. Again, the Yakima River overall had the highest estimated number of observed lamprey combined, and in particular, Wapato and Sunnyside diversions contained the largest estimated number of larval/juvenile lamprey (Figure 11).

For most of the diversions, the general allocation of larvae above and below screens remained the same for observed lamprey and estimated number of larvae. However, the allocation ratio between above and below the screens reversed for some sites (such as Roza, Packwood, and Wapatox diversions), and the estimated number of larvae are higher above the screens compared to below the screens for these sites (Figures 8 and 11).

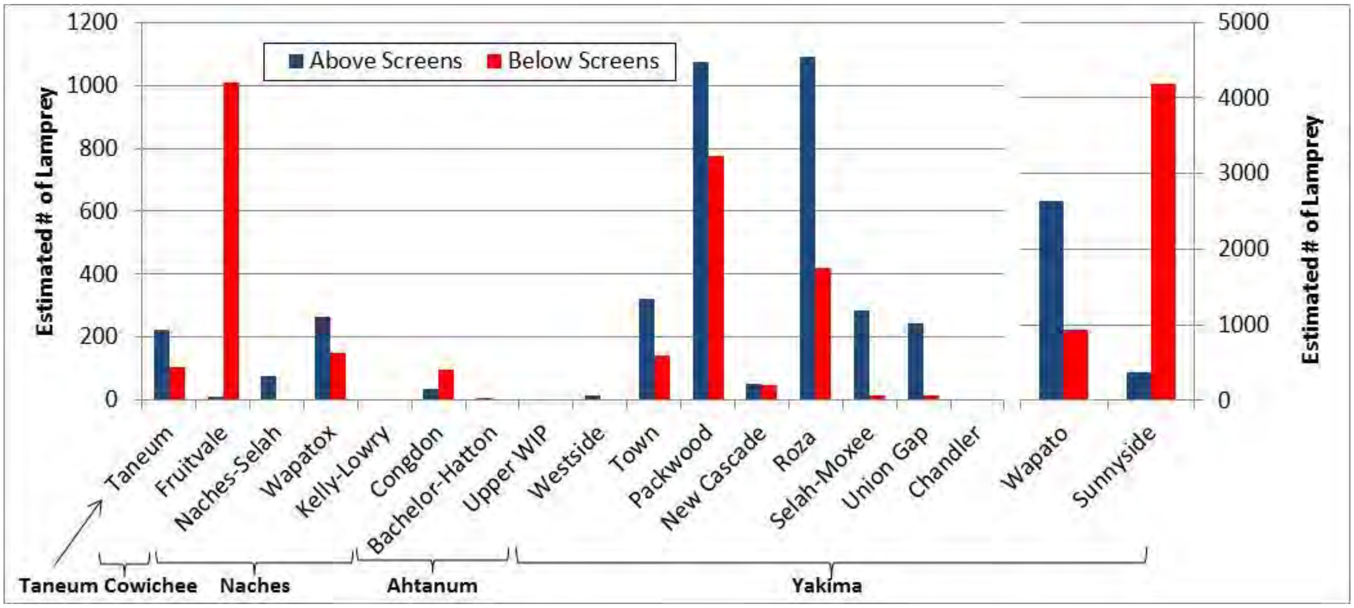


Figure 11. Estimated number of lamprey above and below fish screens for each diversion surveyed in the Yakima River Subbasin. The diversions are ordered from upstream to downstream (left to right) within their respective watersheds; bar graphs for Wapato and Sunnyside diversions, however, were placed all the way to the right next to a secondary y-axis due to their substantially higher values.

The estimated number of lamprey was highest 1) below the fish screens, followed by 2) above the screens, 3) in the canal above the screens and 4) in the canal below the screens (Figure 12). However, lamprey density had almost an inverse relationship with the estimated total counts; the highest density was found in the canal below the screens which had the lowest amount of estimated number of larvae whereas we found the lowest density below the fish screens which had the highest number of estimated larvae.

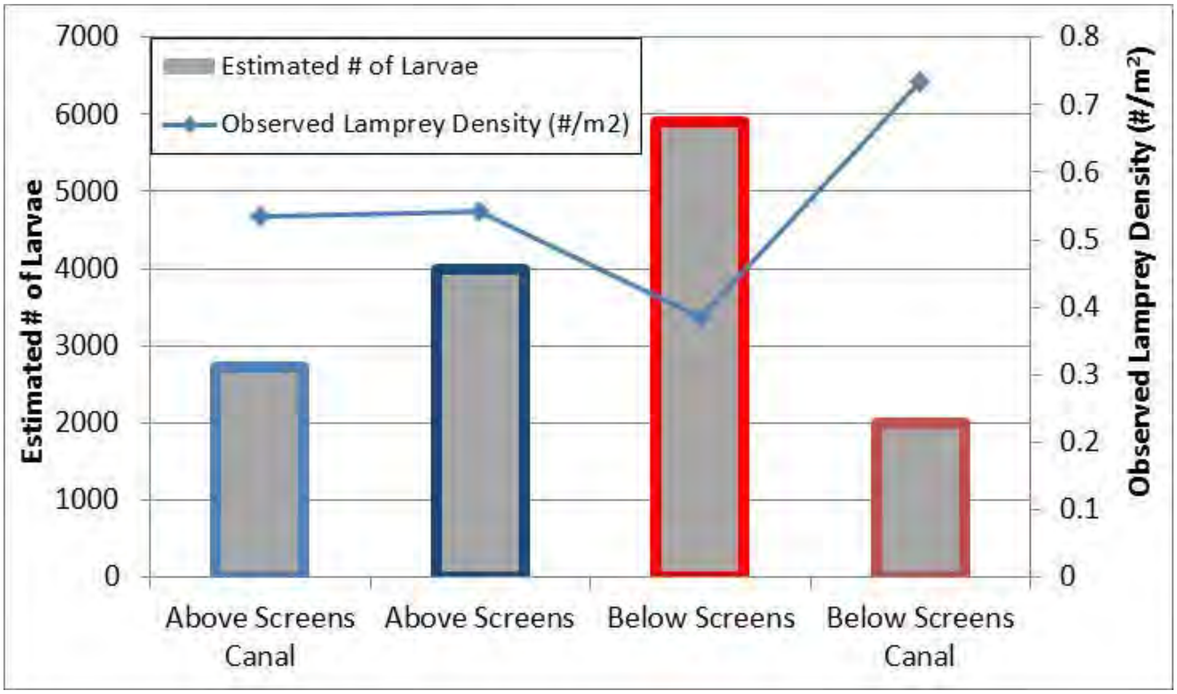


Figure 12. Estimates of the total number of entrained lampreys within the Yakima River Subbasin by location based on site specific habitat availability (primary y-axis) and density of observed lamprey (secondary y-axis). "Canal" refers to the habitat away from the fish screens.

Matched Pair Analysis

Because there are other variables that can strongly influence how many lamprey we may find at each site (such as head gate configuration, proximity to natural rearing habitat, etc.), we conducted a matched pair analysis to compare 1) the observed lamprey numbers and 2) habitat availability between the area above the screens and area below the screens within each site. We used the ratio to compare the two values within each site, and we excluded the canal habitat further away from the fish screens. We only compared sites that were surveyed both above and below the fish screens area that had at least one fish captured in both locations. The relationship between estimated habitat area and number of observed lamprey was very strong ($r^2 = 0.67$) and the slope was 1.1 indicating that a certain amount of increase in the ratio of habitat area will result in roughly the equal amount of increase in the ratio of observed lamprey numbers (Figure 13). The intercept for the above screens area was 0.262 higher than that for the below screens area, suggesting that the ratio of observed lamprey numbers were on average higher by 0.262 in above screens area compared to below screens area given an equal ratio of habitat area. We also compared the ratio of the observed lamprey numbers and that of the estimated fine sediment volume (Figure 14). The relationship was even stronger ($r^2 = 0.69$) compared to the habitat area comparison, and the difference in intercept was smaller (0.119), suggesting that the ratio of observed lamprey numbers were on average only higher by 0.119 in the above screens area compared to below screens area given an equal ratio of fine sediment volume. Taneum Diversion had a low ratio of observed lamprey numbers below the screens, whereas Wapatox Diversion had a high ratio of observed lamprey numbers below the screens considering the volume of fine sediment available at these sites. This is most likely due to the amount of wetted habitat available for the survey; Taneum Diversion had only 4.7% of the overall habitat available for survey below screens (compared to 29.3% above screens) whereas Wapatox Diversion had 39.8% of the overall habitat available for survey below screens (compared to 18.4% below screens).

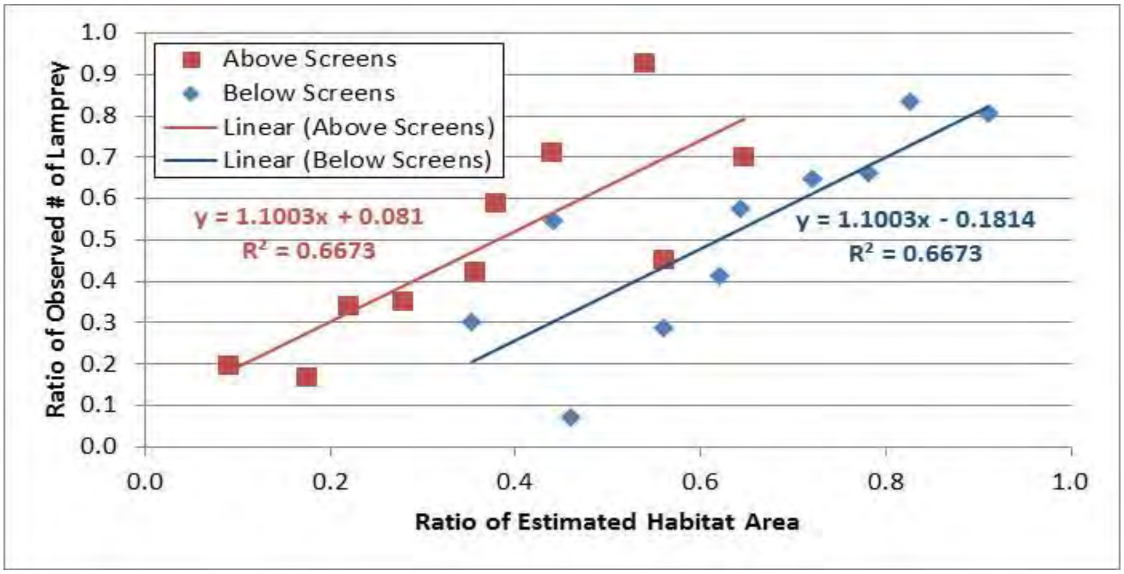


Figure 13. Matched pair analysis of the ratios for estimated habitat area (x-axis) and observed number of lamprey (y-axis) between above and below screens areas. The trend line equation and r square values are also shown on the graph (using the same color codes). The trend line slopes for above screens area and below screens area are identical due to the fact that they are paired.

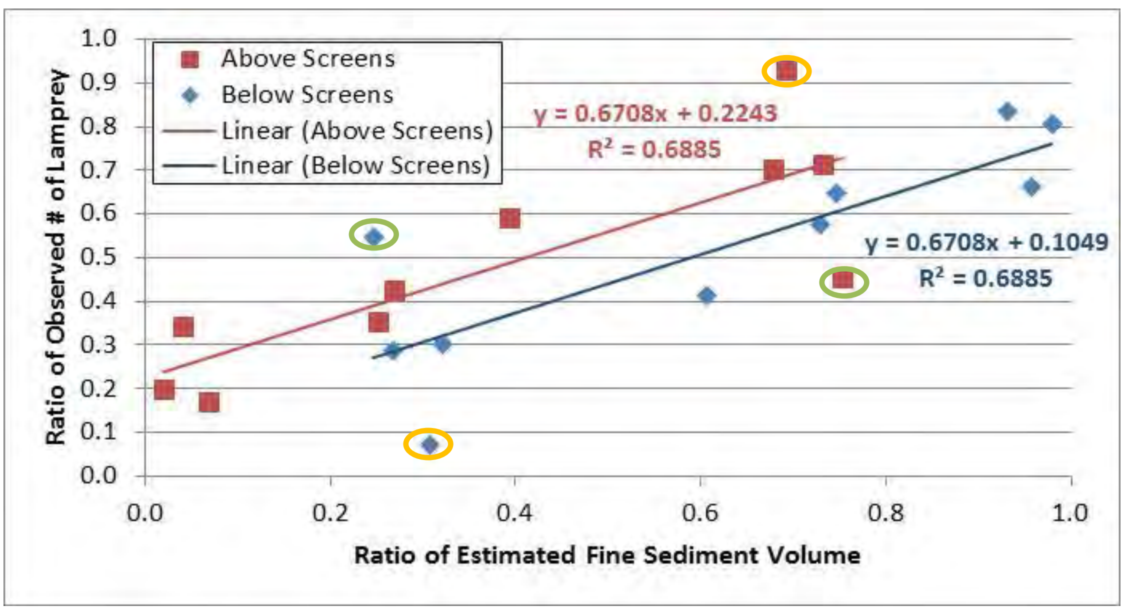


Figure 14. Matched pair analysis of the ratios for estimated fine sediment volume (x-axis) and observed number of lamprey (y-axis) between above and below screens areas. The trend line equation and r square values are also shown on the graph (using the same color codes). The trend line slopes for above screens area and below screens area are identical due to the fact that they are paired. The orange circles highlight the paired ratios from Taneum Diversion and the green circles highlight the paired ratios from Wapatox Diversion, which appear as outliers compared to the rest of the group.

<u>Size Class Analysis</u>

A total of 813 larvae were sampled for lengths, including individually numerated missed fish and subsamples of captured lamprey. When we compare size classes of lamprey above and below screens, we see some clear differences in upstream and downstream groups (Figure 15). There is a distinct spike in the proportion of small size class larvae (10-60 mm) in the “Below Screens” group, whereas the large size class larvae (>60 mm but especially >90 mm) are much more prevalent in the “Above Screens” group. Within the canal area (further upstream and downstream from the fish screens area), we did not observe any notable difference in the size classes of lamprey between upstream and downstream areas, indicating that lamprey in the canal further downstream from the fish screens may be rearing in the canal for multiple years.

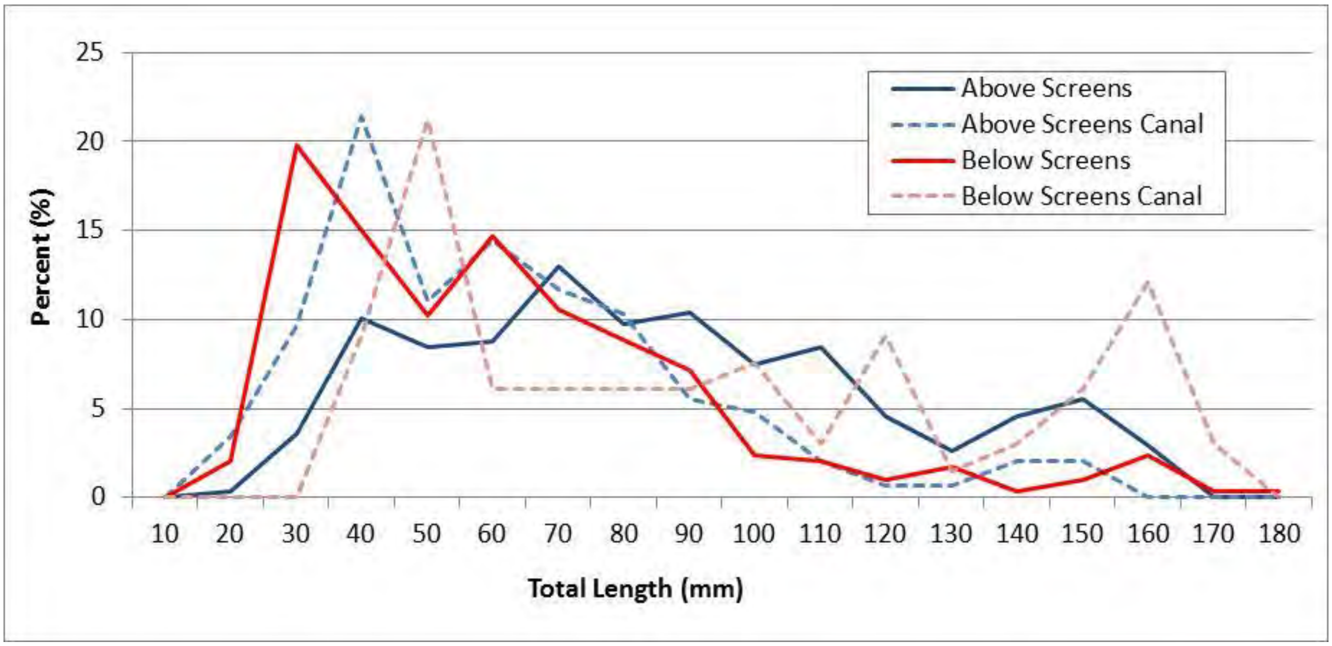


Figure 15. Percent histogram of lamprey total length for all sampled lamprey grouped by capture locations.

Analysis of lamprey size classes above and below fish screens were also conducted specifically for the four types of screens we surveyed: 1) drum screen 3/32” wire cloth mesh, 2) drum screen 1/8” wire cloth mesh, 3) vertical screen 1.75 mm vertical mesh, 4) vertical screen 3/32” perforated mesh (Figure 16). Larval lamprey were distinctively smaller below the screens compared to above the screens at sites with 3/32” wire cloth mesh drum screens and 1.75 mm vertical mesh vertical screens (A and C in Figure 16). Larvae 20-30 mm in size were considerably more prevalent below the screens for 3/32” wire cloth mesh drum screens and larvae 30-40 mm in size were noticeably more common below the screens for 1.75 mm vertical mesh vertical screens. The difference in size classes above and below screens was small and subtle at sites with 1/8” wire cloth mesh drum screens with slightly higher proportion of larvae being in the range of 30-90 mm below the screens (B in Figure 16). At sites with 3/32” perforated mesh vertical screens, larval/juvenile lamprey were actually larger downstream of the fish screens, which is most likely influenced by larvae that rear multiple years in the canal area (D in Figure 16).

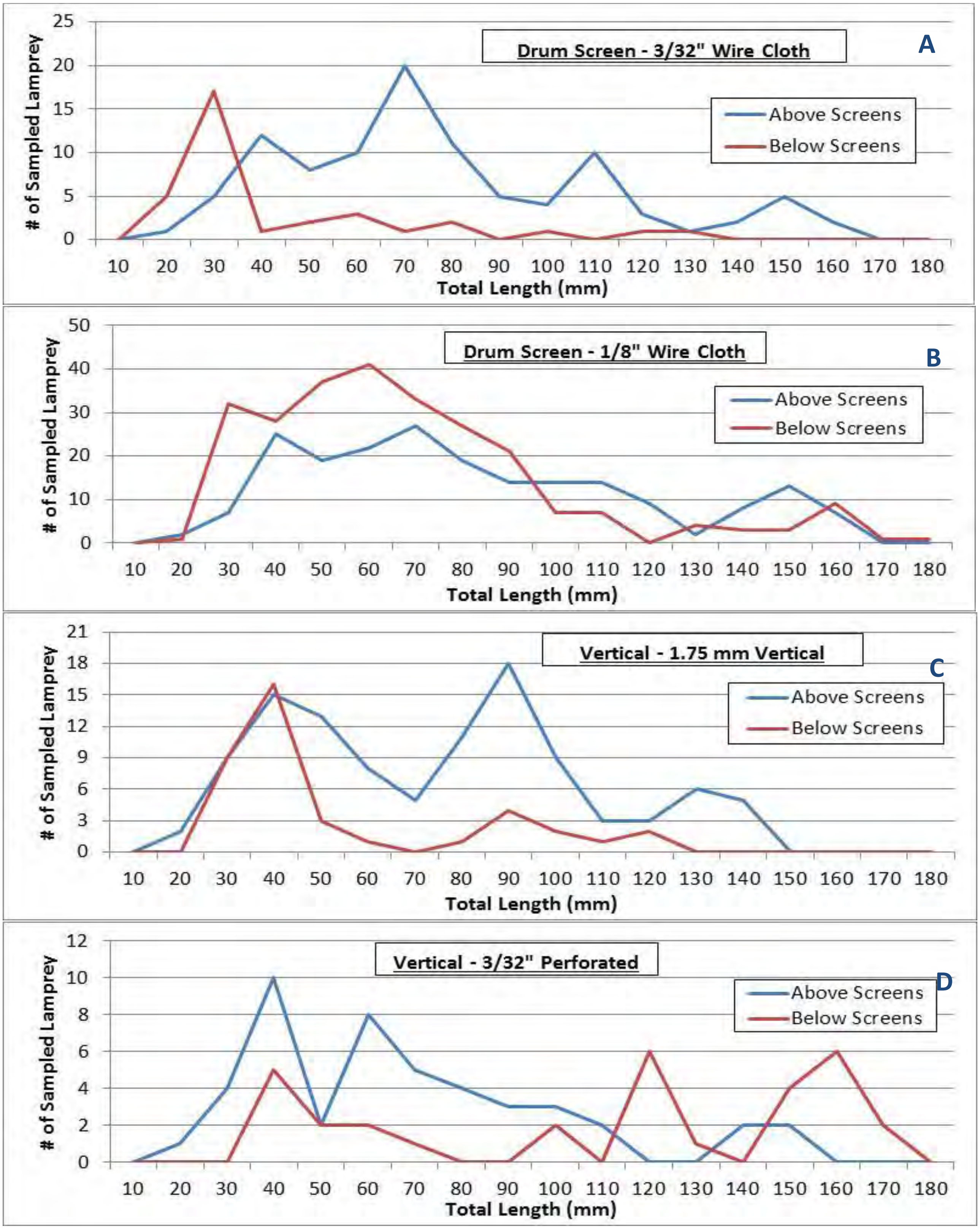


Figure 16. Frequency histograms of lamprey total length for all sampled lamprey grouped by location (above and below screens) for (A) 3/32" mesh drum screen, (B) 1/8" mesh drum screen, (C) vertical mesh vertical screen, and (D) perforated mesh vertical screen sites.

Based on the size classes of larval/juvenile lamprey rearing below the fish screens, smaller mesh screens appeared to make a difference in reducing the larger larvae from moving through the screens (Figures 16 and 17). Drum screens with 3/32" wire cloth mesh performed the best in that respect, followed closely by vertical screens with 1.75 mm vertical mesh. Vertical screens with 3/32" perforated screens did reduce medium size larvae from passing the screens, but larger larvae were also present, potentially indicating larvae rearing for multiple years in the canal. Finally, drum screens with 1/8" wire cloth mesh performed the worst with no apparent decrease in medium size larvae up to 90 mm.

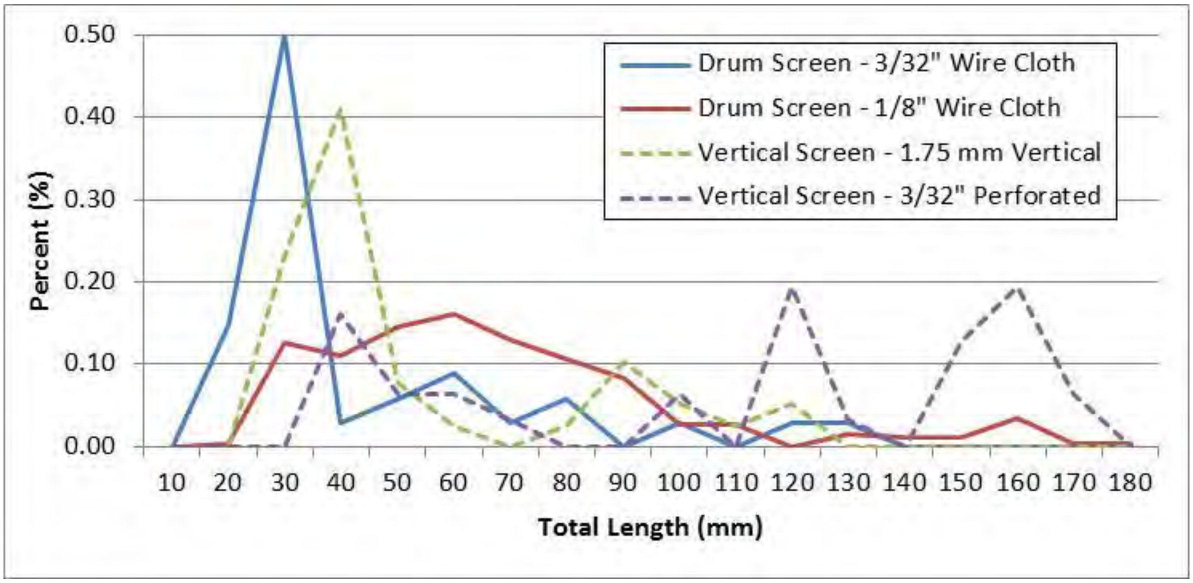


Figure 17. Percent histogram of lamprey total length for all sampled lamprey captured below the fish screens, grouped by screen type / mesh size.

<u>Summary:</u>

Mean maximum fine sediment depth was higher for the drum screen sites (3/32" and 1/8") compared to the vertical screen sites, although this may be influenced considerably more by the site conditions rather than the type of screen present (A in Figure 18). One thing to note is that on average the sediment depth is deeper below the screens in 1/8" drum screen sites, slightly shallower below the screens in 3/32" drum screen sites, and considerably shallower below the screens in vertical screen sites (vertical and perforated) compared to above the screens. Estimated habitat area was higher below the screens compared to above the screens for all sites (B in Figure 18). The overall amount of habitat area were much higher in drum screen sites compared to vertical screen sites, which is likely influenced heavily by the site conditions rather than the type of screen present. The density of observed larval/juvenile lamprey were consistently higher above the screens than below the screens for all four major screen types (C in Figure 18), and this was in sharp contrast with the trend observed in the estimated habitat area graph. Although density was slightly higher below the screens compared to above the screens in 1/8" mesh drum screen sites, the difference was considerably less compared to the three other groups of sites. The overall estimated number of lamprey was higher below the screens for 1/8" mesh drum screen sites and perforated mesh vertical screen sites, whereas a larger number of lamprey were estimated above the screens for 3/32" mesh drum screen sites and vertical mesh vertical screen sites (D in Figure 18). Drum screen sites with 1/8" mesh provided the highest estimated contribution of entrained lamprey, followed by perforated mesh vertical screen sites (much of which stems from canal habitat).

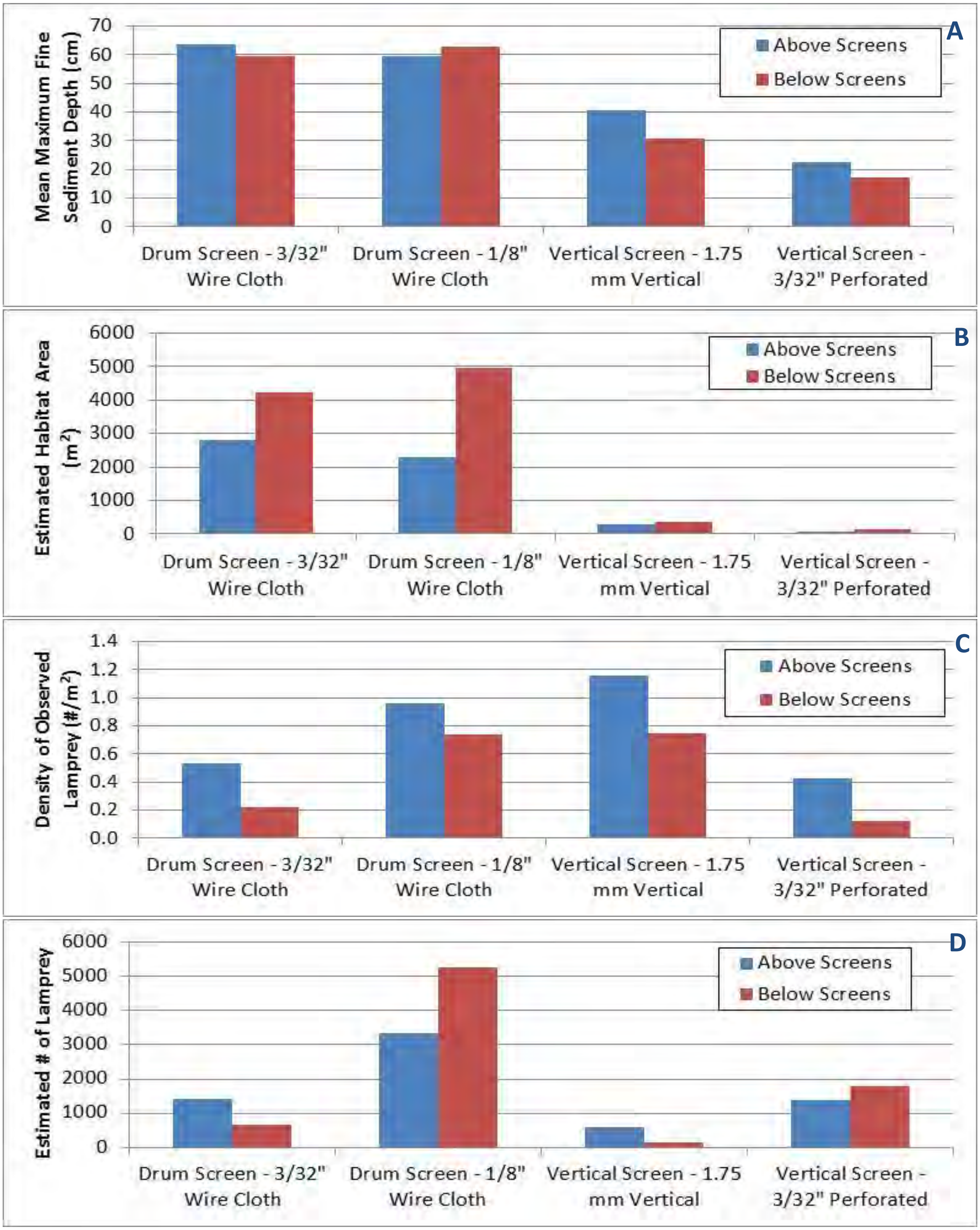


Figure 18. Bar graphs displaying (A) mean maximum fine sediment depth, (B) total estimated habitat area, (C) density of observed lamprey, and (D) total estimated number of lamprey above and below screens by the screen type / mesh size. Graph A, B, and C exclude canal habitat, whereas Graph D contains canal data.

Discussion:

Based on all the above data and information, we can make the following general conclusions:

1. Irrigation diversions are serving as refuge habitat for larval/juvenile lamprey. The amount of Type I/II habitat available within the diversion system is enormous (~15,000 m^2 just directly above and below the fish screens, and a substantially larger sum available in the canal further upstream and downstream from the fish screens) (Figure 10). Diversions typically provide steady constant flow with an abundance of organic matter and fine sediment deposition, serving as ideal habitat for larval lamprey. Although this in itself is beneficial for the larval/juvenile lamprey, the problem is related to the dewatering in October, which forces the majority of larval/juvenile lamprey to move out of their existing preferred habitat.
2. The amount of habitat available is strongly linked to the number of larval/juvenile lamprey present. If there is a large amount of fine sediment habitat available above the fish screens (as in Union Gap Diversion), more larval lamprey will be found there (Figures 8, 10, and 11). On the other hand, if there is a large amount of habitat available below the fish screens (as in Sunnyside Diversion), more larval lamprey will distribute themselves down there. Hypothetically speaking, larval lamprey may be drifting downstream along with the fine sediment, and while in transit, they are constantly seeking fine sediment depository areas to burrow into. If the majority of fine sediment is moving through the fish screens, it is likely that larvae are also moving in the same direction. Furthermore, in addition to the surface area, the volume of fine sediment within the available habitat may be effective in predicting the abundance of larval/juvenile lamprey, which takes into account the three dimensional quality of the habitat (Figures 13 and 14).
3. Mesh size does matter. Although even the smallest mesh size (such as 1.75 mm) cannot effectively prevent small larval lamprey from passing through the screens, the diversion sites with finer mesh screens appeared to be more effective in reducing at least some of the medium sized larvae from moving downstream (Figures 15, 16, and 17). No existing screens can completely prevent lamprey passage as the smallest sized larval lamprey can be as small as 6 mm x 0.6 mm; a 0.5 mm (500 micron) mesh, roughly 1/50" in size, would be required for that, which is neither practical nor feasible in the near future. However, by using the smallest mesh size (such as 3/32" and 1.75 mm), we found that many of the medium and large larval lamprey can be effectively deterred from moving past the fish screens. For larger juvenile, such as transformers, the majority were found upstream of the fish screens (Figure 9). In some instances, transformers were found downstream of fish screens, but these were most likely due to larvae spending multiple years downstream of the fish screens rather than passage.
4. Density of observed lamprey were higher above the screens than below the screens in all four types of sites we surveyed, suggesting that the screens are preventing some larval/juvenile lamprey from moving downstream (C in Figure 18). The density levels were reduced by 23.5% in 1/8" mesh drum screen sites, 58.8% in 3/32" mesh drum screen sites, 35.5% in 1.75 mm mesh vertical screen sites, and 70.8% (albeit based on a very small sample) in 3/32" mesh vertical screen sites. The density levels of lamprey may be an indicator for general abundance, although it may also be a product of the higher amount of habitat that is available below the screens. For example, the highest levels of density were found further downstream in the canal area, most likely due to the patchily distributed limited available habitat (Figure 12).

5. Artificial structures can be used to create fine sediment habitat for larval lamprey to burrow into. Based on survey observations, larval/juvenile lamprey were frequently found in fine sediment created around various types of structures ranging from bypass walls and ecology blocks to woody debris and used tires. In Town and Naches-Selah diversions, high densities of larvae were found directly above and below ecology blocks (Figure 19). Structures placed above the fish screens can be beneficial because it prevents lamprey from rearing directly in front of the fish screens and this may reduce lamprey-screen interaction and potentially entrainment. Alternatively, structures placed below the fish screens can be beneficial as they can capture fine sediment that would have otherwise traveled further down the canal, and this will likely entice lamprey to stay as well.

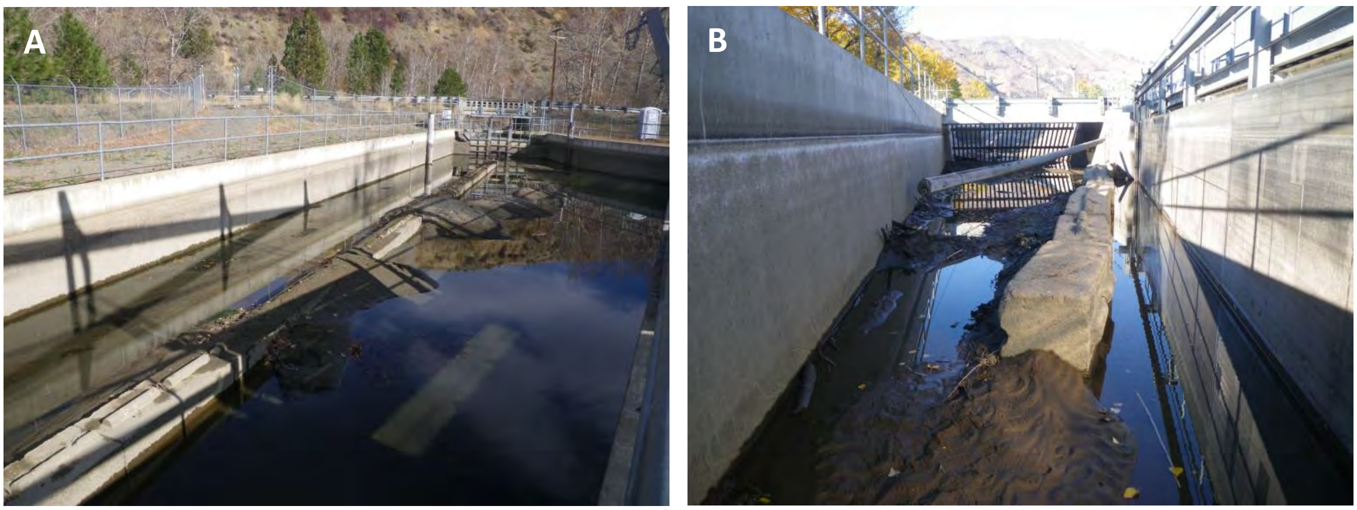


Figure 19. (A) Ecology blocks placed downstream of the drum screens at Town Diversion, effectively capturing much of the fine sediment that would have otherwise moved further down the canal. (B) Ecology blocks placed upstream of the vertical screens at Naches-Selah Diversion, preventing fine sediment to collect in front of the fish screens.

Appendix: Diversion Summaries

1. Chandler Diversion: Yakima River (rkm 74.3)

Location: The Chandler Diversion is located along side of the Prosser Salmon Hatchery in Prosser, WA.
Date(s) visited: October 24, 2013
Screen Type: Drum Screen - 3/32" Wire Cloth
Number of Screens: 23
Screen Length: 4 m
Temp: 12.5°C above / --°C below-canal
Life Stages (# of observed lamprey): No Lamprey Observed

Table 1a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	200	1801	110	0 (0)	0.00
Canal	Sand	100	2507	0	-	-

Table 1b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	-	1400	0	-	-
Canal	Sand	-	7236	0	-	-

Observations:

The area directly above the fish screens were surveyed on October 24, 2013, focusing on areas by the wetted channel margin among the exposed dry fine sediment. Not a single lamprey was captured or observed. There were some aquatic worms, which is usually a sign of potential larval lamprey presence. Despite the lack of lamprey found in the diversion, there was an abundance of highly suitable Type I habitat with plenty of organic matter mixed in. To test whether the fine sediment contains contaminants that may limit larval lamprey survival, we brought some fine sediment from the finest quality Type I habitat area back to the Prosser Fish Hatchery and experimentally began rearing 21 western brook lamprey translocated from other diversions; so far all of the larvae appear healthy. We were not able to survey the area upstream of the trash rack because there was a crew working on salvage for other fish. We did not survey the area downstream of the fish screens because it did not seem likely they would be in the less suitable habitat below the screens if they were not found in the highly suited habitat. The lack of larval lamprey at Chandler may be due to a combination of the excessively high summer temperature (approaching 80 F) and limited larval movement during the fall-winter season. However, macrophthalmia (transformed lamprey) are captured at Chandler Juvenile Fish Monitoring Facility from winter to spring indicating they are leaving the system around this period.

Photo 1a: Overview of Chandler Diversion.

Photo 1b: Close up of Chandler Diversion displaying observed habitat (grey) and surveyed area (green).

2. Sunnyside Diversion: Yakima River (rkm 171.0)

Location: Sunnyside Diversion is located off of Yakima Valley Hwy south of Union Gap, WA.
Date(s) visited: November 5th, 6th, 7th, and 18th, 2013
Screen Type: Drum Screen -1/8" Wire Cloth
Number of Screens: 16
Screen Length: 3 m
Temp: 9.8°C above / 10°C below
Life Stages (Total # of observed lamprey): Ammocoetes (1183), Transformers (23)

Table 2a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	30	223	141	117 (236)	1.67

Table 2b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand/Silt	145	2261	524	390 (970)	1.85

Size Class Analysis for Captured and Observed Lamprey:

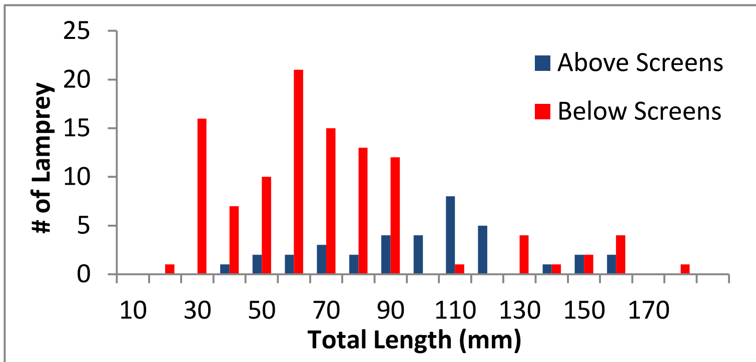


Figure 2a. Frequency histogram displaying size class distribution of captured lamprey above screens and below screens for Sunnyside Diversion.

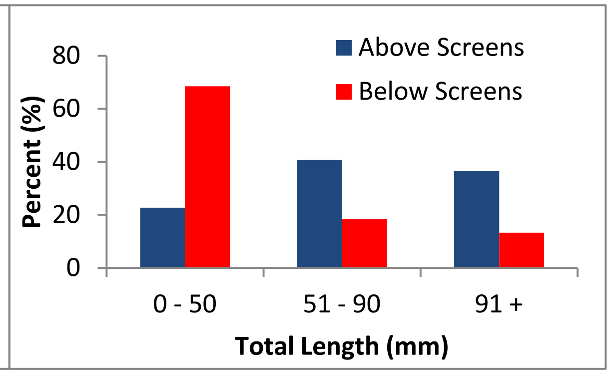


Figure 2b. Percentage of all observed lamprey in each size class above screens, above screens canal, below screens and below screens canal for Sunnyside Diversion.

Observations:

During the course of our survey, the drum screens were raised. Because of this, our gathered fish data may not accurately represent size class distribution above and below the screens. On November 5th, one drum screen was raised; November 6th and 7th, six drum screens were raised, and on November 18th, all drum screens were raised. We surveyed the above screen area on the 5th and 6th, and the below screen area on the 6th, 7th, and 18th. The water level was the highest on the 5th, and gradually decreased over the survey period.

The above screen area had patches of Type I habitat consisting of fine sand near the bypass on the right bank and a fine/coarse sand mix close to the center of the above screen area. The largest patch of Type I habitat, as well as a large collection of wood and other organic matter, was present near the bypass. We found fish in all surveyed patches of Type I habitat. The highest densities of ammocoetes were located in this large area of Type I habitat mixed with organic matter, as well as in a patch of habitat located at the trash racks along the concrete wall closest to the drum screens. Transformers were found against the downstream end of the concrete wall at the center drum screens in a cobble and woody substrate mixed with fine sediment. Whitefish, suckers and large trout were observed near the screens and in the deeper pools. An adult Chinook salmon carcass was found at the center drum screen behind the concrete wall. Ammocoete size classes ranged greatly above the screens, though the majority of the lamprey observed fell into the medium size class (51 – 90 mm). No animal tracks were observed.

On each survey date below screens, there was an abundance of exposed Type I habitat. Type I habitat below the screens consisted of fine sand with a patch of deep silt behind the first upstream drum screen. The exposed sediment area became greater on each proceeding survey date as the water level was lowered. There was a several meter long section of no sediment between the screens and the start of the Type I habitat. This gap gradually narrowed as you approached closer to the left bank drum screens. More larvae were observed below screens than above screens. We observed a lot of larvae throughout the downstream area, as well as a wide range of size classes, with most observed lamprey placed in the medium (51 – 90mm) and small (0 – 50mm) size classes. A surveyable pool, located near the maintenance launch, contained one of the highest densities of ammocoetes (despite the oil residue). The other high density area was behind the center group of drum screens. This area, behind the center drum screens, had the highest density of ammocoetes during each of the three survey dates, as the pool of water was dried up on the 18th. Transformers were found behind the 3rd and 4th drum screens in an area of shallow sediment and some cobble. Animal tracks were prevalent along the water's edge, as well as juvenile salmon, small whitefish, and suckers. Timing of the survey was great with easy navigation and access to prime habitat areas. However, more survey dates may be needed in the future to salvage more fish from the below screen area.

Photo 2a: Overview of Sunnyside Diversion.

Photo 2b: Close up of Sunnyside Diversion displaying observed habitat (grey), surveyed area (green), high density areas for ammocoetes (pink) and high density areas for transformers (yellow).

3. Wapato Diversion: *Yakima River (rkm 175.5)*

Location: Wapato Diversion, also known as Parker and New Rez, is located off of Highway 97 near Union Gap, WA.
Date(s) visited: October 17th, 22nd and 24th; November 12th and 14th; December 2nd and 4th - 2013
Screen Type: Drum Screen -1/8" Wire Cloth
Number of Screens: 15
Screen Length: 7 m
Temp: 12.0°C above / 4.8°C above-canal / --°C below / -- °C below-canal
Life Stages (Total # of observed lamprey): Ammocoetes (1489), Transformers (26)

Table 3a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt/Sand/Clay	150	1940	1074	361 (919)	0.86
Canal	Sand	60	757	60	64 (82)	1.37

Table 3b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand/Silt	43	2477	1285	256 (372)	0.29
Canal	Sand	30	10497	229	120 (142)	0.00 - 0.87

Size Class Class Analysis for Captured and Observed Lamprey:

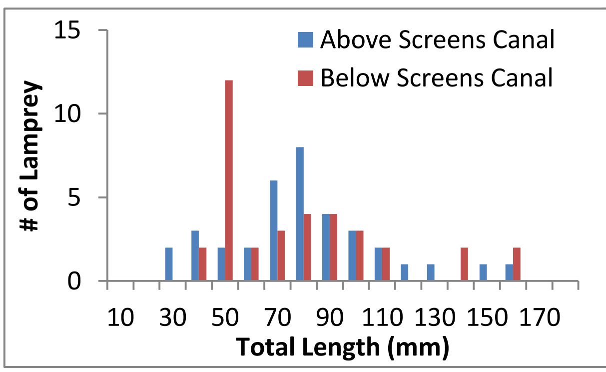


Figure 3a. Frequency histogram displaying size class distribution of captured lamprey above screens canal and below screens canal for Wapato Diversion.

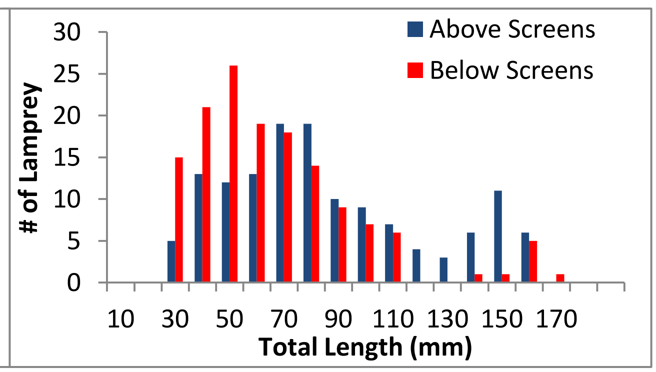


Figure 3b. Frequency histogram displaying size class distribution of captured lamprey above screens and below screens for Wapato Diversion.

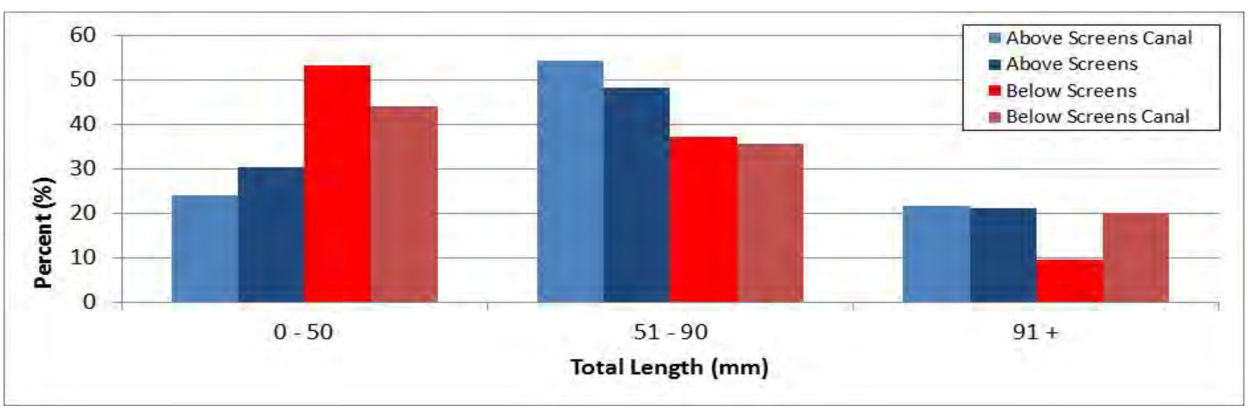


Figure 3c. Percentage of all observed lamprey in each size class above screens, above screens canal, below screens and below screens canal for Wapato Diversion.

Observations:

The above screen area was surveyed on October 17th, 24th and November 12th and 14th. We observed an abundance of fine sediment. The majority of the Type I habitat along, and close to, the bank was silt. The Type I habitat composition gradually changed to sand closer to the screens. There was a several meter wide stretch of armored areas, with shallow, patchy sediment, stretching the entire length of the screens. Accumulated fine sand and organic matter collected at the upstream corner of the uppermost drum screen, and in the downstream corner of the two concrete bypass walls above the screens. We found all transformers in these piles of sediment. The uppermost drum screen corner had the highest density of transformers. Over the course of the survey, the edges of the sediment along the waterline had the most ammocoetes with the highest density being near the trash racks. The individual concrete sections below the trash racks each contained a small amount of sediment and some larvae were found here. The water level was moderate during the first two survey dates with a small island of exposed sediment present. The moderate water level was due to a problem with the head gate closure. The water was deep in most places which made lamprey capture, and our navigation through the deep sediment, difficult. On the other hand, the water level was very low during the November sampling dates which made navigation and capture much easier. The above stream canal was surveyed on December 4th. Parts of the canal were covered in ice so we were only able to sample a small area a few hundred feet above the trash racks. Tires and other debris were present which allowed for sediment to collect and this is where most lamprey were found. Several fish were still missed so more sampling dates may be beneficial to salvage more fish from the canal.

The below screen area was surveyed on October 22nd and November 12th and 14th. There was an abundance of fine sediment consisting of silt, which collected in large, scattered piles and fine sand which collected in areas of gravel and cobble. One of the sets of wooden paneling, the paneling that sits behind each drum screen, had fallen from a center drum screen, lying directly behind it. The larvae captured in this location, on average, were larger than other larvae sampled throughout the below screens area, being mostly of the medium size class (51 – 90 mm). A lot of the fine sediment was mixed with some cobble and gravel (i.e. Type II habitat), though they still contained lamprey. The highest density of ammocoetes was captured near the maintenance launch and along the bank. The transformers were found in relatively high numbers along the concrete lip in front of the first upstream drum screen. The water level was high on the October sampling date, which made lamprey capture difficult, though more Type I habitat was surveyable. In November, however, the water level was very low which limited the amount of surveyable habitat, though navigation was easy.

We surveyed the below screen canal on November 12th, 14th and December 2nd. We recently removed a drift net that was stretched across the canal for the recent irrigation season. The collected Type I habitat, fine sand, was sampled on November 12th. The sediment was shallow, but stretched the bottom of the canal. Five larvae were observed at this location and were of the small (0 – 50mm) and medium (51 – 90mm). On November 14th, we traveled 3.30 kilometers down the canal to a site that had surveyable habitat. Tires and other debris were present and aided in the collection of fine sediment. The Type I habitat present was mainly shallow areas of fine sand. Over one hundred larvae were captured in this location, with the highest densities being near the debris, such as tires. Although the primary size class present was the small (0 – 50 mm) size class, these larvae ranged greatly in size (40 – 160mm) representing all size classes. On December 2nd, we surveyed 10 more sites further downstream the canal. We started at 3.32 km and traveled the entire canal, stopping every two to five kilometers and observing available habitat. We sampled 3 sites and no lamprey were observed. The majority of the canal was dewatered, with small pools located sporadically throughout the canal. There was an abundance of Type 1 habitat, mostly fine sand. Areas that were not covered in sand were armored. There was much less sediment towards the end of the canal. An earlier survey date closer to the time of dewatering may allow for more Type I habitat to be surveyed.

Photo 3a: Overview of Wapato Diversion

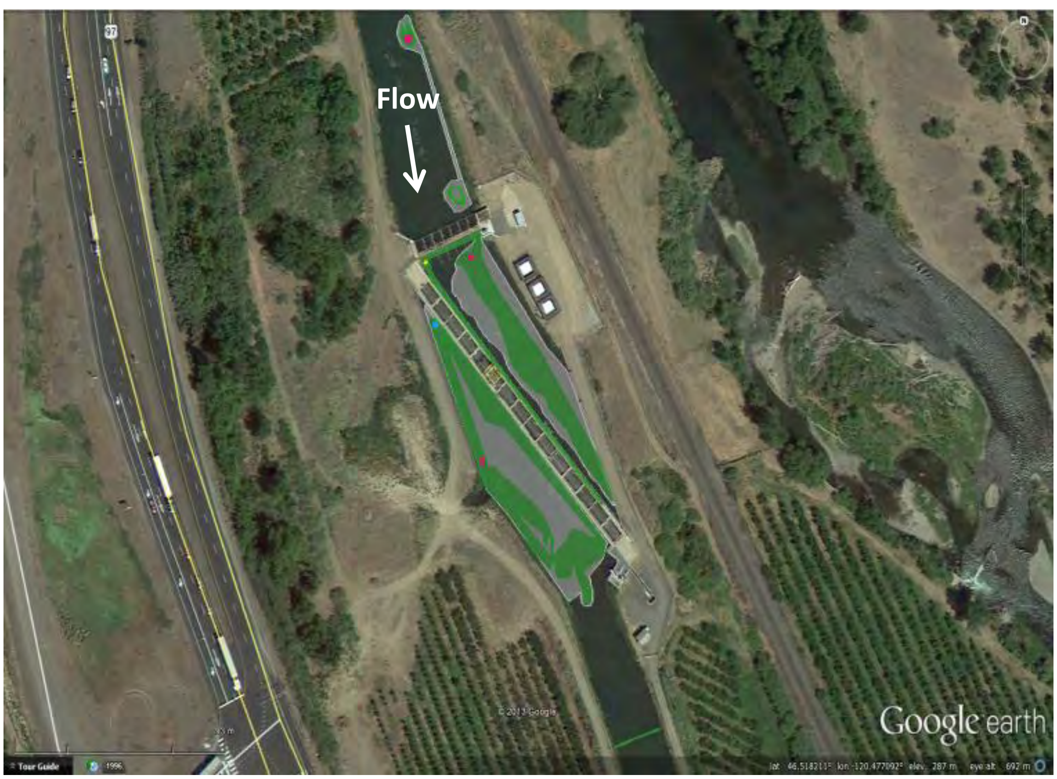


Photo 3b: Close up of Wapato Diversion displaying overall habitat (grey), surveyed area (green), high density areas of ammocoetes (pink), high density areas for transformers (yellow), and high density areas for ammocoetes +

Photo 3c: Overview of canal between the screens and the lowest point of observed larvae.

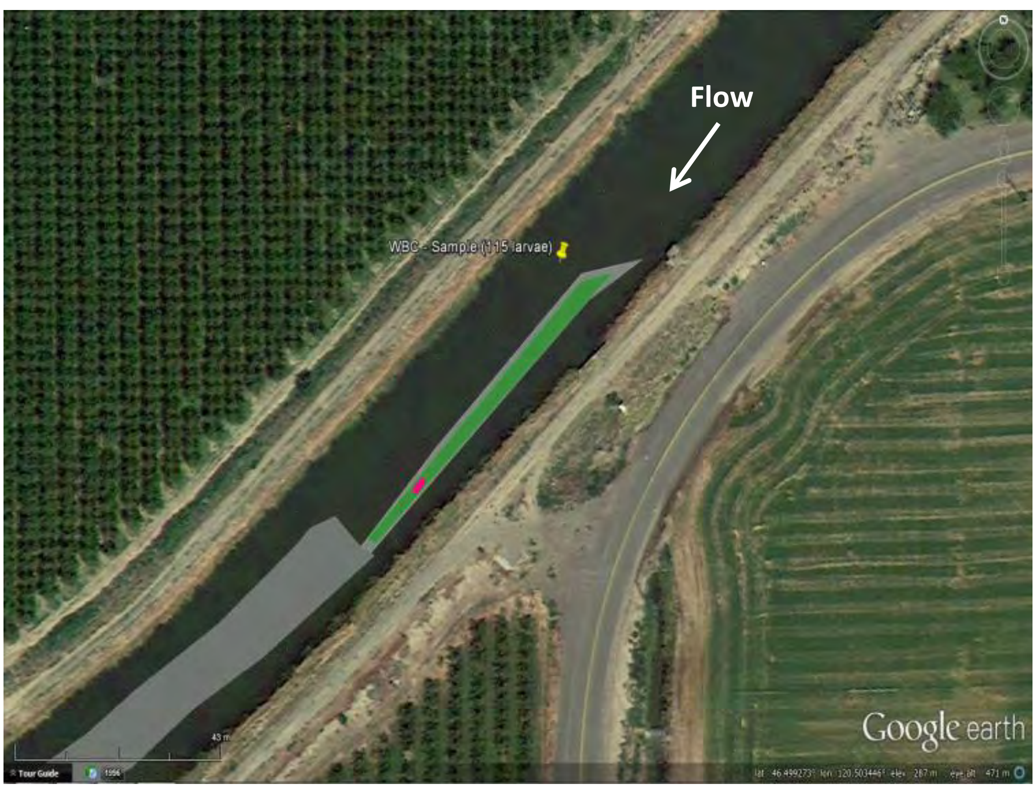


Photo 3d: Close up of lowest surveyed site on Wapato canal (3.30 km downstream) where larvae were observed. Displays observed habitat (grey), surveyed area (green), and high density area for ammocoetes (pink).

4. Union Gap Diversion: *Yakima River (rkm 188.7)*

Location: The Union Gap Diversion is located behind Bureau of Reclamation office on Terrace Heights outside of Yakima, WA.
Date(s) visited: October 21st, 2013
Screen Type: Vertical - 1.75 mm Vertical
Number of Screens: 4
Screen Length: 4 m
Temp: --°C above / --°C below-canal
Life Stages (Total # of observed lamprey): Ammocoetes (89), Transformers (2)

Table 4a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Clay	6	8	3	0 (1)	0.33
Canal	Clay	75	790	280	45 (85)	0.30

Table 4b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Clay	17	38	14	3 (5)	0.36
Canal	Armored	-	0	-	-	-

Size Class Analysis of Captured and Observed Lamprey:

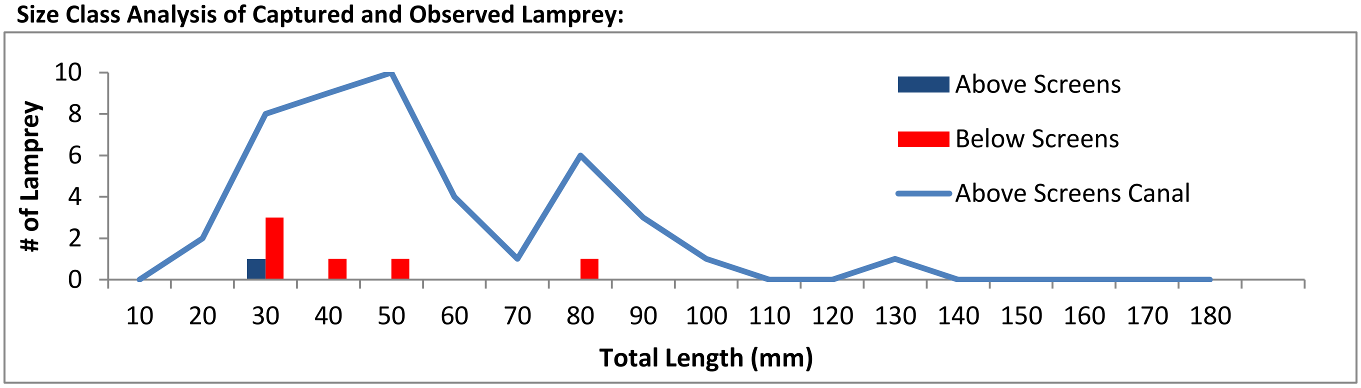


Figure 4a. Frequency histogram displaying the size class distribution of observed lamprey above screens, above screens canal and below screens for Union Gap Diversion. Above screens canal is all captured lamprey. Above screens and below screens is observed lamprey.

Observations:

The canal above the screens was the first area to be surveyed at Union Gap Diversion. Throughout the canal there was an abundance of milfoil that limited sight during the survey. The majority of the canal was dewatered with a lot of dewatered Type I habitat (~20% was surveyable). There was Type I habitat (clay mixed with woody debris and other organic matter) present in the pool right below the canal's head gate. One transformer was found here, as well as a few ammocoetes. There was a long stretch of rock and cobble downstream from the head gate pool. Near the center of the canal began a stretch of patchy Type I habitat that continued downstream almost to the bridge. The majority of ammocoetes were found near the middle reaches of the canal. We surveyed as much of the canal as we could, trying to cover the majority of the surveyable habitat. Many lamprey were missed within the canal with the majority being of the medium size class (51 – 90 mm) as we were trying to cover more ground with limited time. Rainbow trout, whitefish, and juvenile Chinook salmon were found throughout the area. Although some Type I habitat was already dried up, survey was generally well-timed because deeper water would make navigation and overall observations difficult.

The Type I habitat in the area directly above the screens was small and mostly dewatered. The edges were sampled and only one small larvae (~ 30 mm) was observed. The majority of this area was concrete. More Type I habitat was present below the screens than above.

This habitat was mostly thin (~5 cm), with deeper areas present and very little exposed concrete. Larvae observed were of the small size class (0 – 50 mm). Survey of these areas was well-timed, though an earlier date may have increased the surveyable habitat.

Photo 4a: Overview of Union Gap Diversion.

Photo 4b: Close up (1) of the Union Gap Diversion head gate pool displaying observed habitat (grey), surveyed area (green), and high density area for transformers (yellow).

Photo 4c: Close up (2) of Union Gap canal displaying observed habitat, surveyed area (green), and high density area for ammocoetes (pink).

Photo 4d: Close up of Union Gap Diversion screens displaying observed habitat (grey), surveyed areas (green), and high density areas for ammocoetes (pink).

5. Taylor Diversion: Yakima River (rkm 201.1)

Location: Taylor Diversion is located in Selah, WA at the end of Ames Road.
Date(s) visited: October 23rd, 2013
Screen Type: Drum Screen - 3/32" Perforated
Number of Screens: 2
Screen Length: 3 m
Temp: 10.9°C above / 10.9°C below-canal
Life Stages (Total # of observed lamprey): Facility measurements only

Observations:

We did not survey at Taylor Diversion. The water level was high, though we could see accumulated organic matter and sediment above and below the screens. This diversion is worth returning to when the canal is dewatered.

Photo 5a: Overview of Taylor Diversion.

Photo 5b: Close up of Taylor Diversion. We could not conduct a larval survey here.

6. Selah-Moxee Diversion: Yakima River (rkm 203.6)

Location: The Selah-Moxee Diversion is located outside Selah in Pamona,WA behind Private Property at the end of Pamona Rd.
Date(s) visited: October 23rd, 2013
Screen Type: Vertical - 3/32" Perforated
Number of Screens: 12
Screen Length: 2 m
Temp: 16.5°C above-canal/ 16.5°C above / 16.8°C below
Life Stages (Total # of observed lamprey): Ammocoetes (31)

Table 6a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt	24	45	0	-	-
Canal	Silt/Sand	33	626	66	17 (30)	.46

Table 6b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Clay/sand	37	131	8	0 (1)	.13

Size Class Analysis for Observed Lamprey:

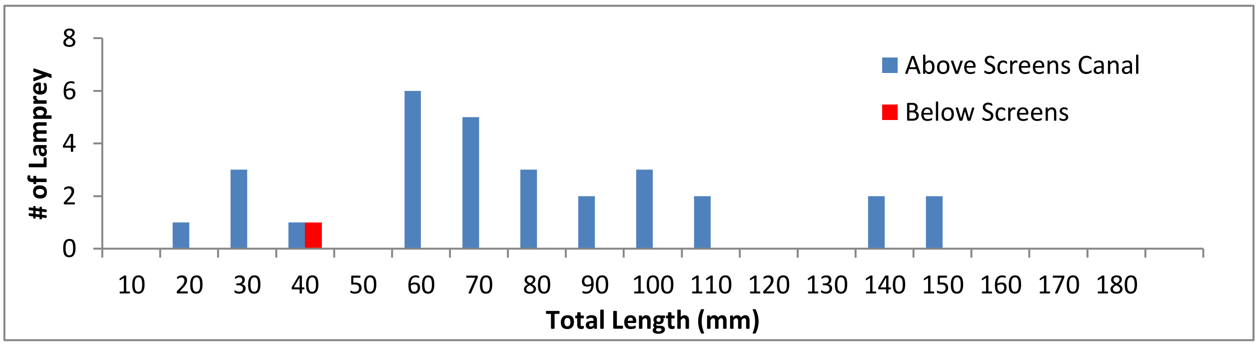


Figure 6a. Frequency histogram displaying the size class distribution of observed lamprey above screens canal and below screens for Selah-Moxee Diversion.

Observations:

The above screen area had deep water and visibility was low. Type I habitat, consisted primarily of silt. Milfoil was present in patches. Fine sediment did not extend all the way to the screens. This area was not surveyed due to low visibility conditions. The above screens canal area was surveyed and ammocoetes were found. From the start of the canal upstream to the head gate was all Type I habitat, primarily silt with patches of fine sand. Milfoil covered almost all the Type I habitat, limiting sight during our survey. Most of our survey in the above screens canal area was from the maintenance launch upstream to the edge of sediment approximately 20 meters downstream from the head gate. The highest density of ammocoetes was along the upstream edge of the sediment. Ammocoete size classes varied (20 – 150mm) throughout the surveyed area. Crayfish were plentiful and small larval fish species, other than lamprey, were also observed by the head gate area. There was minimal amount of exposed sediment at the maintenance launch with animal tracks present near the water's edge. Survey timing was perfect, though navigation through the canal was difficult and limited due to the deep sediment.

The below screens area had exposed Type I habitat near the screens. The fine sediment, mainly clay, was present from the screens downstream to the start of the canal. Organic matter was limited. We surveyed the edges of Type I habitat just below the screens, as well as a small patch near the start of the canal. Only one small larvae (~ 40 mm) was observed in a shallow patch of sediment near the start of the canal. An earlier survey date with more water may allow for more habitat to be surveyed, though this would also increase navigation difficulties due to the thick clay substrate.

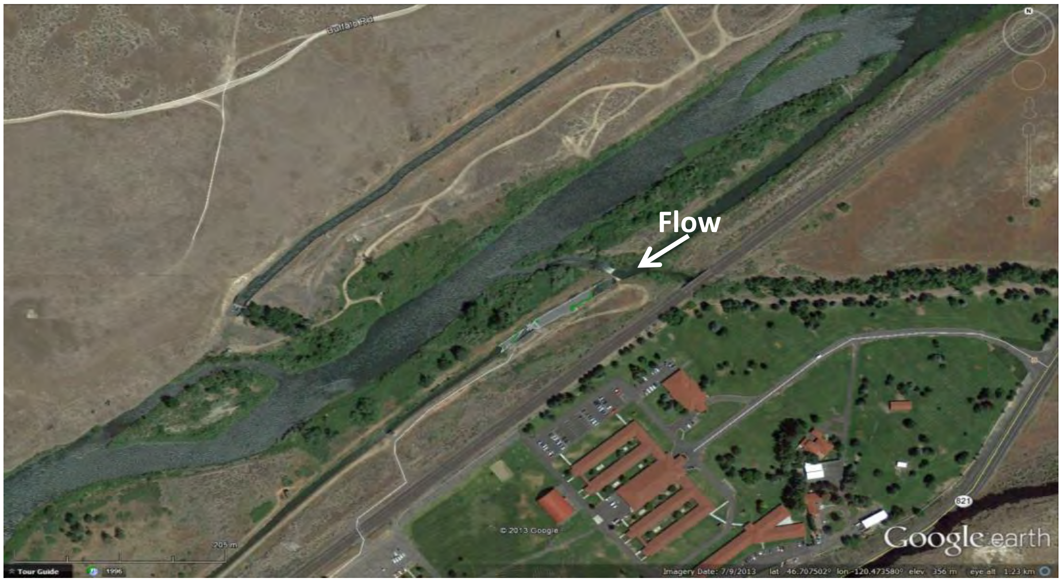


Photo 6a: Overview of Selah-Moxee Diversion.

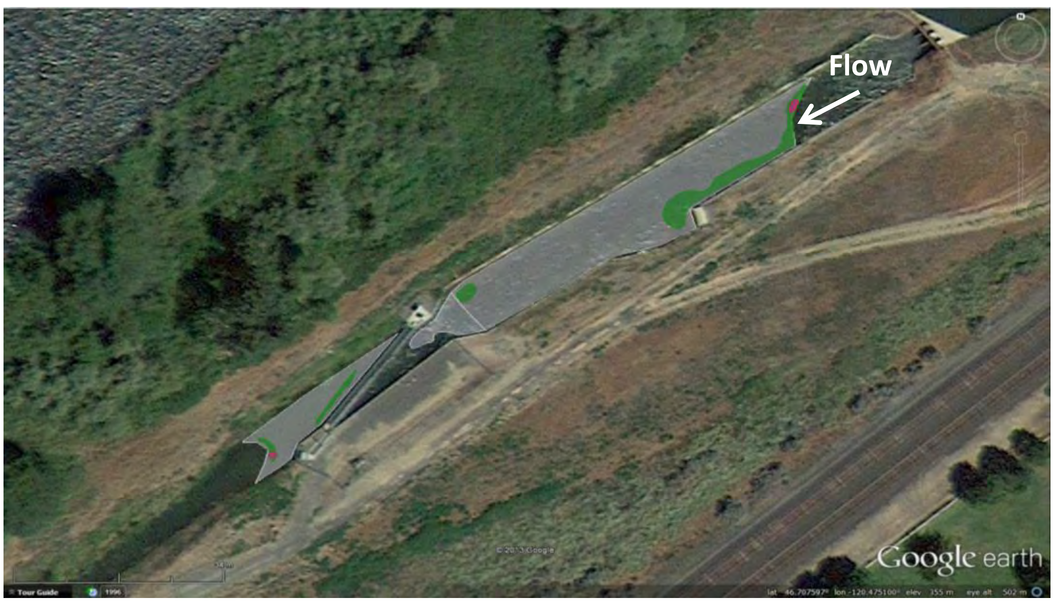


Photo 6b: Close up of Selah-Moxee Diversion displaying overall habitat (grey), surveyed area (green), and high density areas of ammocoetes (pink).

7. Roza Diversion: Yakima River (rkm 210.7)

Location: Roza Diversion is located above Roza Dam along Canyon Road near Selah, WA.
Date(s) visited: October 25th and 28th, 2013
Screen Type: Drum Screen - 3/32" Wire Cloth
Number of Screens: 27
Screen Length: 4 m
Temp: --°C above / --°C below-canal
Life Stages (Total # of observed lamprey): Ammocoetes (102), Transformers (4)

Table 7a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt	26	697	23	31 (36)	1.57

Table 7b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	165	2488	416	50 (70)	0.17

Size Class Analysis of Observed Lamprey:

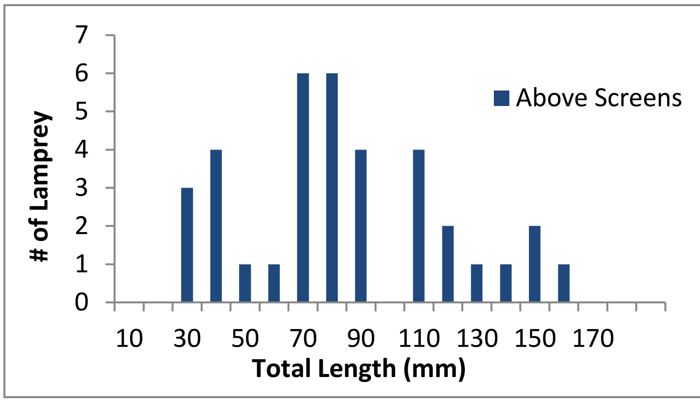


Figure 7a. Frequency histogram displaying size class distribution of observed lamprey above screens canal and below screens canal for Roza Diversion.

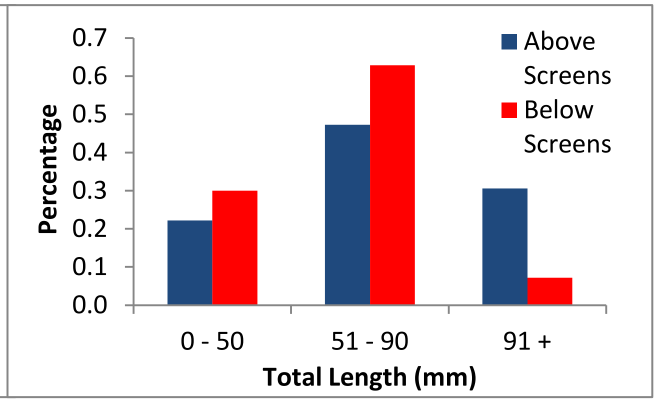


Figure 7b. Percentage of all observed lamprey in each size class above and below screens for Roza Diversion.

Observations:

The area above the screens at Roza Diversion was surveyed on October 28th, 2013. There are 5 individual bays, each with its own set of screens. We surveyed Bays (lowest number upstream) One, Four, and Five. Both transformers and ammocoetes were found in each bay. The highest density of transformers was found in Bay Five against the upper most drum screen. The primary available sediment was silt. In each bay that was surveyed, the highest density of ammocoetes was against the bay's upper most drum screen. Woody debris and sediment was most abundant in these areas. Each bay was almost entirely covered in a thin layer (~5cm) of fine sediment. Surveyable habitat was only located under each set of drum screens. An earlier survey date closer to dewatering may allow for more habitat to be surveyed. Bird tracks were abundant throughout each bay area and Rainbow Trout, juvenile Chinook salmon, whitefish and suckers were observed at each surveyed location under the drum screens.

The area below the screens was surveyed on October 25th, 2013. Very little sediment was present behind each set of drum screens and was most abundant along the banks of the below screen area away from the screens. Milfoil covered habitat was located along the banks, and the majority of this habitat was dewatered, except for the inside edges which were sampled. The habitat along the banks provided the highest density of ammocoetes. Due to lack of survey time, the size class percentages were estimated for missed and captured fish. The majority of the fish observed were of the medium size class (51 – 91mm). Areas of gravel and cobble were present. No animal tracks were observed and small whitefish were plentiful. Water level was deep which made the survey challenging. A later date from the start of the dewatering may be more beneficial.

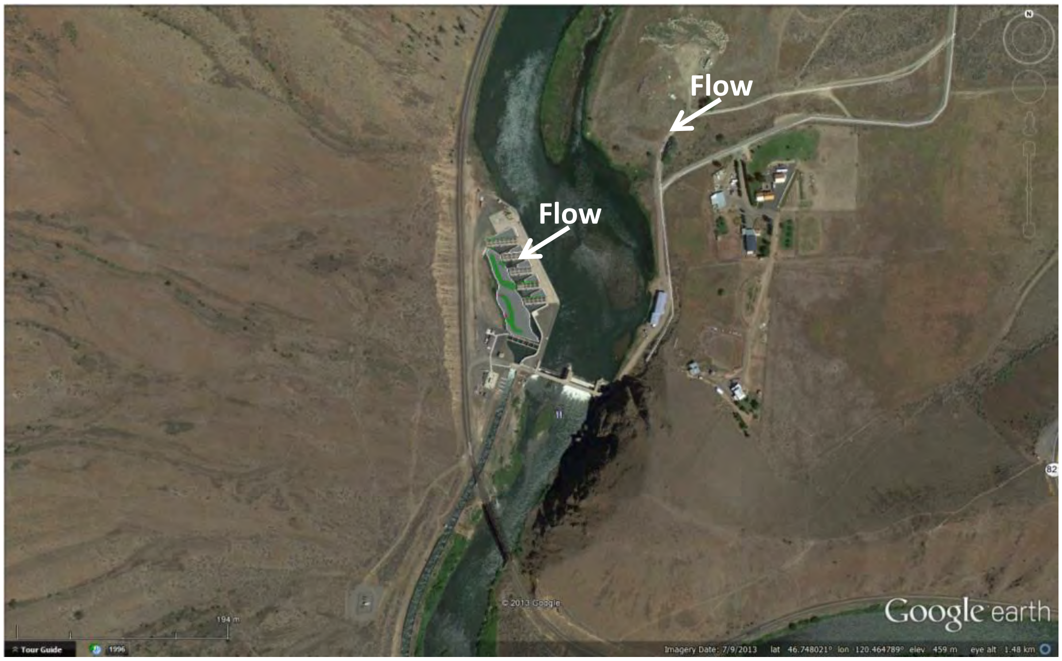


Photo 7a: Overview of Roza Diversion.

Photo 7b: Close up of Roza Diversion displaying observed habitat (grey), surveyed areas (green), and high densities for both transformers and ammocoetes (blue).

8. New Cascade Diversion: Yakima River (rkm 262.3)

Location: New Cascade Diversion is located off of Old Hwy 10 outside of Ellensburg behind private property.
Date(s) visited: October 21st, 2013
Screen Type: Drum Screen - 3/32" Wire Cloth
Number of Screens: 8
Screen Length: 4 m
Temp: 9.6°C above / 9.8°C below
Life Stages (Total # of captured lamprey): Ammocoete (17)

Table 8a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt	68	99	20	4 (10)	0.50
Canal	-	-	1033	-	-	-

Table 8b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt	64	162	24	1 (7)	0.29
Canal	-	-	516	-	-	-

Size Class Analysis of Observed Larvae:

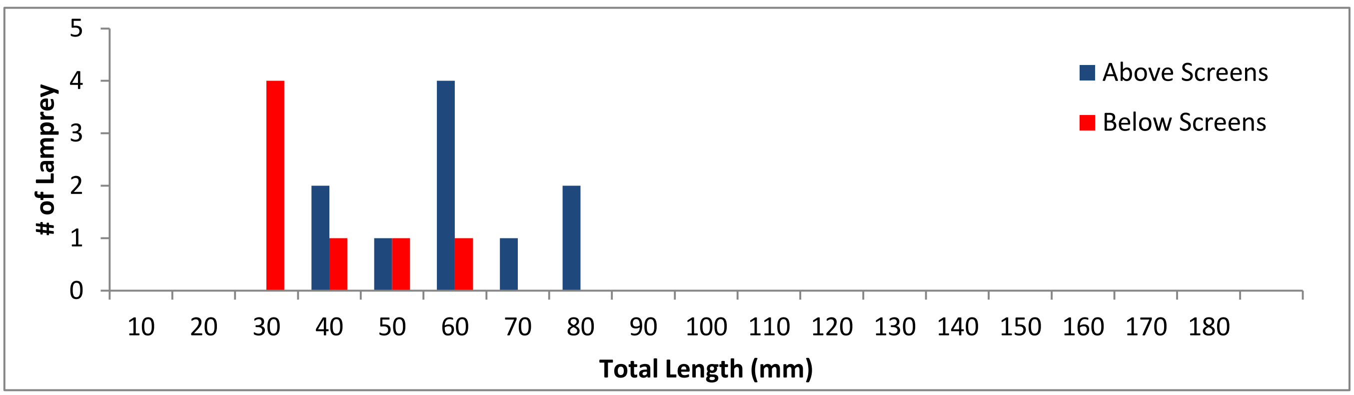


Figure 8a. Frequency histogram displaying size class distribution of observed lamprey above and below screens for Taneum Diversion.

Observations:

New Cascade Diversion was sampled first below the screens. There was no Type I habitat directly in front of the screens. This area of concrete was covered in water. The majority of Type I habitat was dewatered, so we could only survey the edges of the available habitat that were covered in water. There was an abundance of aquatic vegetation and organic matter mixed in with the fine sediment. Several ammocoetes (30 – 60 mm) were found at the upper most edges of fine sediment closest to the screens. The timing for the survey was perfect. The top layer of the exposed fine sediment was dry, allowing for easy access throughout the canal. A small number of animal tracks were present along the water's edge. Small fish (other than lamprey) were present close to the screens. We observed the canal and mapped what habitat we saw, but could not sample due to lack of water.

The above screens area had deep water in front of the screens, with small fish present. Aquatic vegetation was abundant throughout. Areas with swift moving water and shallow fine sediment yielded the most larvae. This was evident in the channel of water moving towards the bypass from the canal along the wall across from the screens. Most of the sediment was deep and dewatered. Animal tracks were spotted on the pile of sediment that was exposed in the center of the canal. The timing of the survey above the screens was perfect due to the ease of access around the deep sediment, possibly maximizing the amount of Type I habitat surveyed.

Photo 8a: Overview of New Cascade Diversion.

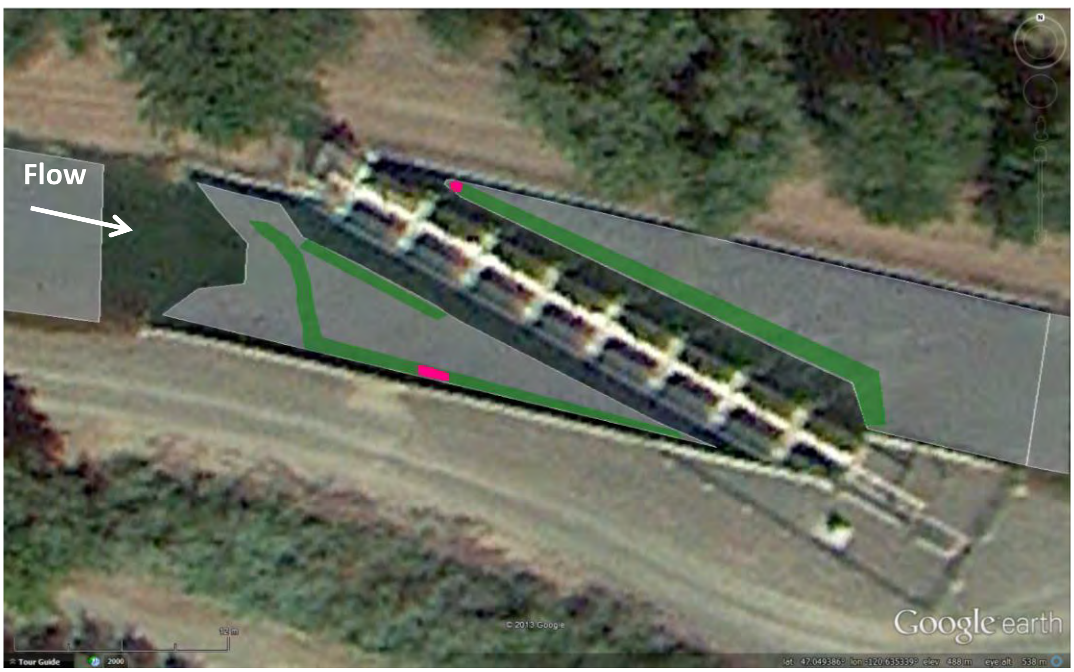


Photo 8b: Close up of New Cascade Diversion displaying habitat, surveyed area, and highest density areas for ammocoetes (pink).

9. Packwood Diversion: *Yakima River (rkm 262.6)*

Location: Packwood Diversion is located near Thorp, WA at the end of Gladmar Park Road.
Date(s) visited: October 22nd, 2013
Screen Type: Vertical - 3/32" Perforated
Number of Screens: 7
Screen Length: 1 m
Temp: 6.7°C above / 6.9°C below-canal
Life Stages (Total # of observed lamprey): Ammocoetes (25), Transformers (5)

Table 9a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Clay	12	1	1	0	0.00
Canal	Clay	180	827	10	3 (13)	1.30

Table 9b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	-	-	0	-	-	-
Canal	Clay	60	137	3	11 (17)	5.70

Size Class Analysis of Observed Lamprey:

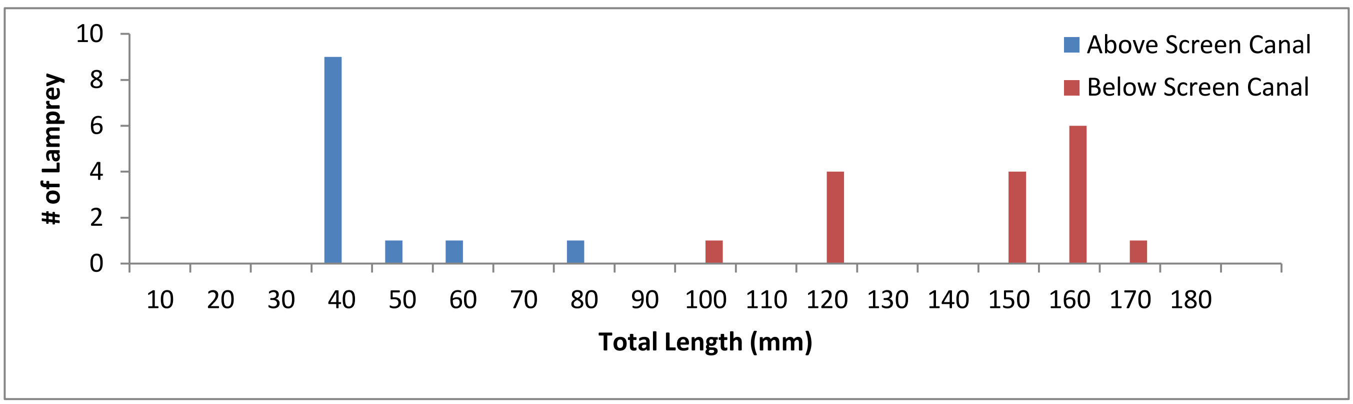


Figure 9a. Frequency histogram displaying size class distribution of observed lamprey above screens canal and below screens canal for Packwood Diversion.

Observations:

There was a very shallow and small (1 m^2) area of Type I habitat above the screens. All available Type I habitat was surveyed and no lamprey were found. The water level was shallow and most of the area was concrete. We also surveyed above the screens in the canal where there was an abundant amount of Type I habitat as far as we could see. The water level was lowered and we were able to survey along the left bank. The canal bank was steep (at the water's edge) and we observed some larvae (30 – 80 mm) here. There were patches of aquatic vegetation and an abundance of animal tracks along the water's edge in the canal. The primary fine sediment type was clay. Survey timing was perfect with easy accessibility and surveyable Type I habitat.

Below the screens there was shallow water and no habitat present. We thus surveyed in the canal below the screens where there was an abundance of Type I habitat as far as we could see. The sediment was primarily clay with most areas covered in Milfoil. Transformers and ammocoetes were observed, with no lamprey below 100 mm. The highest density of lamprey was below the Iron Horse Trail bridge against the wooden support poles. The large size class (91+ mm), and number, of lamprey was quite unusual considering that they were all found below the screens. The survey was well-timed because all Type I habitat was still covered in water, but the deep sediment made the survey challenging. We do not believe this canal gets dewatered, thus ammocoetes may be rearing in this area for multiple years, which would explain the large (+100 mm) lamprey that were found.

Photo 9a: Overview of Packwood Diversion displaying observed habitat (grey).

Photo 9b: Close up of Packwood Diversion displaying observed habitat (grey), sampled area (green), highest density area for ammocoetes (pink) and high density area for ammocoetes + transformers (blue).

10. Town Diversion: Yakima River (rkm 264.7)

Location: New Cascade Diversion is located off of Old Hwy 10 outside of Ellensburg behind private property.
Date(s) visited: October 21st, 28th, and 30th, 2013
Screen Type: Drum Screen – 1/8" Wire Cloth
Number of Screens: 9 + (1) Vertical - 3/32" Perforated
Screen Length: 4 m
Temp: -- above / -- below
Life Stages (Total # of observed lamprey): Ammocoetes (109), Transformers (4)

Table 10a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Clay	20	123	26	29 (39)	1.50
Canal	Clay	42	26	4	13 (21)	5.25

Table 10b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Clay	26	222	82	43 (53)	0.65

Data for Captured Lamprey:

Table 10c. Summary of information for captured lamprey based on location.

Location	Small (0-50mm) - (%)	Medium (51-90mm) - (%)	Large (91+mm) - (%)
Above/Below Screens	0.500	0.278	0.222
Above Screens Canal	0.619	0.333	0.048

Observations:

Town Diversion was first visited on October 21st, but the diversion had yet to be dewatered. We took facility measurements and left. We revisited the diversion on October 28th to find the same result. However, On October 30th the canal was dewatered and all drum screens, except one, were raised. We sampled the maintenance launch above the trash racks. Sediment had collected here and was easy to survey. Some larvae were found here. There was no other observed habitat above the trash racks, except for a small amount of aquatic vegetation and organic material.

We surveyed above and below screens. Above screens there was a limited amount of Type I habitat. Type I habitat was located behind the trash racks, and in small patches between the trash racks and the screens. Organic matter, mixed with a small amount of fine sediment, was the primary substrate located in front of the screens. There is one vertical, perforated screen at this diversion in the center of the line of drum screens. The organic matter that was piled in front of this vertical screen yielded the highest number of larvae.

Ecology blocks that are present below the screens gathered a large amount of Type I habitat. We sampled around the ecology blocks. The majority of the lampreys were found behind these blocks in areas with organic matter and shallow sediment. The area of deep sediment in front of the blocks did not appear to have as many lamprey. We observed whitefish below the screens as well. No animal tracks were present above or below the screens. The timing of the survey on October 30th was perfect. We were able to easily survey and navigate the canal.

Due to time constraints, the larvae were not separated by above and below screens, thus we do not have accurate size class data for observed fish. We only have the overall size classes (small, medium, and large percentages) for captured larvae on the October 30th sample date.

Photo 10a: Overview of Town Diversion.

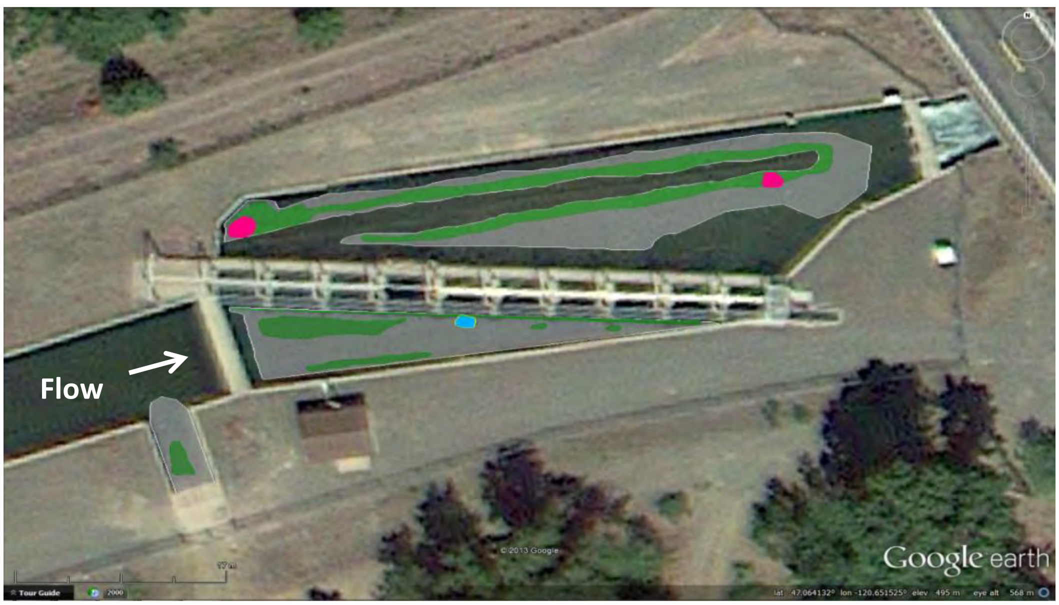


Photo 10b: Close up of Town Diversion displaying observed habitat (grey), surveyed sites (green), and highest density areas for both ammocoetes (pink) and ammocoetes + transformers (blue).

11. Westside Diversion: Yakima River (rkm 272.0)

Location: Westside Diversion is located near Thorp, WA off N. Thorp Road
Date(s) visited: October 21st, 2013
Screen Type: Drum Screen -1/8" Wire Cloth
Number of Screens: 4
Screen Length: 4 m
Temp: 10.7°C above / 10.9°C below
Life Stages (Total # of observed lamprey): Ammocoete (10)

Table 11a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt/Clay	34	22	9	6 (7)	0.79
Canal	Silt/Clay	34	1722	12	0 (0)	0.00

Table 11b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt/Clay	33	12	12	3 (3)	0.25
Canal	Silt/Clay	40	375	0	0	0 (0)

Size Class Analysis of Observed Lamprey:

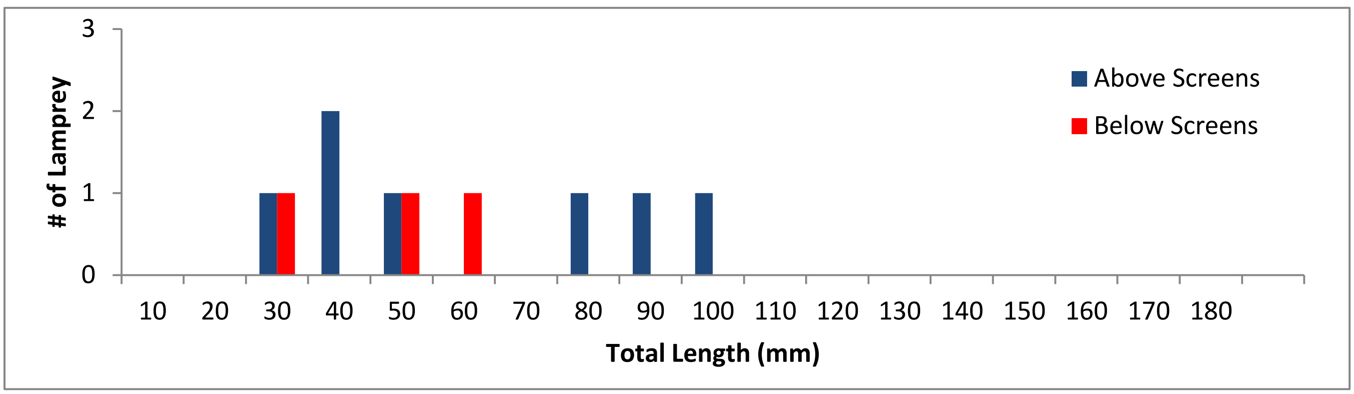


Figure 11a. Frequency histogram displaying size class distribution of observed lamprey above and below screens for Westside Diversion.

Observations:

Above the screens at Westside Diversion there were several individual piles of sediment separated by concrete. Milfoil covered these piles of sediment, which potentially blocked our sight of some lamprey during our survey. The majority of larvae were found along sediment pile edges. Edges were not as heavily covered in milfoil and provided the best visibility. Larvae were also observed leaving the sediment from under the milfoil. A sediment patch located in the center of the above screen area had the highest density of larvae. We moved up the canal, which is almost all sediment covered in milfoil, and sampled a small section that appeared to be free of milfoil for easy observation of lamprey, yet no lamprey were observed. The primary sediment type within the above canal was the same as directly above the screens. Survey was well-timed because the water level was still above almost all the present Type I habitat.

Directly below the screens there was minimal amount of habitat, with the majority of the area being concrete. The sediment was piled at the start of the canal and the maintenance launch several meters below the screens. We found no fish directly below the screens. We found fish at the edges of sediment by the maintenance launch and start of canal. The sediment in the below canal was covered in milfoil, and little to no water was present, thus we could not electrofish. An earlier date closer to the time of dewatering would allow for more habitat area to be surveyed below the screens.

Photo 11a: Overview of Westside Diversion.

Photo 11b: Close up of Westside Diversion above canal and screens displaying observed habitat (grey), sampled areas (green), and highest density areas for ammocoetes (pink).

12. Lower WIP Diversion: Ahtanum Creek (rkm 16.5)

Location: Lower WIP Diversion is located off of 79th Ave. near Union Gap, WA.
Date(s) visited: October 15th, 2013
Screen Type: Drum Screen - 3/32" Perforated
Number of Screens: 2
Screen Length: 2 m
Temp: --°C above / --°C below-canal
Life Stages (Total # of observed lamprey): No Survey

Table 12a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand/Silt	Unknown	45	-	-	-

Table 12b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand/Silt	Unknown	40	-	-	-

Observations:

We did not survey Lower WIP Diversion. The diversion appeared to have been dewatered for several weeks and the water was stagnant with low visibility. Tumbleweed and other debris collected in the diversion. Facility measurements and observed habitat was recorded.

Photo 12a: Overview of Lower WIP Diversion

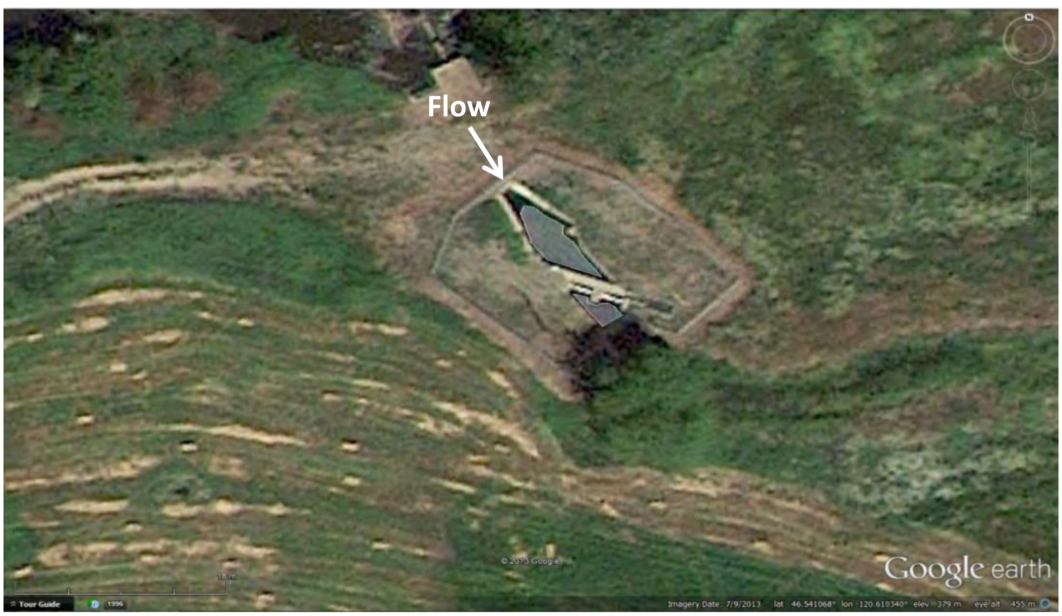


Photo 12b: Close up of Lower WIP Diversion above canal and screens displaying observed habitat (grey). No larval survey was conducted due to excessively low water conditions.

13. Bachelor-Hatton Diversion: Ahtanum Creek (rkm 31.8)

Location: Bachelor-Hatton Diversion is located off of a gravel road near Ahtanum, WA downstream of Upper WIP Diversion.
Date(s) visited: August 27th, 2013 and October 15th, 2013
Screen Type: Drum Screen - 3/32" Wire Cloth
Number of Screens: 4
Screen Length: 4 m
Temp: August 18.0°C above / 18.6°C below-canal / October --°C above / --°C below-canal
Life Stages (Total # of observed lamprey): Ammocoetes (4)

Table 13a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	54	63	40	1 (4)	0.10

Table 13a. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	26	14	14	0 (0)	0.00

Observations:

We surveyed Bachelor-Hatton Diversion on August 27th. The above screen area had Type I habitat, consisting mostly of fine sand, from the screens to a few meters below the head gate. Water level was low and the water was cloudy with only moderate visibility. There was very little organic matter and aquatic plants. The deepest fine sediment was near the bypass a few feet from the screens. Four small ammocoetes (30 – 50mm) were observed at the end of the concrete along the right bank (facing upstream). One larvae was kept for genetic analysis to determine species. No animal tracks were observed above the screens. Other small larval species of fish were observed near the screens.

Type I habitat was patchy below the screens, and consisted of fine sand in small piles. Organic matter, such as leaves and sticks, was present and vegetation was growing on top of exposed sediment. The area between the patches of fine sediment was mostly concrete covered in a very thin layer of silt. We surveyed all available Type I / II habitat and no lamprey were observed. No animal tracks or any species of fish were observed. The survey was well-timed. However, the above screen area would be easier to survey with a lower water level, possibly allowing for less murky conditions. We returned on October 15th to take facility measurements. The water level appeared to be at the same level, both above and below screens, though the water appeared to have an oil stain across the top. We did not survey on this date.

Photo 13a: Overview of Bachelor-Hatton Diversion.

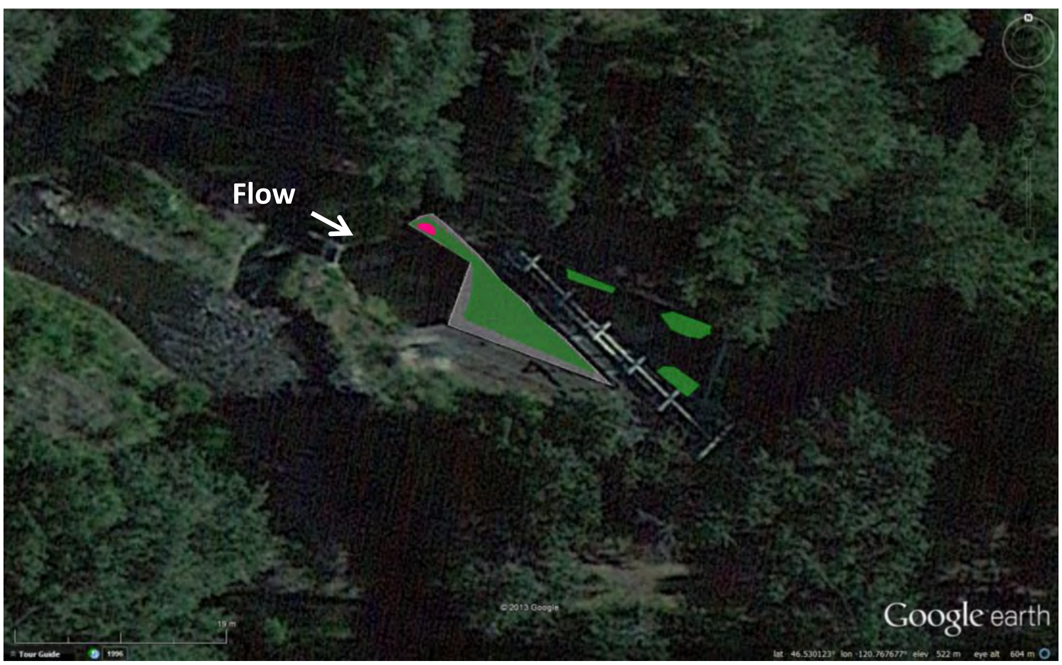


Photo 13b: Close up of Bachelor-Hatton Diversion above canal and screens displaying observed habitat (grey), sampled areas (green), and highest density areas for ammocoetes (pink).

14. Upper WIP Diversion: Ahtanum Creek (rkm 32.8)

Location: Upper WIP Diversion is located at the end of a gravel road off of Ahtanum Road near Ahtanum, WA.
Date(s) visited: August 27th and October 15th, 2013
Screen Type: Drum Screen - 3/32" Wire Cloth
Number of Screens: 4
Screen Length: 4 m
Temp: August: 16.0°C above/ 16.1°C below; October --°C above / --°C below
Life Stages (Total # of observed lamprey): Ammocoetes (1)

Table 14a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand/Silt	47	45	15	0 (1)	0.07

Table 14b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	53	40	1	0 (0)	0.00

Observations:

We surveyed Upper WIP Diversion on August 27th. The water level was still high, but we determined that we could see well enough for a survey. The present Type I habitat, above the screens, was primarily fine sand with areas of silt along the wall away from the drum screens. The deepest fine sediment was located behind the downstream most drum screen close to the bypass. The sediment was shallow in front of the screens. Our visibility was moderate and we observed only one small larvae (~ 50mm) near the edge of the fine sediment in front of the upstream most drum screen. Organic matter was moderately present. No other fish species were observed.

We did not enter the water below the screens due to high water and low visibility. Type I habitat was fine sand and silt. A deep mound of sediment was located near the concrete wall away from the drum screens so we shocked this area from the bank. No lamprey, or other fish species, were observed. Very little organic matter was present. A later date after the beginning of the dewatering of this canal would be beneficial for a more accurate survey.

Photo 14a: Overview of Upper WIP Diversion.

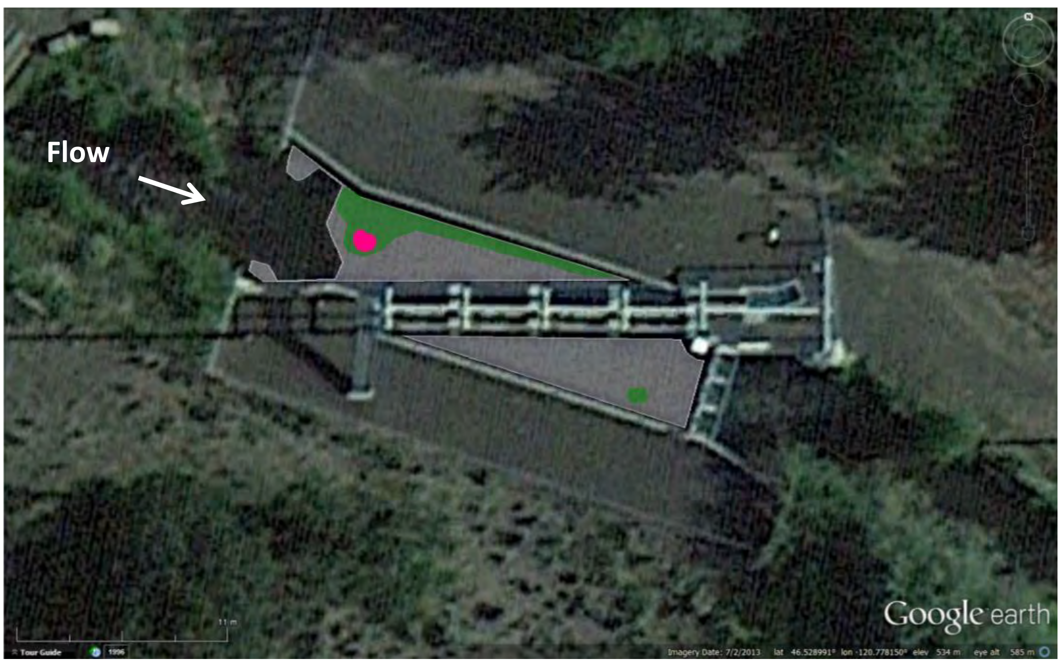


Photo 14b: Close up of Upper WIP Diversion above canal and screens displaying observed habitat (grey), sampled areas (green), and highest density areas for ammocoetes (pink).

15. Old Union Diversion: Naches River (rkm 4.0)

Location: Old Union Diversion is located in Yakima, WA off of the Fruitvale Blvd west-bound on ramp to Highway 12.
Date(s) visited: October 23rd, 2013
Screen Type: Vertical - 3/32" Perforated
Number of Screens: 4
Screen Length: 1 m
Temp: 9.7°C above / 9.7°C below-canal
Life Stages (Total # of observed lamprey): Facility measurements only

Observations:

We did not survey at Old Union Diversion. The water level was high, though we could see accumulated organic matter and sediment above and below the screens. This diversion is worth returning to when the canal is dewatered.

Photo 15a: Overview of Old Union Diversion. Notice Fruitvale Diversion to the left.

Photo 15b: Close up of Old Union Diversion. We could not conduct a larval survey here.

16. Congdon Diversion: Naches River (rkm 13.9)

Location: Congdon Diversion is located west of Yakima, WA off of South Naches Road.
Date(s) visited: October 16th and 17th, 2013
Screen Type: Drum Screen - 3/32" Wire Cloth
Number of Screens: 3
Screen Length: 4 m
Temp: --°C above / --°C below-canal
Life Stages (Total # of observed lamprey): Ammocoetes (34)

Table 16a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	35	24	8	9 (12)	1.50

Table 16b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand/Silt	40	62	14	9 (22)	1.57
Canal	Armored	-	0	0	-	-

Size Class Analysis of Observed Lamprey:

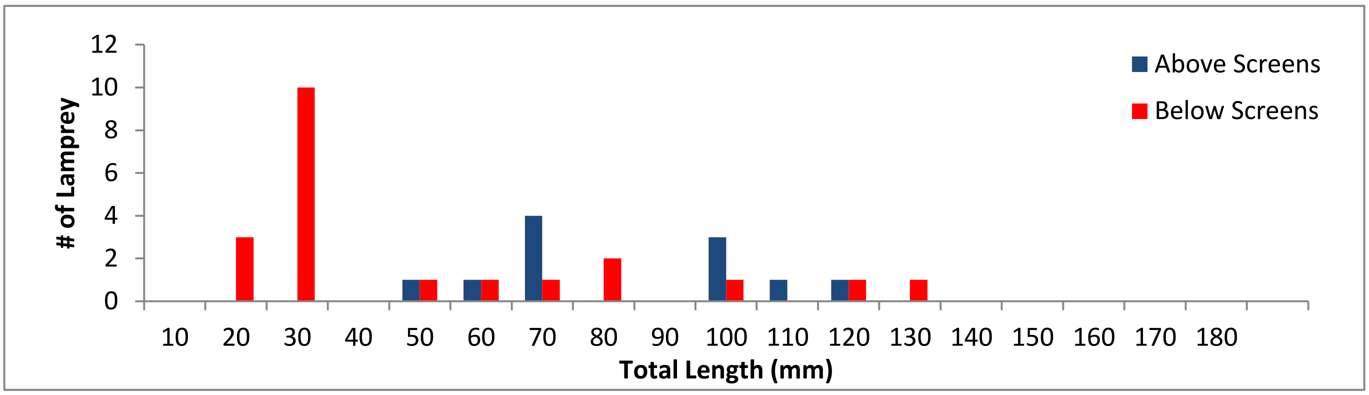


Figure 16a. Frequency histogram displaying size class distribution of observed lamprey above screens canal and below screens canal for Congdon Diversion.

Observations:

Type I habitat was abundant above the screens and consisted of fine sand. The water level was very low, with deep pools at the trash racks. Some organic matter and aquatic vegetation was present. Below the screens was primarily Type I habitat as well. The Type I habitat ranged from silt (near the canal and in the small gate section above the upstream drum screen) to fine sand, which covered the remaining area. Water level was deepest behind the upstream most drum screen. Aquatic vegetation was present on the patches of silt, but otherwise the sediment was bare. Animal tracks were present below the screens in exposed sediment areas. Small larval fish, other than lamprey, were observed both above and below the screens.

We released VIE tagged Western Brook Lamprey (31 – 1710mm) and young-of-the-year Pacific Lamprey (7 – 25mm) into the canal on September 24-26, 2013, for a mark-release-recapture study to observe behavior and dispersal within the facility. See Appendix 2.6 for more information on this study. We sampled both above and below the screens to record any lamprey that held in the above screen area or passed through the screens. On the first survey date, October 16th, we used a Smith-Root Electrofisher because our equipment was being repaired. Very few larvae were observed below the screens and no larvae above the screens. We were unable to set the Smith-Root Electrofisher to the desired settings for lamprey.

On October 17th, we returned with our normal electrofishing gear. We captured ammocoetes with and without VIE tags both above and below the screens. Above the screens we observed several ammocoetes (50 – 120mm), but no ammocoetes small enough to be the released Pacific Lamprey. The highest density of lamprey was along the concrete wall across from the drum screens in water moving swiftly towards the bypass. Below the screens, ammocoete size classes ranged greatly (20 – 130mm). The highest densities below the screens were near the canal, where we found mostly small larvae (~30 mm), and in the small gated section next to the upstream most drum screen, where we found the largest tagged ammocoete (124mm). Timing of this survey was perfect because of the low water level.

Photo 16a: Overview of Congdon Diversion.

Photo 16b: Close up of Congdon Diversion displaying observed habitat (grey), sampled areas (green), and highest density areas for ammocoetes (pink).

17. Kelly- Lowry Diversion: Naches River (rkm 22.3)

Location: Kelly-Lowry Diversion is located in Naches, WA off North Naches Road.
Date(s) visited: October 24th, 2013
Screen Type: Drum Screen - 3/32" Wire Cloth
Number of Screens: 2
Screen Length: 4 m
Temp: 7.2°C above / --°C below
Life Stages (Total # of observed lamprey): No Lamprey Observed

Table 17a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	50	14	3	0	0.0

Table 17b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand/Silt	15	1	0	-	-

Observations:

Above screens area at Kelly-Lowry Diversion had an abundance of deep Type I habitat, primarily a mix of fine and coarse sand, from the screens to the trash racks. Most of the Type I habitat was dewatered. All drum screens were fully raised. Navigating the above screen area was difficult due to the deep sediment, thus limiting the amount of habitat we were able to survey. No lampreys or other fish species were observed and no animal tracks were present. The above canal was not observed or surveyed. Below the screens there were small patches of shallow dewatered habitat, and most of the area was concrete and was not surveyed. Sand was the primary available fine sediment below the screens. The survey was well-timed. With deeper water we would not have been able to navigate the above screen area, but the small amount of habitat below the screens would still have been surveyable.

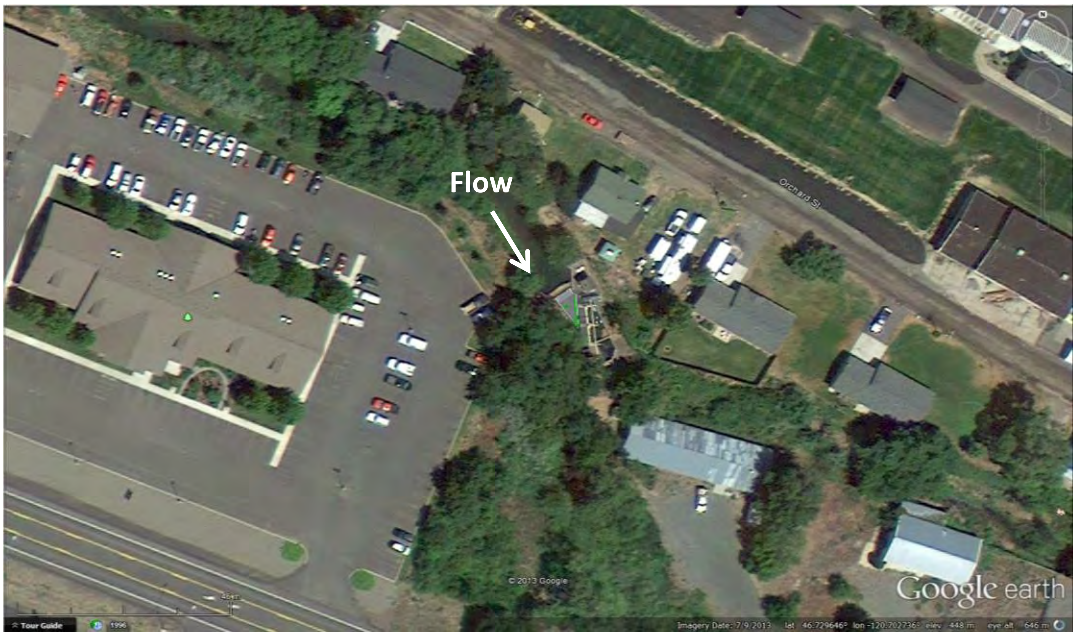


Photo 17a: Overview of Kelly-Lowry Diversion.

Photo 17b: Close up of Kelly-Lowry Diversion displaying observed habitat (grey) and surveyed area (green).

18. Wapatox Diversion: Naches River (rkm 28.6)

Location: Wapatox Diversion is located west of Naches, WA off of Hwy 12.
Date(s) visited: October 31st, 2013
Screen Type: Vertical - 1.75 mm Vertical
Number of Screens: 24
Screen Length: 1 m
Temp: --°C above / --°C below-canal
Life Stages (Total # of observed lamprey): Ammocoetes (108)

Table 18a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt/Clay	60	217	40	34 (49)	1.23

Table 18b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Silt/Clay	25	117	68	53 (59)	0.87

Size Class Analysis for Captured and Observed Lamprey:

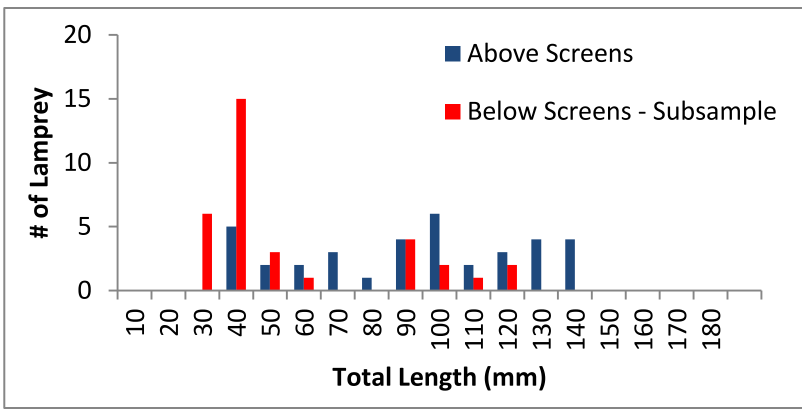


Figure 18a. Frequency histogram displaying the size class distribution of observed lamprey above screens and below screens for Wapatox Diversion. Above screens are all captured lamprey. Below screens are a subsample of captured lamprey.

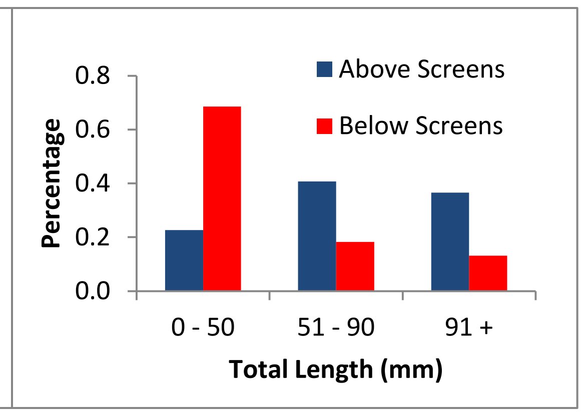


Figure 18b. Percentage of all observed lamprey in each size class above screens, above screens canal, below screens and below screens canal for Wapatox Diversion.

Observation:

Above the screens there was deep fine sediment from the screens to the trash racks, and it was Type I habitat consisting primarily of silt and clay. There was a lot of aquatic vegetation and woody debris as well. During our survey of Wapatox, we were accompanied by Joel Hubble (the Reclamation) and his crew who were doing fish salvage for trout and juvenile salmon. His crew dug a path through the fine sediment against the set of screens on the right bank. We surveyed along this path, finding a high density of ammocoetes near the path's center. We also surveyed the edge of the sediment below the trash racks. The water here was deep which made larvae capture difficult. There was a high density of larvae just below the trash racks by the first left bank screen. There is a gap between the above set of screens and the below set of screens. Sediment and organic matter collected in this gap and it seems possible that lamprey get caught inside here. Animal tracks were present throughout this area as well as whitefish, small trout and salmon, dace and suckers. Survey timing was perfect because of the path that Joel's crew shoveled, and the low water level.

There was no aquatic vegetation or woody debris below the screens. The fine, silt and clay, was shallow at the downstream end of the screens, but increased in depth when moving upstream along the screens. Both the left and right sets of screens had accumulated woody debris along their base. The sediment was deep against the screens and became shallow further away. Navigating the deep sediment directly behind the screens was difficult due to the soft sediment. The highest density of larvae was found on the sediment edge just below the joining of the two sets of screens. The fine sediment stopped just before the start of the canal. There were animal tracks near the water's edge. Timing of the survey was perfect due to low water levels and easy navigation. For both above and below screens, deeper water would make walking through the sediment very difficult and a survey could not be performed.

Photo 18a: Overview of Wapatox Diversion.

Photo 18b: Close up of Wapatox Diversion displaying observed habitat (grey), sampled areas (green), and highest density areas for ammocoetes (pink).

19. Naches-Selah Diversion: Naches River (rkm 30.6)

Location: Naches-Selah Diversion is located west of Naches, WA off of Hwy 12 further upstream from Wapatox Diversion.
Date(s) visited: October 24th, 2013
Screen Type: Vertical - 1.75 mm Vertical
Number of Screens: 18
Screen Length: 1 m
Temp: 6.8°C above / 7.0°C below-canal
Life Stages (Total # of observed lamprey): Ammocoetes (25)

Table 19a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	56	68	22	23 (25)	1.14
Canal	Armored	-	0	0	-	-

Table 19b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	50	143	4	0 (0)	0.00
Canal	Armored	-	0	0	-	-

Size Class Analysis of Observed Lamprey:

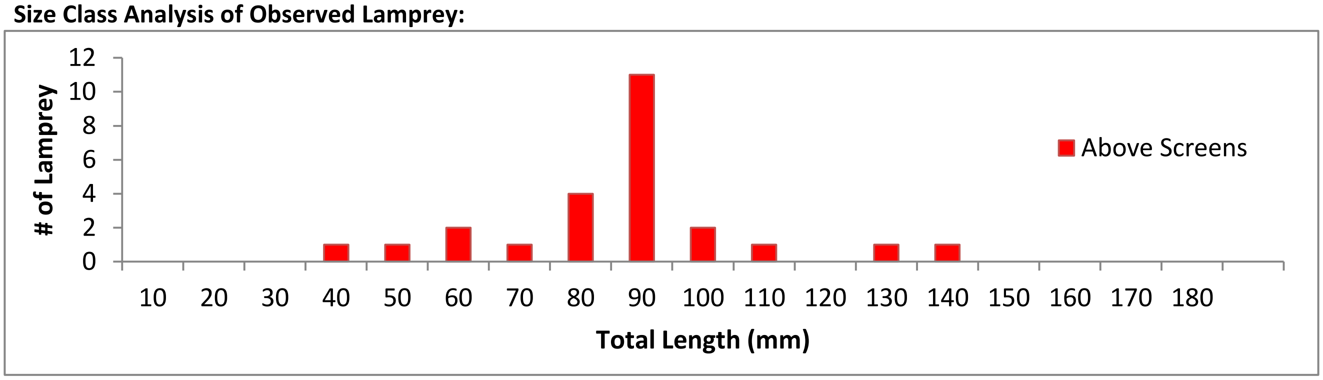


Figure 19a. Frequency histogram displaying the size class distribution of observed lamprey above screens and below screens for Naches-Selah Diversion.

Observations:

Type I habitat was present throughout the above screen area and consisted of fine sand. Its deepest areas were along the trash racks and on the front side of the ecology blocks. Woody debris and other organic matter were thick, especially along the ecology blocks, and little to no fine sediment accumulated on the opposite side facing the screens. Ammocoetes were found both in front and behind the ecology blocks. The most upstream point of the ecology blocks gathered a large amount of woody debris and fine sediment. Here we found a high density of ammocoetes, the majority being of medium (51 – 90mm) and large (91+ mm) size classes. Near the center of the screens, on the opposite concrete wall, was another high density area where primarily small (0 – 50 mm) and a few medium (51 – 90mm) size classes of ammocoetes were found. The majority of observed lamprey were found in these two locations with a few observed near the bypass and in shallow sediment areas behind the ecology blocks. Timing of this survey may have been a little late. The area is easy to navigate. More water may be beneficial to cover more Type I habitat. Animal tracks were present near the water's edge and below the trash racks. Longnose Dace and whitefish were also present.

Fine sand was present in patches directly below the screens. The sediment started to increase in depth downstream from the center screens. It reached its maximum depth on the left bank just below the screens. There was a small surveyable puddle near the bank on the opposite side from the screens. This area was surveyed and no lamprey were observed. There were several dead whitefish and longnose Dace below the screens. This is possibly from several high water events where water rose over the screens earlier in the year. No animal tracks were observed and little to no organic matter was present. An earlier survey date would allow for more Type I habitat to be surveyed.

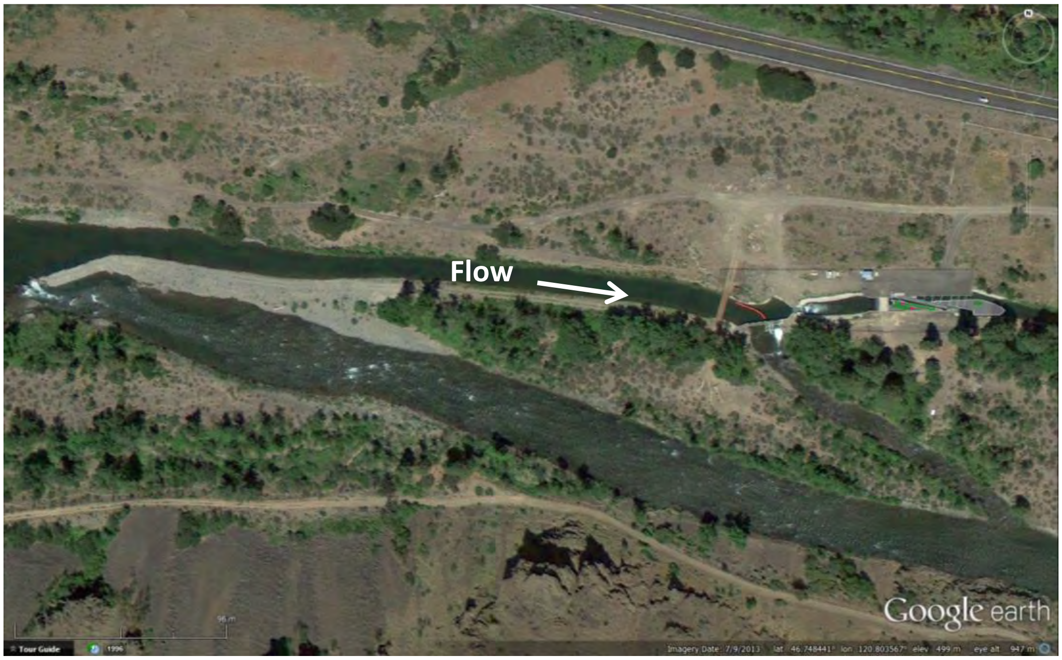


Photo 19a: Overview of Naches-Selah Diversion.

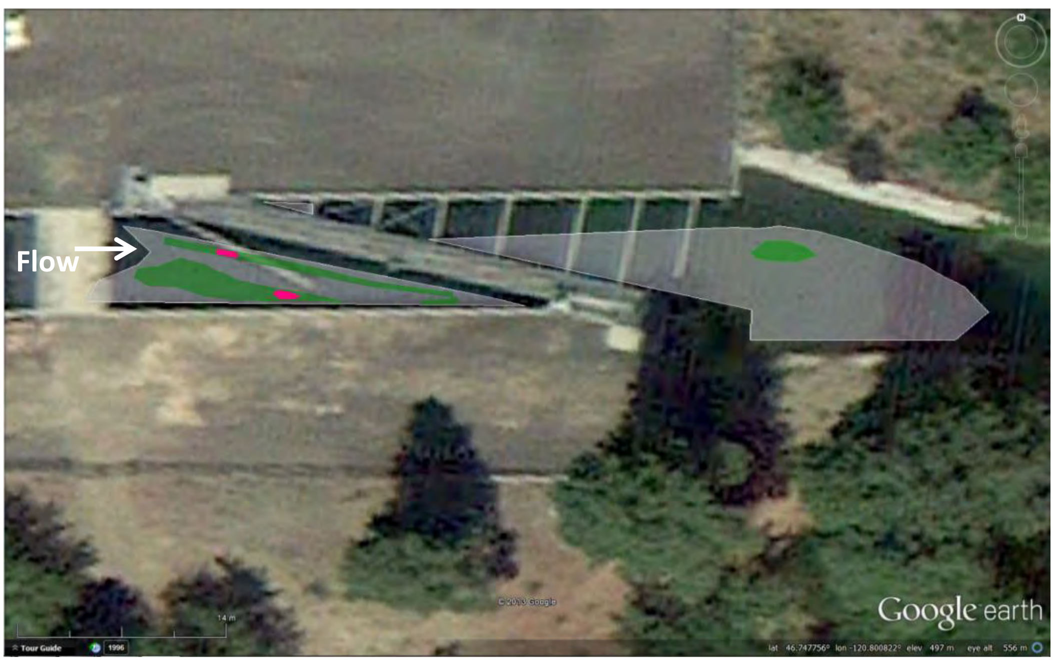


Photo 19b: Close up of Naches-Selah Diversion displaying observed habitat (grey), sampled areas (green), and highest density areas for ammocoetes (pink).

20. Fruitvale Diversion: Cowichee Creek (rkm 0.1)

Location: Fruitvale Diversion, also known as Naches/Cowichee Diversion, is located in Yakima, WA off of the Fruitvale Blvd west-bound on ramp to Highway 12.
Date(s) visited: October 23rd, 2013
Screen Type: Vertical - 3/32" Perforated
Number of Screens: 8
Screen Length: 1 m
Temp: 11.8°C above / 12.0°C below-canal
Life Stages (Total # of observed lamprey): Ammocoete (16)

Table 20a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	30	18	6	3 (3)	0.50

Table 20b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	24	5	0	-	-
Canal	Sand	68	155	2	9 (13)	0.65

Size Class Analysis for Observed Lamprey:

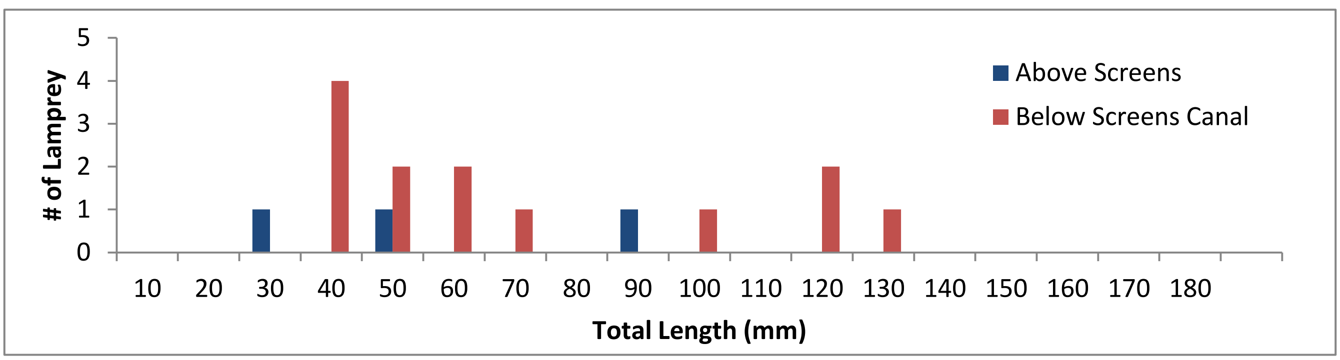


Figure20a. Frequency histogram displaying size class distribution of observed lamprey above screens and below screens canal for Fruitvale Diversion.

Observations:

Fruitvale Diversion was first surveyed above the screens. There was an abundance of Type I habitat, accumulated coarse and fine sand, right above the screens up to near the head gate. Right below the head gate, there was a pool of water with patches of Type I habitat. These patches are where we observed the highest density of ammocoetes. Very little woody debris or other organic matter were present. No animal tracks or other species of fish were observed. Nearly the entire area below the screens, from the screens to the canal gate, was covered in sand that appeared to be finer than above the screens. No water was present so we were unable to survey this area. The timing seemed a little late as there was a lot of exposed habitat and we were unable to survey below the screens.

As far as we could see, the canal below the screens had Type I habitat consisting of coarse and fine sand. We surveyed the only pool of water in the canal directly below the canal gate. The downstream edge of the pool consisted of fine sediment. A wide range of ammocoete size classes were observed (20 – 160mm), with the majority being of the medium size class (51 – 90mm). The observed density of larvae here was higher than above the screens. No animal tracks were observed and there were other fish species in this pool. The survey was well-timed because it was easy to access this pool of water, though an earlier survey closer to the start of the dewatering may allow for more habitat to be surveyed.

Photo 20a: Overview of Fruitvale Diversion.

Photo 20b: Close up of Fruitvale Diversion displaying observed habitat (grey), sampled areas (green), and highest density areas for ammocoetes (pink).

21. Taneum Diversion: Taneum Creek (rkm 3.7)

Location: Taneum Diversion is located near Thorp, WA off of Thorp Cemetery Road.
Date(s) visited: October 21st, 2013
Screen Type: Drum Screen - 3/32" Wire Cloth
Number of Screens: 4
Screen Length: 4 m
Temp: 6.1°C above / 6.3°C below
Life Stages (Total # of observed lamprey): Ammocoete (68), Transformer (3)

Table 21a. Summary of information for above screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Sand	25	75	22	54 (66)	3.00
Canal	Armored	-	0	0	-	-

Table 21b. Summary of information for below screens.

Location	Available Sediment	Max. Sediment Depth (cm)	Total Observed Habitat Area (m^2)	Total Survey Area (m^2)	# Of Captured Lamprey (Total # observed)	Survey Density of Lamprey Observed (L/m^2)
Screens	Clay	13	64	3	3 (5)	1.67
Canal	Armored	-	0	0	-	-

Size Class Analysis of Observed Lamprey:

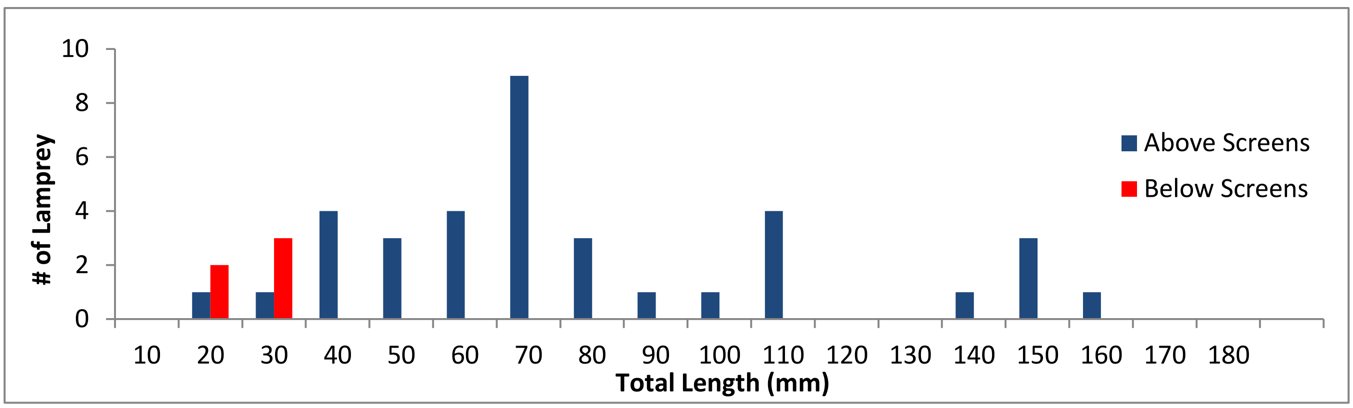


Figure 21a. Frequency histogram displaying size class distribution of observed lamprey above and below screens for Taneum Diversion.

Observations:

Taneum Diversion was first surveyed above the screens. A large amount of Type I habitat was dewatered and not sampled. Sticks, leaves, and other organic matter were collected in piles at the base of each drum screen. All transformers were captured in one location against the screens. The highest density of larvae was located within a small puddle that formed against the concrete wall above the first drum screen at the gauge marker. Ammocoete size classes ranged greatly (20-140 mm) within this puddle. Due to the low water level, a survey closer to the start of the dewatering may be more beneficial to survey a greater portion of the available habitat. There was an abundance of animal tracks present along the water's edge, suggesting heavy predation on small fish and potentially lamprey.

There was very little surveyable habitat below the screens (3.0 m^2). The vast majority of the present Type I habitat was located at the maintenance launch several meters below the last drum screen. However, this habitat was mostly dewatered, though its edges were surveyed and no larvae observed. The area directly below the screens was primarily concrete with small patches of shallow sediment mixed with woody debris. All larvae (size classes 20-40 mm) were located in one shallow sediment patch located below the last drum screen. Less animal tracks were observed here than above the screens. The canal both above and below the screens was observed, yet no Type I habitat was observed.

Photo 21a: Overview of Taneum Diversion

21b: Close up of Taneum Diversion displaying observed habitat (grey), surveyed areas (green), and highest density areas for both transformers (yellow) and ammocoetes (pink).

Pilot Assessment of Larval Lamprey Habitat and Occupancy at the Inlet of Sunnyside Diversion Prior to the Beginning of Irrigation Season

Yakama Nation FRMP, Pacific Lamprey Project

January 1, 2014

Abstract

The well documented decline of Pacific Lamprey numbers is a serious problem in the Mid and Upper Columbia River Basin. In the Yakima River Basin, irrigation diversions have been identified as a potential threat to Pacific Lamprey, hypothesized from the result of dewatered canal surveys that show large numbers of juvenile/larvae entrained below fish screens after the canals are dewatered. We hypothesized that a large percentage of entrained larvae may enter the canal when diversion head gates first open in the spring (typically in mid-March). Our objective was to determine the amount of Type I habitat (preferred larval lamprey habitat - containing fine sediment and/or organic matter), larval lamprey density, and estimate the number of larval lamprey within the area of interest above the head gate at Sunnyside Diversion. Sunnyside Diversion is located within the existing range of Pacific Lamprey and a large number of larvae (predominantly Western brook lamprey) are found at the fish screens every year in the fall during the dewatering season. On March 3, 2013, we confirmed the presence of larval lamprey and mapped available habitat within the area of interest. Although we were unable to assess

habitat directly upstream of the head gate (due to the water depth and clarity), we estimated that 725 larval lamprey may reside within the observed habitat. On August, 20, 2013, three months after the irrigation season began, no larvae were detected in approximately the same location, suggesting they either moved around locally within the area of interest, migrated down river, or became entrained in the diversion.

Introduction

The well documented decline of Pacific Lamprey is occurring in many watersheds throughout the Columbia River Basin. Irrigation canals are a potential major threat to this species as juvenile/larvae move downstream during outmigration or seek new habitat. Since 2010, dewatered canal surveys, performed by the Yakama Nation in collaboration with the Bureau of Reclamation, have shown that large numbers of juvenile lamprey (up to several thousands in Wapato and Sunnyside diversions) become entrained in irrigation diversions throughout the Yakima River Subbasin. Captured lampreys (both as larva and transformer life stages) are predominantly Western brook Lamprey, yet some small numbers of Pacific lamprey still reside in the mid-reaches of the Yakima River. Due to size restrictions (only larvae >50mm can be properly identified) and large overall number of captured and missed lamprey, many observed lamprey cannot be unidentified to species.

Juvenile lampreys may be attracted to the large amount of organic debris and fine sediment that collect in the irrigation diversions, or use the diversions as an area of refuge from high water events. Dewatered canal surveys, focusing above and below the fish screens, give us valuable information related to the species and number of juvenile/larval lampreys entering irrigation diversions. However, to develop a preventative solution to juvenile lamprey entrainment, a key question that needs to be addressed is “When are larval lampreys entering the irrigation canals?” Do larvae move into a canal steadily throughout the irrigation season, with an influx of movement during the spring snowmelt and high water events? Alternatively, a large percentage may become entrained when the head gate first opens in the spring.

When the head gate closes in the fall, a large amount of fine sediment and organic debris may begin to collect at the base of the head gate and within the area immediately upstream, due to the diversion’s general position along the channel margin. A large number of larval lamprey may move into this habitat. The head gate opens from the bottom, where Type I habitat most likely accumulates, so any larvae rearing immediately upstream of the head gate may become instantly entrained, or entrained over a several week period as high water events push larvae from immediately upstream of the head gate downstream to new refuge habitat inside the diversion. Consequently, a high density of larvae above the head gate in mid-March may contribute significantly to the overall number of larval entrainment.

Methods:

Study Area

Sunnyside Diversion is a major diversion of the lower Yakima River (river km 171.0). The purpose of this study was to assign, evaluate, and survey an area of interest immediately upstream of the Sunnyside Diversion head gate. We chose Sunnyside Diversion because in past years, a large number of juvenile/larval lamprey (up to several thousand per year) have been found here, and the diversion lies within the known range of Pacific Lamprey, thus having a potential impact on the Pacific Lamprey population.

Overview

Drysuits, large dip nets, and a backpack-electrofisher were used to conduct surveys before and after the opening of the head gate. To achieve our goal, we evaluated the following as accurately as possible (by survey date):

- March 3, 2013 (prior to the opening of the head gate):
  - Area (m^2) of available Type I habitat (including the base of the head gate)
  - Area (m^2) of surveyed habitat
  - Absence/presence of juvenile lamprey
  - Density and estimated number of juvenile lamprey within observed Type I habitat

- August 20, 2013 (five months post the opening of the head gate):
  - Note any changes in available Type I habitat
  - Area (m^2) of surveyed habitat
  - Absence/presence of juvenile lamprey
  - Density of juvenile lamprey

Pre-Irrigation Season

On March 3, 2013, we determined an area of interest (Figure 1 and Figure 2) immediately upstream of the Sunnyside head gate. Its location along the channel margin and low water velocities were determined ideal for potential sediment deposition and attraction of juvenile/larval lamprey. Drysuit gear (Figure 3) allowed us access to the deep-water area of interest above the Sunnyside head gate. Visible Type I habitat (fine sediment and/or organic debris) was mapped out by swimming throughout the area of interest. A large dip net lined with fine mesh (1 mm) fiberglass window screen, was used to survey Type I habitat by scooping and sifting the fine sediment (Figure 4). We surveyed sites along the left bank (facing downstream) in areas that were shallow enough for a complete survey (1.0-1.5m water depth). The scooped sediment was then sifted and searched for larval lamprey. Five scoops from randomly selected locations were monitored in each sampled site (approximately 30cm x 30cm area per scoop; 0.45 m^2 per surveyed site). Larval lamprey were measured for total length (mm) and identified to species if total length was larger than 50 mm. Sifted fine sediment and organic matter was returned to the river at each respective location and larvae were released after the survey for all three sites was completed. We sampled a total of three sites with the dip net, and the survey density of lamprey was calculated accordingly.

Figure 1. Area of interest (grey) immediately upstream of the head gate of Sunnyside Diversion.

Figure 2. Overview of the area of interest (March 3, 2013).

Figure 3. Ralph Lampman searching for Type I habitat using drysuit gear (March 3, 2013).

Figure 4. A larval Western brook lamprey, sifted fine sediment, and aquatic vegetation against the fine mesh net (March 3, 2013).

Mid-Irrigation Season

On August 20th, hip waders and an AbP-2 Electrofisher were used to survey available larval habitat close to the bank. Three pulses per second (125 V direct current) at 25% duty cycle with a 3:1 burst pulse train (three pulses on, one pulse off) was delivered to elicit larvae/juvenile to emerge from the substrate. After emerging, larvae/juvenile were stunned with a current of 30 pulses per second for collection. All surveyable Type I habitat was sampled, located in shallow water (<1 m) along the upstream left bank within the area of interest (Figure 5 and Figure 6). We also mapped and estimated the amount of exposed Type I habitat since the first survey date.

Figure 5. Overview of surveyed area, facing downstream from center, on August 20th, 2013.

Figure 6. Overview of survey area, facing upstream from center (August 20, 2013)

Results:

Pre-Irrigation Season

A total of 196 m^2 of available Type I habitat was observed on March 3, 2013 (Table 1, Figure 7). We were unable to assess the entire area of interest due to low water clarity and deep water (>5m deep). This confirms the fact that there is Type I habitat present within the area of interest, but does not deny nor confirm Type I habitat against the base of the head gate. Each survey location was similar in its sediment composition, composing primarily of silt and clay. Using dip nets, we found larvae (Figure 4 and Figure 8) in two of the three survey sites (A and B), confirming the presence of lamprey in the area of interest. The two large larvae (>50mm) were identified to be Western Brook. Overall, five larvae were captured and measured in the 1.35 m^2 of surveyed habitat (Figure 9), resulting in an average of 3.70 larvae/m^2. Approximately 10% of sites A and B and 5% of site C was surveyed. Based on this, we inferred that an estimated 725 larval/juvenile lamprey were present in the observed Type I habitat within the area of interest.

Table 1. Summary information from the March 3, 2013, dip net survey

Available Sediment	Survey Method	Area of Interest (m^2)	Observed Type I Area (m^2)	Surveyed Type I Area (m^2)	Lamprey Present?	# of Captured Lamprey	Density of Lamprey ($\#/m^2$)	Estimated # of Larvae in Observed Habitat
Silt/Clay	Dip Net	463	196	1.35	Yes	5	3.70	725

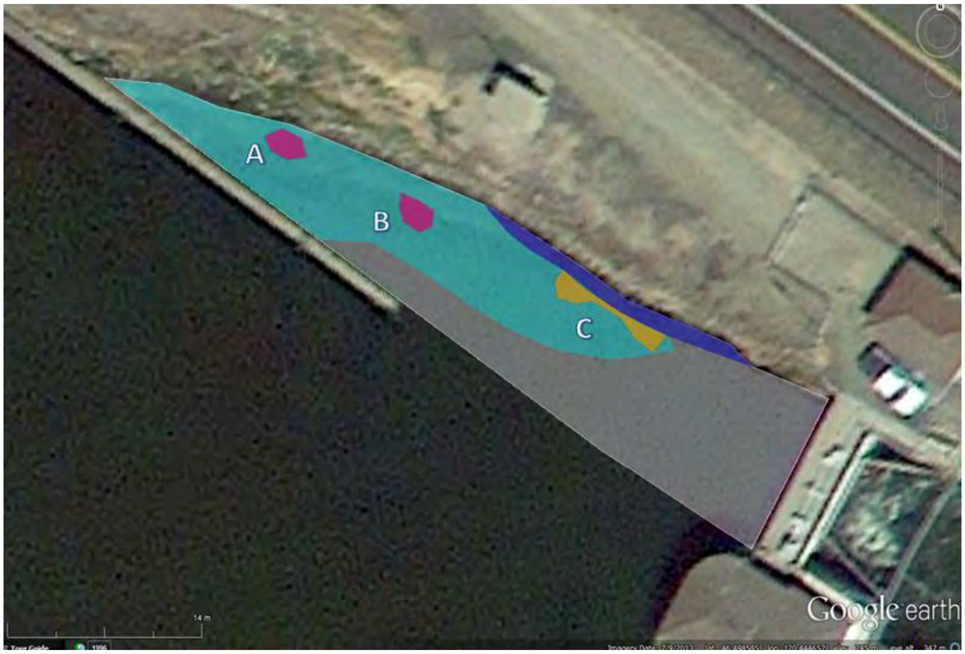


Figure 7. March 3, 2013 survey - overview of interest area displaying observed Type I habitat (light blue), observed coarse sediment habitat (dark blue), unknown habitat (grey), and dip net survey locations A, B, and C [sites where larvae present (pink) and sites where larvae absent (orange)].

Figure 8. Two small larvae (30mm and 50mm) in the hand of Ralph Lampman (March 3, 2013).

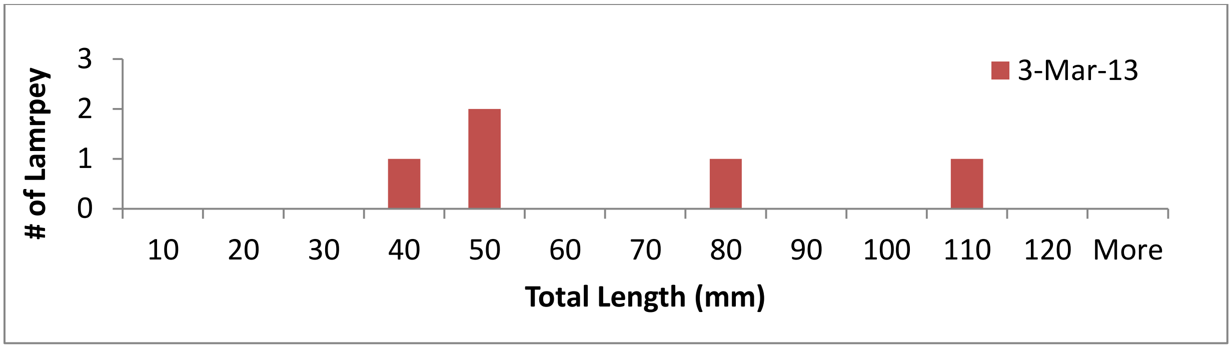


Figure 9. Frequency histogram displaying size class distribution of larvae captured within the area of interest on the March 3, 2013, dip net survey.

Mid-Irrigation Season

All available shallow water Type I habitat (<1m), 10 m^2, was surveyed with an electrofisher on August 20, 2013, and no lamprey were captured or observed (Table 2, Figure 10). This suggests that lamprey may potentially be absent in the area of interest during the summer when irrigation water is being diverted; however, more surveys are needed to confirm this. A total of 12 m^2 of Type I habitat was exposed and dry along the left bank and was the only notable habitat change between the March and August survey dates. The type of fine sediment available was very comparable to the previous survey back in March (Figure 11). No lamprey were captured, thus the density of lamprey was estimated to be 0.00 fish per square meter.

Table 2. Summary information from the August 20th, 2013 electrofishing survey

Available Sediment	Survey Method	Area Surveyed (m^2)	Lamprey Present?	Area of Exposed Habitat (m^2)	Density of Lamprey (L/m^2)
Silt/Clay	AbP-2 E-Fisher	10	No	12	0.00

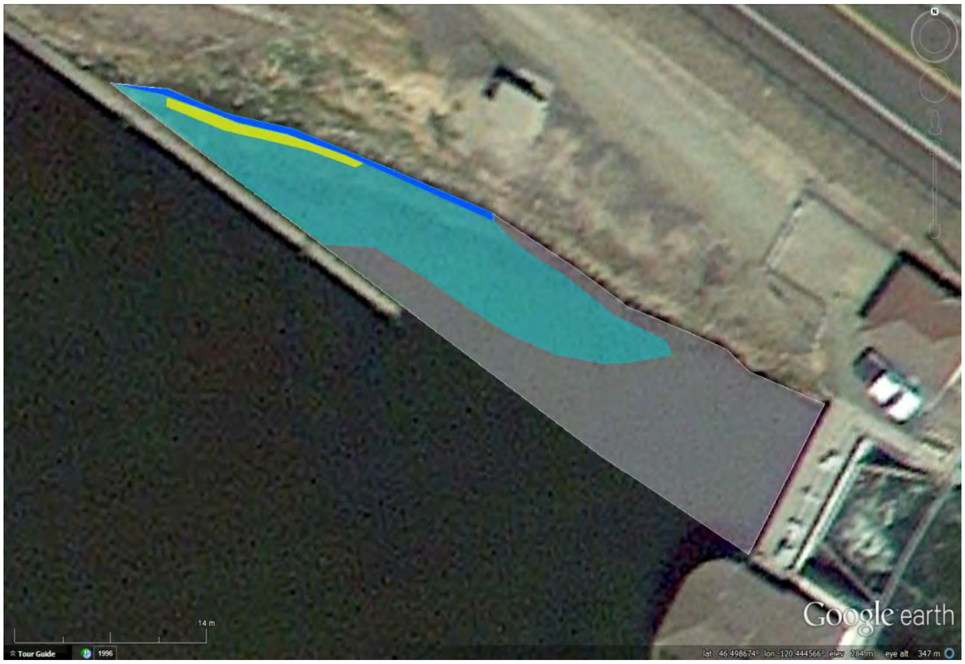


Figure 10. August 20, 2013 survey - overview of interest area displaying electrofishing survey area (yellow), observed dewatered habitat (blue), Type I habitat (light blue), and unknown habitat (grey).

Figure 11. Sediment composed of silt and clay for the survey location (August 20, 2013). This sediment was very similar to that from the survey on March 3, 2013.

Conclusion:

From our analysis of the area of interest above the Sunnyside head gate, we were able to suggest that at a minimum 40 % of the area was composed of Type I habitat before the head gate opened in late spring, 2013. Prior to the head gate opening, we confirmed larval lamprey were present within the Type I habitat available, and estimated the total number of larvae in the area to be approximately 725. More thorough surveys and sampling, however, are needed to verify the accuracy of this estimated number. We observed 1206 juvenile lamprey during the canal surveys in Sunnyside Diversion after canal dewatering in the fall of 2013. Our estimated number above the head gate, therefore, represented roughly 60 % of the observed number within the canal. It is unclear, however, what percent, if any, of the larvae residing directly above the head gate became entrained after its opening.

Our survey three months after the opening of the head gate, on August 20, 2013, suggested that juvenile lamprey may be absent within the area of interest. The survey locations, on each surveyed date, were very close to each other, so an immediate hypothesis would suggest that larvae would be present in this location on the August survey date. However, as the water level dropped between March and August, larval lamprey may have moved to deeper water, sought refuge elsewhere in the area of interest, migrated down the river, or possibly became entrained in the diversion.

We were unable to observe the base of the head gate and the area several meters in front of the gate due to water depth and turbidity. A scuba survey or remote underwater cameras may be beneficial to observe the type of sediment collected at the base of the head gate. In addition, fine sediment present in the diversion when it first opens might provide a rough indication of the amount of fine sediment that pushes through when the gate first opens, based on river water clarity and the clarity of the water entering the canal. Due to the dangers of swimming in this area when the gate is opened, observation of deep water habitat from shore may be difficult during this period. Setting plankton nets or other types of nets in the canal from the initial opening for one to two weeks would also provide an idea of lamprey movement into the canal during this period. An anchored boat or raft may be beneficial to observe habitat within the area of interest immediately after the opening of the head gate to note any immediate changes. A boat mounted electrofisher like those used by the USFWS and Pacific Northwest National Laboratory would be beneficial to survey deep water habitat above the head gate and to get a more accurate estimate of juvenile density and overall numbers.

Prepared for Yakima Nation Fisheries Research Management Program (FRMP)

LAMPREY RESEARCH PROJECTS SUMMARY REPORT:

Sunnyside Diversion and Prosser Hatchery Experiments

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Summer 2013

Contents

I. Lamprey Monitoring Methodology Development at Sunnyside Diversion Rotary Drum Fish Screens

i. Field Testing Sampling Methods with Sediment Fish Traps

Background

In the lower, more arid portion of the Yakima River Basin, an extensive irrigation network, or system of irrigation diversion dams and diversions, redirects surface water for agricultural and urban communities along the Yakima River. The basin is home to five storage dams, six reservoirs, more than five diversion dams, three power plants and approximately 464,000 acres of irrigable lands served by its irrigation network (Neitzel *et al.* 1996). Across the entire basin, these surface water diversions total to almost 60% of the mean annual stream flow and in summer months, return flows from irrigated lands are equivalent to between 50 to 70% of the flow in lower Yakima River (Johnsen *et al.* 2013; Fuhrer *et al.* 2004).

The extensive infrastructure of irrigation dams and diversions may impact and hinder the upstream migration of adult anadromous fish. Additionally, with summer air temperatures reaching over 90°C, areas of the Yakima River can warm to temperatures that are inhospitable for protected fish species. Between 1985 and 2006 in the Yakima River Basin, over sixty Phase I and Phase II fish facilities were installed as part of a mitigation plan for the impacts of federal hydroelectric projects on fish and wildlife. Presently, approximately eighty-four fish ladders and fish screens are maintained and operated in the basin (Neitzel *et al.* 1990; Hudson 2008). Thus, for over thirty years, the basin has been a site for fisheries enhancement programs, with a focus on salmon and steelhead (*Oncorhynchus* spp.) runs (Neitzel *et al.* 1990; Neitzel *et al.* 1996; Chamness 2007).

However, the total impact of the irrigation dams and diversion canal infrastructure on different Pacific lamprey life stages remains unknown. In recent years, Yakama Nation Fisheries Research and Management Program (YNFRMP) scientists initiated multiple projects to better understand the abundances and behavior of migratory adult Pacific lamprey, *Entosphenus tridentatus*, and/or the resident Western Brook lamprey, *Lampetra richarsonii*, within the Yakima River Basin (YNFRMP 2012a). Additional research is needed on juvenile/larval life stages of lamprey in the Yakima River Basin. This interim report provides a summary of pilot projects undertaken on larval lamprey life stages—ammocoetes—at the Sunnyside Diversion (a Phase 1 Fish Screen Facility) and at the Yakama Nation Prosser Fish Hatchery in Prosser, Washington, between mid-June through August 2013.

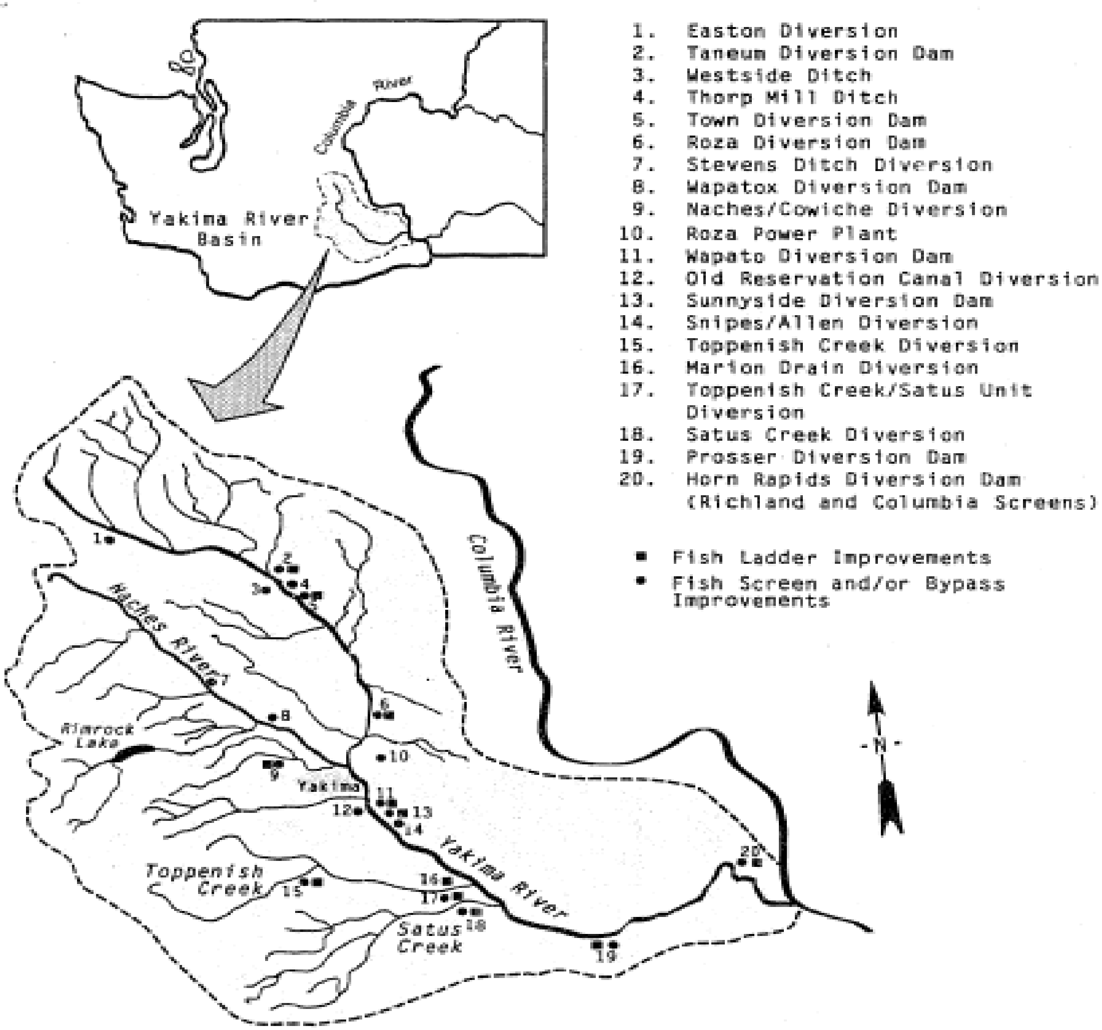


Figure 1: The Yakima River Basin and identified Fish Ladders, Fish Screen and/or Bypass Improvements (image from Neitzel *et al.* 1990). The Sunnyside Diversion Dam and the Sunnyside Rotary Drum Fish Screens (N 46 29' 47.13", W 120 26'23.03"; Sunnyside Diversion is identified as number " 13" above) are a Phase I Fish Passage Facility in the Basin (also refer to Figure 2 and Figure 6).

Pilot Study at Sunnyside Diversion

At Sunnyside Diversion (Wapato, WA; 46°29’ 47.13”N, 120°26’23.03”W), the primary goal for the summer of 2013 (mid-June through July and August), was the development and field testing of a potential monitoring and sampling method for larval lamprey—an initial design of a passive sediment fish trap—on either side of the rotary drum fish screens (Figure 2). Our sampling time-frame spanned the irrigation season for when water levels in the diversion were high and when Pacific lamprey migrate and move through the Yakima River system. Prior surveys, between 2010 through 2012, by YNFRMP biologists documented hundreds and thousands of lamprey larvae in sediments accumulating on the downstream side of the rotary drum screens (or fish screens) at this site (YNFRMP 2012b; EPA 2013).

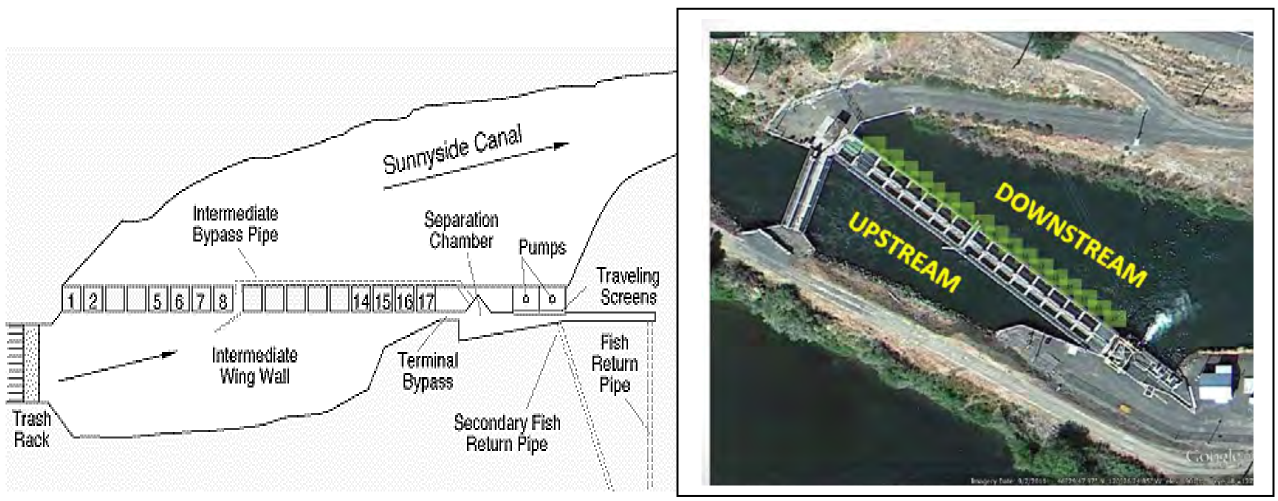


Figure 2: Schematic of the Rotary Drum Fish Screens at Sunnyside Diversion (left). On the right, a Google Earth image of the rotary drum fish screens showing the upstream and downstream areas where the sediment fish traps were placed for this pilot study. The water in the lower left corner is the Yakima River mainstem.

Approach and Methods

Between mid-June and August, we field–tested a particular design of a passive sediment ammocoete trap, or sediment trap. Within each trap, we placed two large, industrial strength nylon bags filled with combinations of sediment and different sediment amendments (Figure 3 and Table 1). Dry sediment was excavated from a large mound of diversion dredge material, located on-site at Sunnyside Diversion. Unsieved sediment was then loaded into the bottom of the nylon bags (approximately 304 ounces, or 38 cups, of dry sediment) and wetted the sediment with approximately 1.5 liter of river water drawn from Sunnyside Diversion. Amendments were then mixed into the sediment. After the first few weeks in June, we determined that tying the nylon mesh bags across the top of outer trap seemed to shore up the solid sides of each bag (Figure 3, left image). This prevented water and sediment from leaking out as traps were lifted from the diversion bottom; also, for the upstream traps, we believe this prevented further sediment loss from the sweeping current on this side of the rotary drum screen structure.

A boom and winch system, (Figure 3, middle image), allowed us to safely deploy and retrieve each trap from the top of the rotary drum screen structure once a week. We deployed eleven traps from mid-June through early July—five on the upstream and four on the downstream side of the rotary drum screens. We added a twelfth trap for sampling on the downstream side of the rotary drum screens on July 5, 2013. Initially, from mid-June through late July (July 23, 2013), we experimented with different types of sediment amendments to see if lamprey would be attracted into a trap with a particular amendment and sediment combination. One bag was filled with only excavated sediment and the second bag contained the same volume of sediment mixed with a particular amendment (Table 1).

Figure 3: Pictures of an assembled sediment trap from June 2013 (left); operating the boom and winch to pull the trap up from the downstream side of the rotary drum screens at Sunnyside Diversion (middle); and sieved material, ready for sorting and identification (right).

Table 1: Summary Table of Sediment Amendments Mixed with Sediment Inside the Passive Sediment Fish Traps from mid-June through late July.

Sediment Amendment Type	Minimum Weight (g)	Amendment Description
<u>Mid-June – late July</u>		
Straw	100	Air-dried straw
Vegetation cuttings	100	Vegetation cuttings (willow, etc.)
Organic Matter	100	Dried or wetted organic matter (collected from trash rack on site or from nearby fish screens)
Pine Bark Mulch	30	Pine bark mulch
Pine Bark Mulch + Straw	30 + 5	Pine bark mulch + active dry yeast
Hatchfry Encapsulon	5	Hatchfry Encapsulon Grade I (<50 microns) – Argent Laboratories
Yeast	5	Active dry yeast
Yeast + Hatchfry Encapsulon	5 + 3	Active dry yeast + Hatchfry Encapsulon Grade I (<50 microns) Argent Laboratories
Salmon Carcass	6	Frozen or fresh salmon carcass
Lamprey Carcass	6	Frozen Pacific lamprey carcass

For the weekly retrieval of each trap's sediment bags at each location (each rotary screen drum), we noted if scour or accretion of sediment had occurred within each bag over the prior week at each location. Where scour occurred, and large volumes of sediment lost from the sampling bags, we avoided re-deploying traps in these areas upstream or downstream of the rotary drum screen structure. Each week, we sifted sediment through 750 micron mesh screens and sorted through sieved material searching for juvenile/larval lamprey life stages. Additionally, we sorted, identified, and tracked relative abundances of macroinvertebrates which recruited into the sediments within each bag for each of the twelve traps.

From mid-July through the end of August, acting on observations we had made over the initial retrievals in June and early July, we decided to include added safety measures and to standardize our sampling methods. First, we sifted the excavated dry sediment through a 750 micron sieve and reduced the sediment volume placed into each reinforced nylon bag to 160 ounces, or 20 cups, sieved sediment. Sieving the dry sediment ahead of time allowed us to 1) select for a finer grain size sediment that will sift easily while searching for the lamprey and also removed sharp items, such as broken glass or ragged aluminum pieces, that could rip the nylon fabric of the mesh bags. We then increased and standardized the amendment types and amounts going into both sediment bags (Table 2).

Table 2: Summary Table of Sediment Amendments Mixed with Sieved Sediments Inside the Passive Sediment Fish Traps, from late-July through August, 2013.

Sediment Amendments	Weight (g)	Amendment Description
Late July – August		
Bag A: Straw +	30	Air-dried straw
Willow cuttings +	30	Willow cuttings
Organic Matter	30	Dry organic matter
Bag B:		
Straw +	150	Air-dried straw
Salmon or Lamprey Carcass	250	Salmon (fresh or frozen) or lamprey (frozen) carcass

Results

Sunnyside Diversion Water Levels and Temperature

Water levels at the Sunnyside Diversion were maintained at between 8.5 to 9.5 meters in depth from mid-June through August. Sunnyside Diversion was subsequently dewatered starting on October 15, 2013.

Passive Fish Sediment Traps

Captured larval lamprey ranged in sizes between 11-79mm, indicating the presence of at least three age classes of fish (0+ to 2+) (Figures 4 and 5 and Table 3). We captured more larval lamprey on the downstream side of the fish screens at Sunnyside Diversion than compared to the upstream side of the fish screens (Table 3). Only one larval lamprey was collected in a sediment trap placed in front of the upstream rotary drum screen at location U9.

On the other hand, in one sampling event, three larvae were captured at D1 and in two July sampling events, two larvae were collected at D10 (Figure 6). Larval lamprey were captured in sediment traps on the downstream Rotary Drum Screens at locations (from left to right): D1, D6, D9, and D10 (Table 3 and Figures 5 and 6).

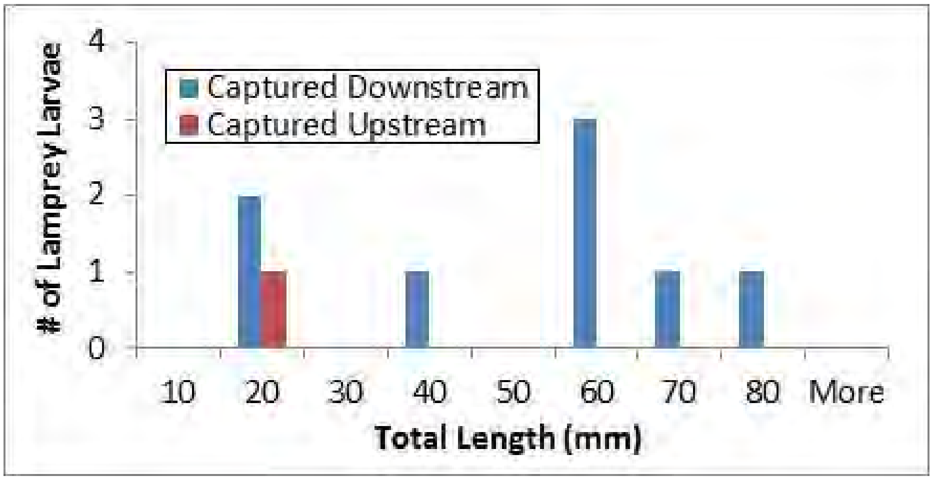


Figure 4: Histogram of total length (mm) for all lamprey larvae captured with the sediment traps at Sunnyside Diversion during the summer of 2013.

Table 3: Dates, fish length, approximate age class, sediment amendment type, and retrieval bay for all larval lamprey captured with the sediment traps at Sunnyside Diversion during the summer of 2013.

Date Collected	Fish length (mm)	Age Class	Sediment Amendment Type	Retrieval Bay (D = downstream; U = Upstream)
Downstream Fish Sediment Traps				
7/3/2013	40	1+	willow	D10
7/3/2013	51	1 to 2+	willow	D10
7/24/2013	11	0+	100g straw	D1
7/24/2013	14	0+	100g straw	D1
7/24/2013	52	1 to 2+	100g straw	D1
7/24/2013	60	2+	100g straw	D10
7/24/2013	79	3+	100g straw	D6
8/14/2013	65	2+	150g straw	D9
Upstream Fish Traps				
7/25/2013	16	0+	organic matter	U9

Figure 5: Pictures of lamprey larvae, showing examples of the smallest size class of 11+ (above) and the larger size class of 60+mm (below) collected in the sediment traps at the Sunnyside Diversion during the summer of 2013.

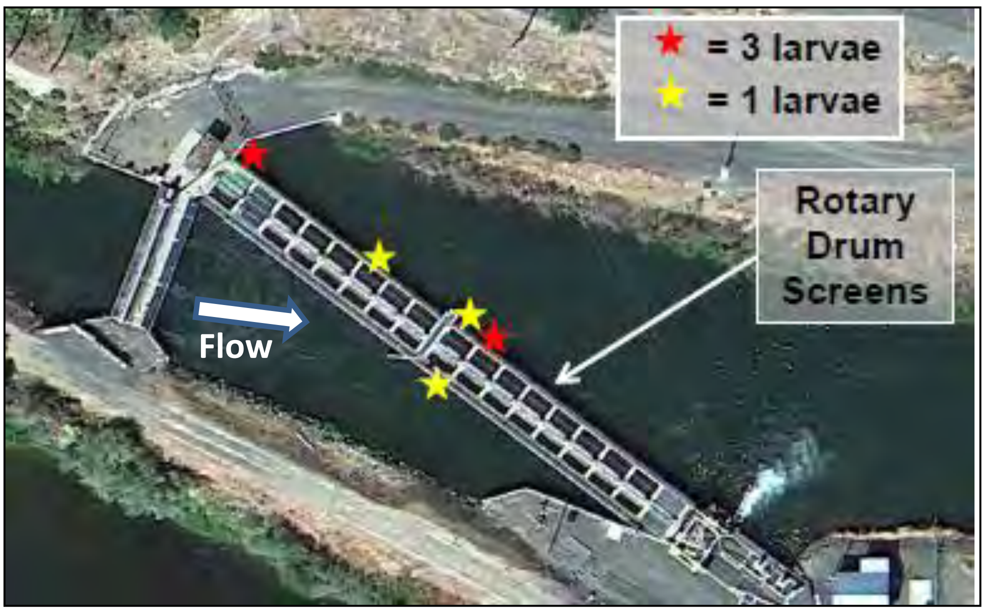


Figure 6: Areas where larval lamprey were collected using the sediment traps at Sunnyside Diversion rotary drum fish screen facility during the sampling period of Summer 2013. The rotary drum screen locations, from left to right, are D1, D6, D9, U9, and D10.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates collected include snails, limpets, crayfish, aquatic worms, leeches, midges, leeches, caddisfly, stonefly, and mayfly larvae, many of which typically cohabited the traps that contained larval lamprey (Figure 7).

Figure 7: Aquatic macroinvertebrates collected within the sediment mesh bags.

Despite the duration and intensity of monitoring efforts to collect larval lamprey, we had low lamprey recruitment from these particular collection designs. We observed that areas with increased flow tended to deposit less fine sediment on the diversion bottom and even scoured fine sediment from passive traps, thereby reducing trapping efficiency. Overall, straw was the most effective sediment amendment within the mesh bags to capture larval lamprey. Secondarily, mesh bags with willow cuttings and organic matter as sediment amendments also showed some success with capture. Because larvae as small as 20mm are in all probability 0+ age class larvae, this comparison indicates that those larval lamprey are moving past the fish screens actively during the irrigation season before dewatering takes place. Finally, we observed that traps that acclimated for fewer than seven days collected no lamprey and much fewer aquatic macroinvertebrates in general.

ii. Modified D-Frame Kick Net

Approach and Methods

In early August, we modified a traditional D-frame kick net by adding on an additional 8-foot wooden extension pole (Figure 8). We constructed this modified net to try to identify softer sediment areas on the downstream side of the rotary drum screens. The current on the upstream side of the rotary drum screen was too strong, so reliable sweeps of bottom sediments were not possible. This modified net was difficult to use because of the water depth and the currents coming off the backside of the rotary drum fish screens. Only one lamprey was caught with this modified net near the downstream rotary drum screen bay, D1.

Figure 8: Yakama Nation staff using the modified D-frame kick net (Left). Lowering the length of the pole to sweep towards the structure and quickly pull up and out of the water to turn the net out into a plastic tub on the structure (Right).

Recommendations

While in use in the diversion, the wooden extension pole constantly flexed. Eventually the extension pole cracked and split at the junction with the D-frame kick net's hollow metal pole. For any future design and use of an extended pole such as this, instead of wood, we recommend finding hollow aluminum pipe to reinforce or make up the extension length.

iii. Lessons Learned and Recommendations for Future Sampling at Sunnyside Diversion

Based on this pilot methods study at Sunnyside Diversion, we have arrived at a few key recommendations. First, based on low capture rates of this particular design of sediment fish trap that operated only on a weekly basis, we recognize that there were perhaps timing considerations for fish movements that our sampling method did not capture. Second, we were restricted to the areas we could reach with our boom and winch system to lower the heavy traps into the diversion, i.e. only immediately next to either side of the rotary drum screen structure. It is possible that more optimal fine sediment habitat for larval lamprey exists away from the fish screens and these areas would be identifiable once the diversion is dewatered.

Areas where we caught multiple lamprey in 2013 (D1 and D10) are at least two locations to focus for future seasonal monitoring. D1 is a slack water area where a lot of finer sediment, ideal for larval lamprey, settles out. Since Yakama Nation Fisheries biologists have mapped fine sediment areas where larvae were found in prior years after dewatering (YNFRMP 2012b), the comparison between previous data and these new data can help inform future monitoring efforts at Sunnyside Diversion.

In July, we had started to capture both lamprey and macroinvertebrates in the sediment traps, and this was after the excavated dry sediments had been placed in the diversion for at least three weeks and up to a month. It is possible that this soak time allowed the dry sediment to better match the sediments found in the diversion. This 'matching' may be important to lamprey larvae in the diversion as these young fish may have cued in on certain characteristics of river sediments that the dry excavated sediments lacked. This observation leads to more questions on sediment quality and chemosensory cues for larval lamprey—areas that warrant further investigation *in situ* and in applied field research projects. A sediment grab sampler may be helpful for sampling and characterizing diversion sediments (such as diatom diversity) and/or nutrient content analysis.

Since the current velocities vary considerably at each rotary drum screen at the structure, we observed scour and/or accretion into the sediment bags at some of our trap locations. We recommend either a different mesh bag design or a modification for the outer cage containing the two sediment bags. For a modified mesh bag design, we recommend a flat-bottomed bag with a slightly deeper area of solid fabric. Additionally, we recommend that the seams of the bag be re-enforced or sewn differently so that they are not vulnerable to splitting or tearing with the weight of sediment. Alternatively, either a solid bottom for the outer cage or internal sediment trays with 1-2.5 inch sides could reduce the loss of water and sediment from each sediment bag. As a final, more ambitious suggestion for monitoring and sampling when diversion waters are high, we suggest that a new design, such as a modified dredge pump and mesh sieve system, could help bring diversion bottom sediments to the surface (or land-side) of the rotary drum screen structure. Modifications to the dredge pump should carefully consider the size and fragility of the larval lamprey.

II. Prosser Hatchery Lamprey Experiments

i. W2 Tank Experiment

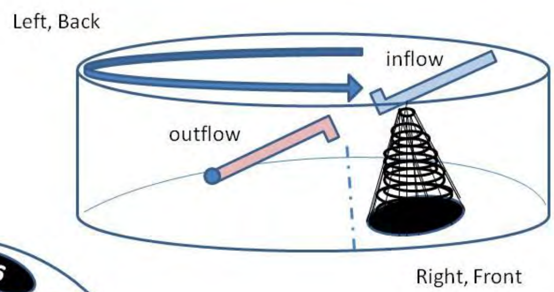
Pacific lamprey may play an important ecological role in the decomposition and retention of organic biomass in river systems. Lamprey have been described metaphorically as the earthworms of river ecosystems (Close *et al.* 2002). Since Yakima NFRMP biologists are presently trying to understand early life history feeding requirements, trials on larval feeding behavior can inform both efforts to culture lamprey and restoration efforts in natural stream areas. In mid-July through August, we initiated a pilot study—a sediment bag feeding experiment—in a 8-ft diameter, circular flowing tank (Figure 9) at the Yakama Nation Prosser Fish Hatchery in Prosser, WA (46°12’56.32”N, 119°45’32.54”W).

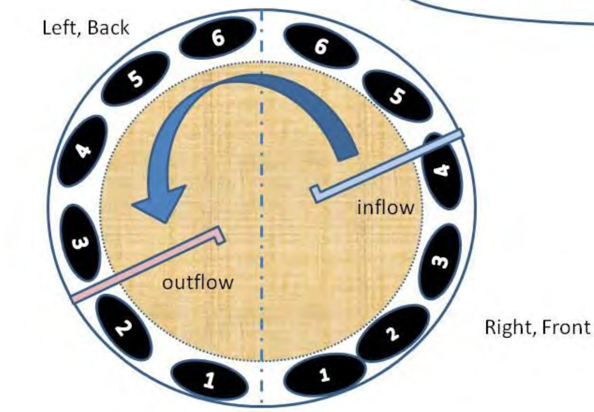
Figure 9: Photo of Vincent George, Heritage University undergraduate student and Yakama FRMP Intern, in front of the W2 Tank while setting up the feeding experiment.

Approach and Methods

The W2 Tank (approximately 8.4 feet in diameter and 2 feet deep) is a flow through tank supplied with 14° C well water, maintaining a temperature between 14° C and 16° C throughout the summer months. One and half weeks prior to launching the sediment bag feeding experiment began, we electroshocked (using a lamprey setting set at125 volts, 25% duty cycle, and 3 bursts per second current rate) with approximately 10 passes over the span of 1.5 hours), netted, counted and measured the size of fish in the W2 tank to get an estimate of how many total lamprey were present in the bottom sediments of the tank. Over 180 lamprey, ranging in size (as measured in fish length in mm) and age classes were captured and re-released back into W2.

Prior to the start or first deployment of twelve sediment bags, containing different amendments within the tank (Figure 10, see inset table bottom right), we swept the sediment towards the center of the tank, creating a 14-inch bare area around the outer circumference of the tank (Figure 10, bottom left). The twelve bags were placed in this bare area, with the long edge of the bag parallel to the tank wall. Each bag was knotted and the top of the mesh bag draped over the wall of the tank, keeping the mesh sides of the bag upright and open, ensuring that lamprey could freely swim in and out of the bag (Figure 10).





W2 Tank Sediment Bag Amendments	
x2	**x1**
salmon(60g)	lamprey (60g)
straw (60g)	straw (30g)
organic Matter (60g)	organic matter(30g)
willow (60g)	willow(30g)
Yeast (6 g)	Yeast (3g)
Control 1 (sand only)	Control 2 (sand only)

Figure 10: Schematic of the W2 tank at Prosser, Washington. Above right, the schematic shows a clear side view into the tank with the placement of a sediment bag and directional flow of water (indicated by the arrow, with the water inflow and outflow pipes for orientation). Schematic, bottom left, looking down into the tank, showing the placement of the 12 sediment bags in a rotating two block design, where the dashed line marks the block division within the tank. Inset table, bottom right, showing the W2 Tank sediment bag amendments for the experiment.

A random number generator was used to independently assign each amendment type to a position within each of the two blocks of the W2 tank. Bags were placed according to the random position assignment for the first four weeks of the experiment. In the fifth week, we rotated the block division by 90 degrees (Figure 11), in order to test for a general position effect within the tank (relative to the inflow and outflow pipes of the tank itself). Towards better understanding and checking for any possible within-tank effects, we compare the results (=fish recruitment into each sediment bag each week), "with" and "without" the block position assignment.

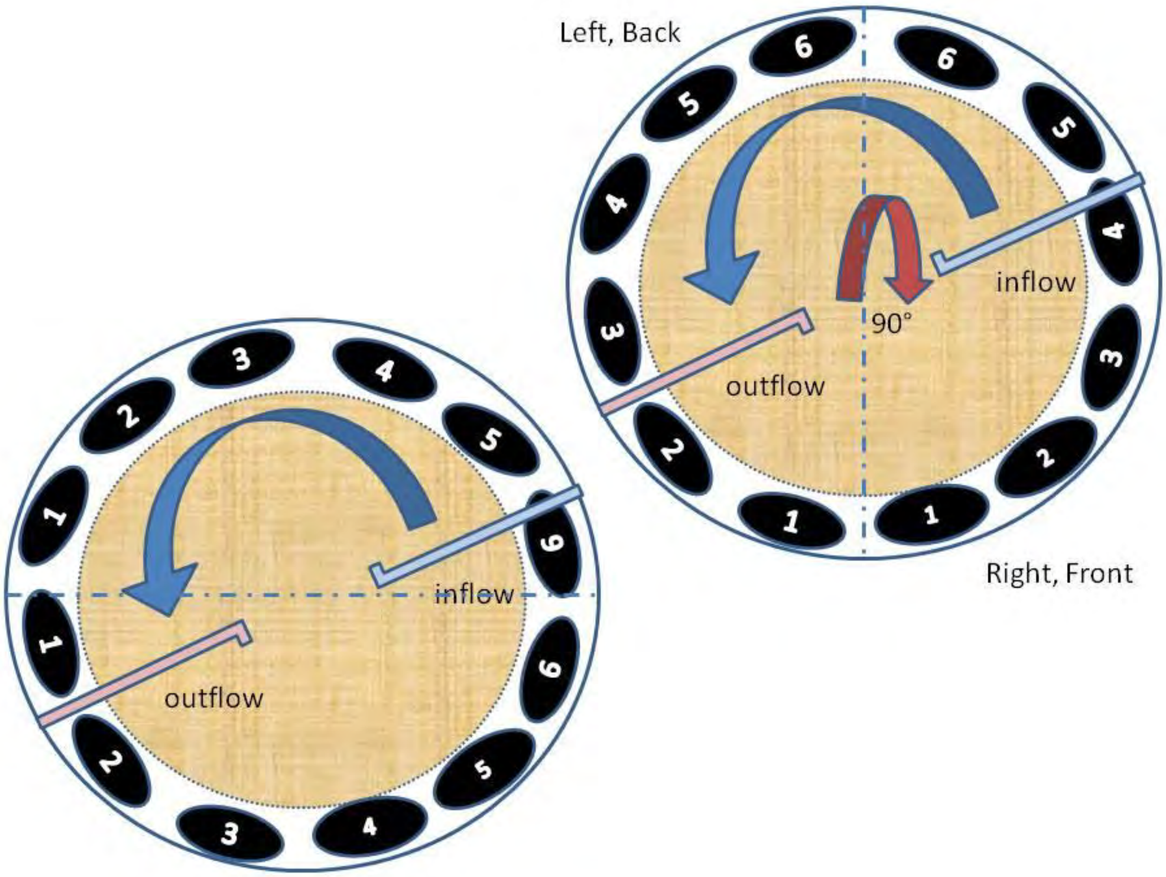


Figure 11: Schematic showing the 90 degree rotation (red arrow, upper right) of the alternating two block design for the assignment of sediment bag amendments to positions within the tank. The blue arrow shows the flow direction of water through the tank, from inflow to outflow pipes.

For each retrieval, we lifted the bag out of the W2 tank and placed them directly into a shallow plastic tub. We would then gently turn out the water and sediment from the mesh bag into the basin. In a deeper plastic basin or medium-sized cooler, we rinsed through the sediment and amendments, retaining these to put back into the mesh back prior to redeployment. Any fish found were set aside in a deep bowl or bucket of cold river water, for measurement and a total fish count. Fish length (mm) was measured. All fish were re-released directly over the center of the W2 Tank and were observed to ensure they did not enter any of the other mesh bags. Over the five weeks of this feeding trial, we replaced/replenished lost amounts of amendments as needed for amendments, such as salmon, lamprey, yeast, or organic matter. Finally, on the first week of retrieving sediment bags, we realized we had accidentally switched the placement block positions of the two sediment bags amended with different amounts of organic matter (60g versus 30g). This placement error did not seem to impact experimental outcomes.

Results

Although numbers varied widely from week to week, lamprey were found in most of the sediment bags over the five-week period of this experiment. A total of 198 lamprey were found in these bags during this 5-week experiment. One strong trend we found was that the total number of lamprey which entered the sediment bags each week increased over the course of the experiment (Figure 12).

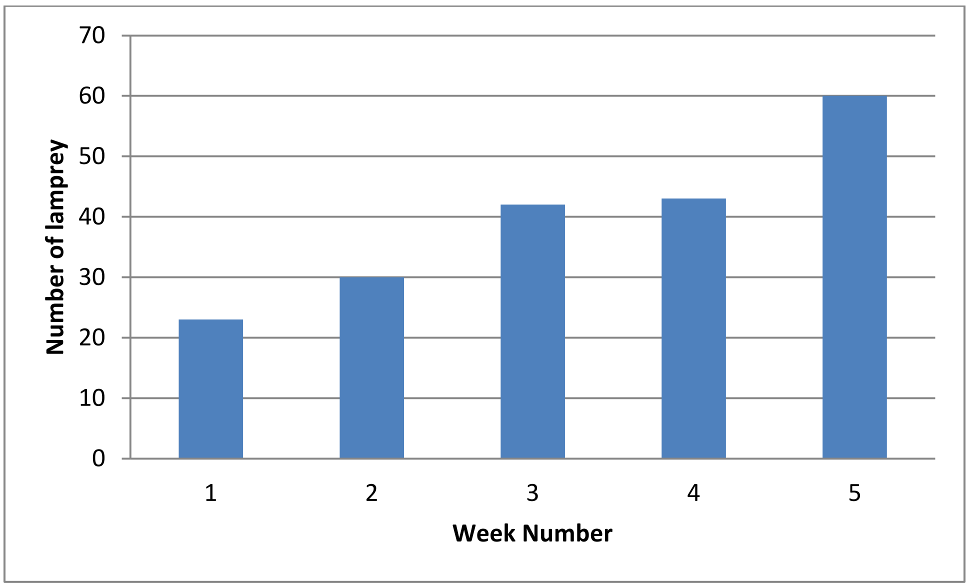


Figure 12: The total number of larval lamprey entering the mesh bags each week during the feeding experiment.

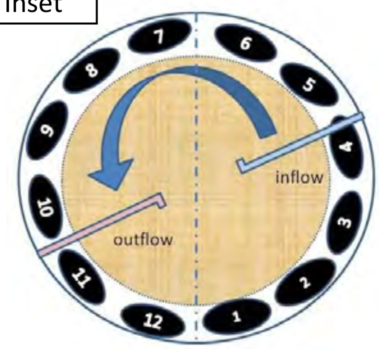
The mean size of lamprey entering the sediment bags was 47 $\pm$ SE 1.44 mm (with the standard deviation of 20.61). Over the five weeks, the median size of lamprey found in the sediment bags was 45mm, whereas the size class of fish entering the sediment bags ranged from the size classes as small as 25-30mm up to 160 mm in length (Refer to Figure 13(a) through 13(d)). Most fish which entered the sediment bags were between 30mm to 55 mm in length (Refer to Figure 13(a) and (b)).

Table 4 shows the total number of fish which entered a sediment bag for each given amendment over the five weeks of the experiment. Irrespective of the alternating block position assignments over the five weeks for each sediment bag (see inset for Table 4 on right), lamprey entered the sediment bags at the twelve possible tank positions between three or five times across all five weeks of the experiment.

Table 4: Table summarizing the total number of fish which entered a mesh bag with each given amendment (at each concentration) and the mesh bags with only sand (control bags for each block). Also listed are the positions for the twelve sediment bags, irrespective of the rotating two block design (refer to inset below).

Amendment	Total Number of Fish Which Entered Sediment Bags Over 5 weeks	W2 Tank Position, Irrespective of block (See Inset)
Control 1 (sand only)	9	5,7,10,11
Control 2 (sand only)	17	1,5,10,11
lamprey (60g)	26	3,6,8,12
organic matter (30g)	14	1,2,3,9,10
organic matter (60g)	13	4,5,7,11,12
salmon (60g)	22	1,6,7,8,9
straw (30g)	12	2,3,5,12
straw (60g)	16	6,7,9
willow (30g)	18	1,3,4,6,11
willow (60g)	15	3,8,10,11
yeast (3g)	19	1,2 ,4,7
yeast (6g)	17	4,6,10,12
	198 total	

Inset



Tank Position x Fish Position Talley

1 x 5	7 x 5
2 x 3	8 x 3
3 x 5	9 x 3
4 x 4	10 x 5
5 x 4	11 x 5
6 x 5	12 x 4

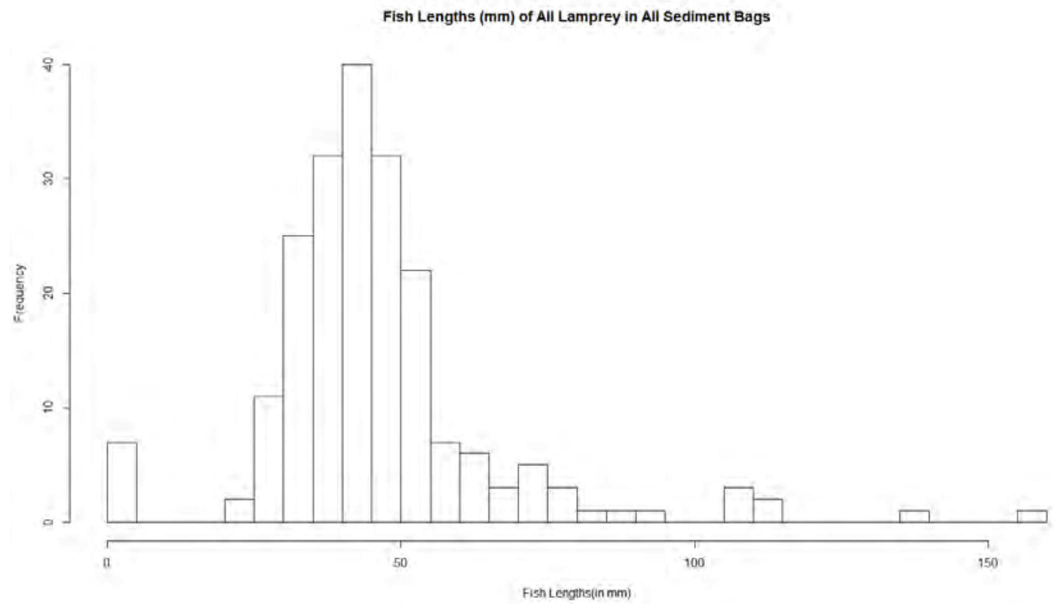


Figure 13 (a): Frequency histogram (in 5mm increments) of total length (mm) from all lamprey found in the sediment bags during the five weeks of the experiment.

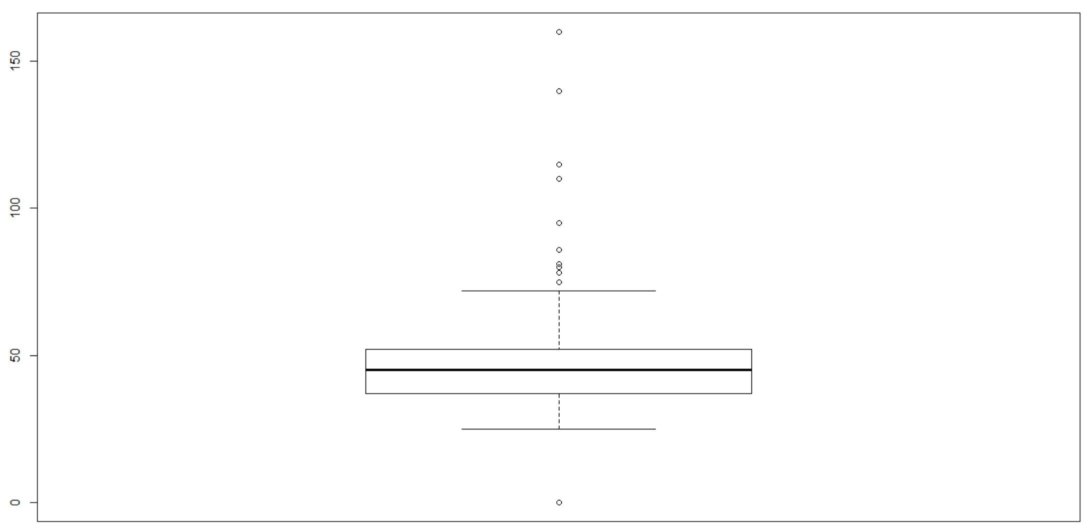


Figure 13 (b): Boxplot of fish lengths (in mm) for all fish which entered the sediment bags over all five weeks of the W2 Tank experiment.

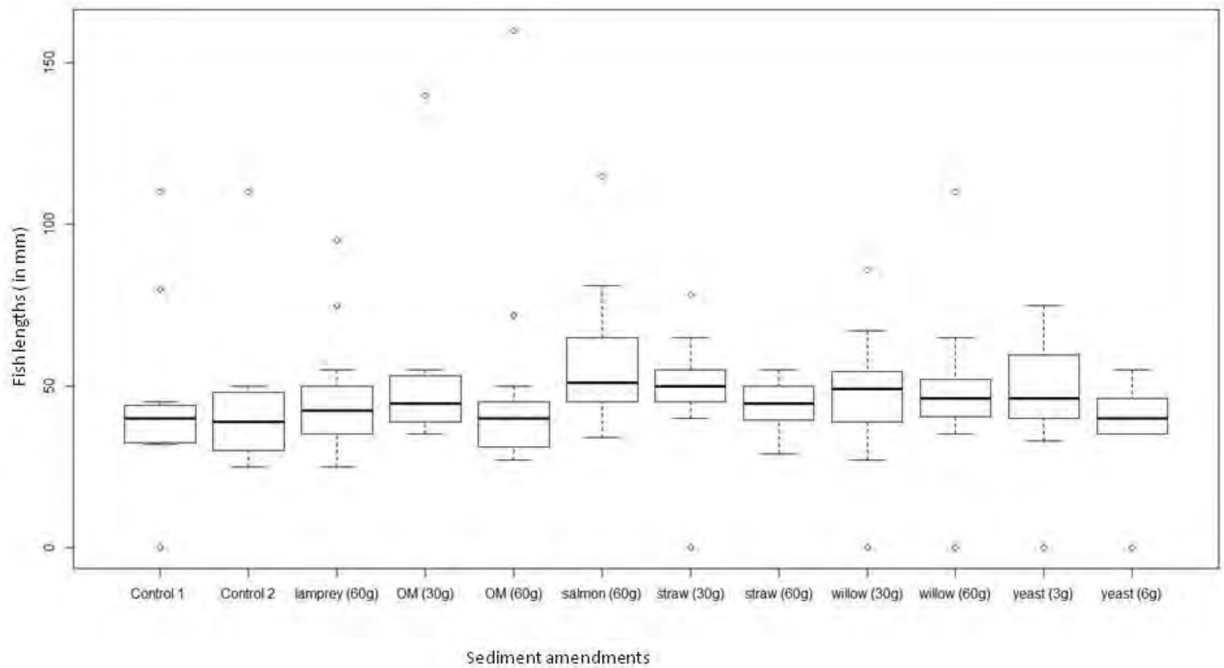


Figure 13 (c): Boxplots of fish lengths (in mm) for all fish which entered the sediment bags, broken out by amendment type across all five weeks of the feeding experiment. The Control 1 and Control 2 sediment bags had no amendments directly added into each bag. The zero data values shown above were included to reflect the six instances where no fish were found in the sediment bag.

Each Week

In Week 1, lamprey were not found in either the Willow (60g) or the Control 1 (sediment only) bags—both were placed on the right front side of the W2 tank at Position 2 and 3 (See Figure 12 and Figure 13 (a). The Lamprey (60g) sediment bag had the greatest number of fish, a total of four fish, ranging in size from 32mm to 52 mm in length. By comparison, the Salmon (60g) sediment bag had just one lamprey at 41 mm in length. The Organic matter (60g) sediment bag had the smallest sized lamprey of all sediment bags, measuring 27mm, whereas the Straw (30g) sediment bag had the largest lamprey, at 78 mm.

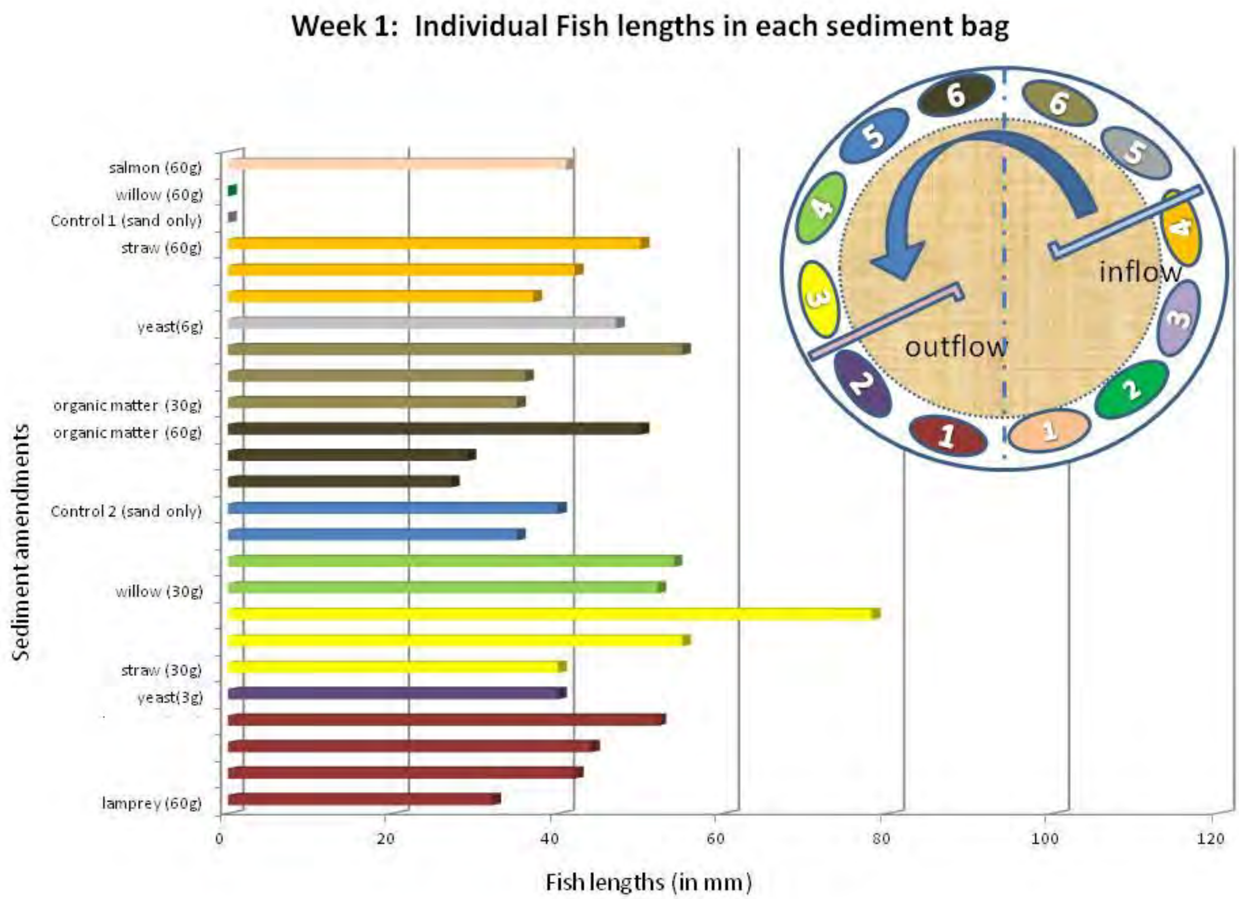


Figure 13 (a): Total length (in mm) of the lamprey which entered each sediment bag in Week 1 (n = 23) of the experiment. The sediment bag positions (alternating two blocks) are shown (inset schematic on the right).

In Week 2, no lamprey were found in the Yeast (3g) sediment bag located at Position 4, towards the right backside of the tank. On the other hand, five lamprey, between 35mm and 55mm in length, were found in the Yeast (6g) sediment bag. Two sediment bags, Yeast (6g) and Control (2) towards the back of the Tank (Figure 13(b)), were found to have five lamprey each in them—one third of the thirty lamprey total collected on this retrieval week. In the Yeast (6g) sediment bag, four of the five lamprey were between 35 mm and 46mm with the largest fish at 55 mm.

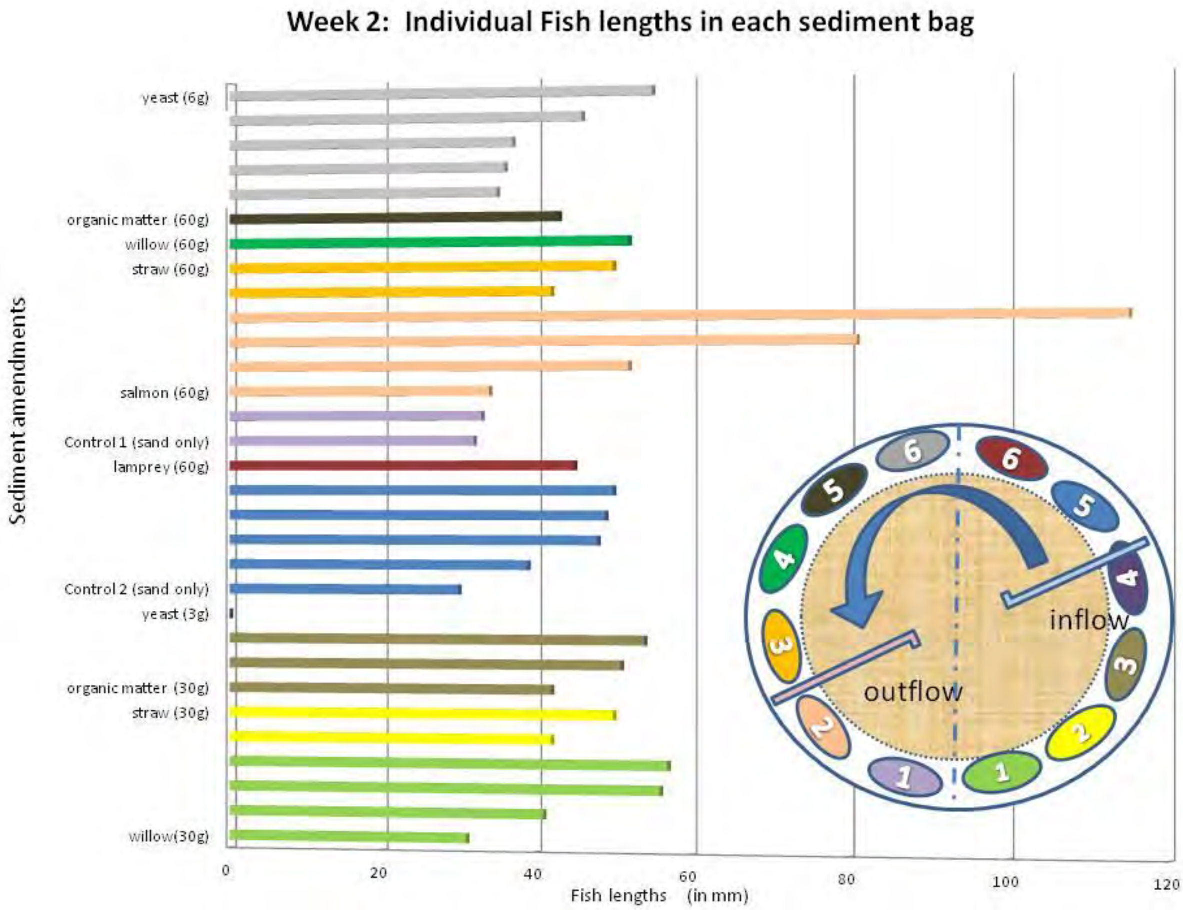


Figure 13(b): Bar chart of Individual Fish lengths (in mm) of the lamprey which entered each sediment bag in Week 2 (n=30) of the W2 Tank experiment. The sediment bag positions (alternating two blocks) are shown (inset schematic on the right).

In the Control 2 sediment bag, one lamprey was 30mm in length, another was 39mm and the three remaining lamprey were between 49 and 50 mm in length. The smallest lamprey found out of all sediment bags sorted in Week 2, at 30 mm, entered the Control 2 sediment bag, (Position 1 on the front right side of the W2 tank). The largest lamprey, 115mm in length, collected in Week 2 was found in the Salmon (60g) sediment bag (Position 2 on the front left side of the W2 tank) along with the second largest lamprey at 81 mm; another two lamprey found in this same sediment bag were 34mm and 52mm in length. Only one lamprey, of 45 mm, was found in the Lamprey (60g) sediment bag (Position 6 on the back right side of the W2 tank). Finally, the Willow (30g) sediment bag contained four lamprey, two of which were between 30mm to 40 mm in length and another two which were just over 55 mm in length.

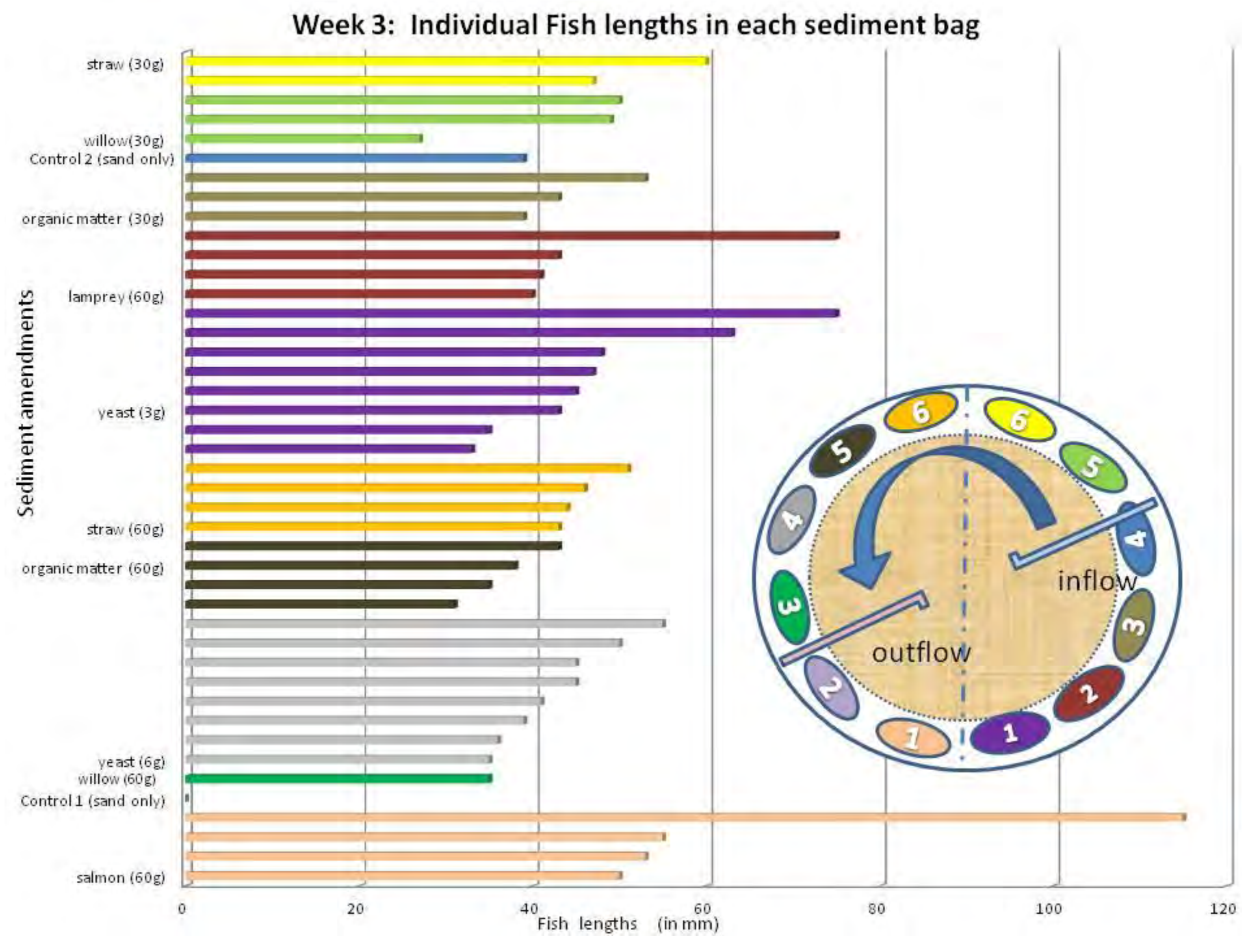


Figure 13 (c): Bar chart of Individual Fish lengths (in mm) of the lamprey which entered each sediment bag in Week 3 (n= 42) of the W2 Tank experiment. The sediment bag positions (alternating two blocks) are shown (inset schematic on the right).

In Week 3, no lamprey were found in the Control 1 (sand only) sediment bag at Position 2 on the left side of the W2 tank. The highest number of fish—eight fish per bag—was found in each sediment bag amended with Yeast. The Yeast (6g) sediment bag, at Position 1 at the front right position of W2, contained six lamprey ranging in size between 35-45 mm and two lamprey, one 50mm and one 55mm in length. The Yeast (3g) sediment bag contained six lamprey ranging in size between 33-48mm and another two lamprey measured at 63mm and 75mm. Four other sediment bags each contained four lamprey each: Salmon (60g) placed at Position 1 in the left front half of the tank (and next to the Yeast (3g) bag); Organic matter (60g) and Straw (60g), both placed on the back left half of the W2 tank; and the Lamprey (6g) sediment bag, also positioned next to the Yeast (3g) bag at the front right of the W2 tank. The three bags on the front side of the tank—Position 1 to the left of the dashed line, Position 1 to the right of the dashed line and Position 2 on the front right—contained a total of 16 lamprey, including the three largest lamprey, (115mm, 75mm, and 75mm), collected in the sediment bags in Week 3.

In Week 4, (Figure 13 (d)) no lamprey were collected in both the Straw (30g) sediment bag (at Position 6, back left of W2 tank) and the Willow sediment bag (Position 6, back right of the W2 tank).

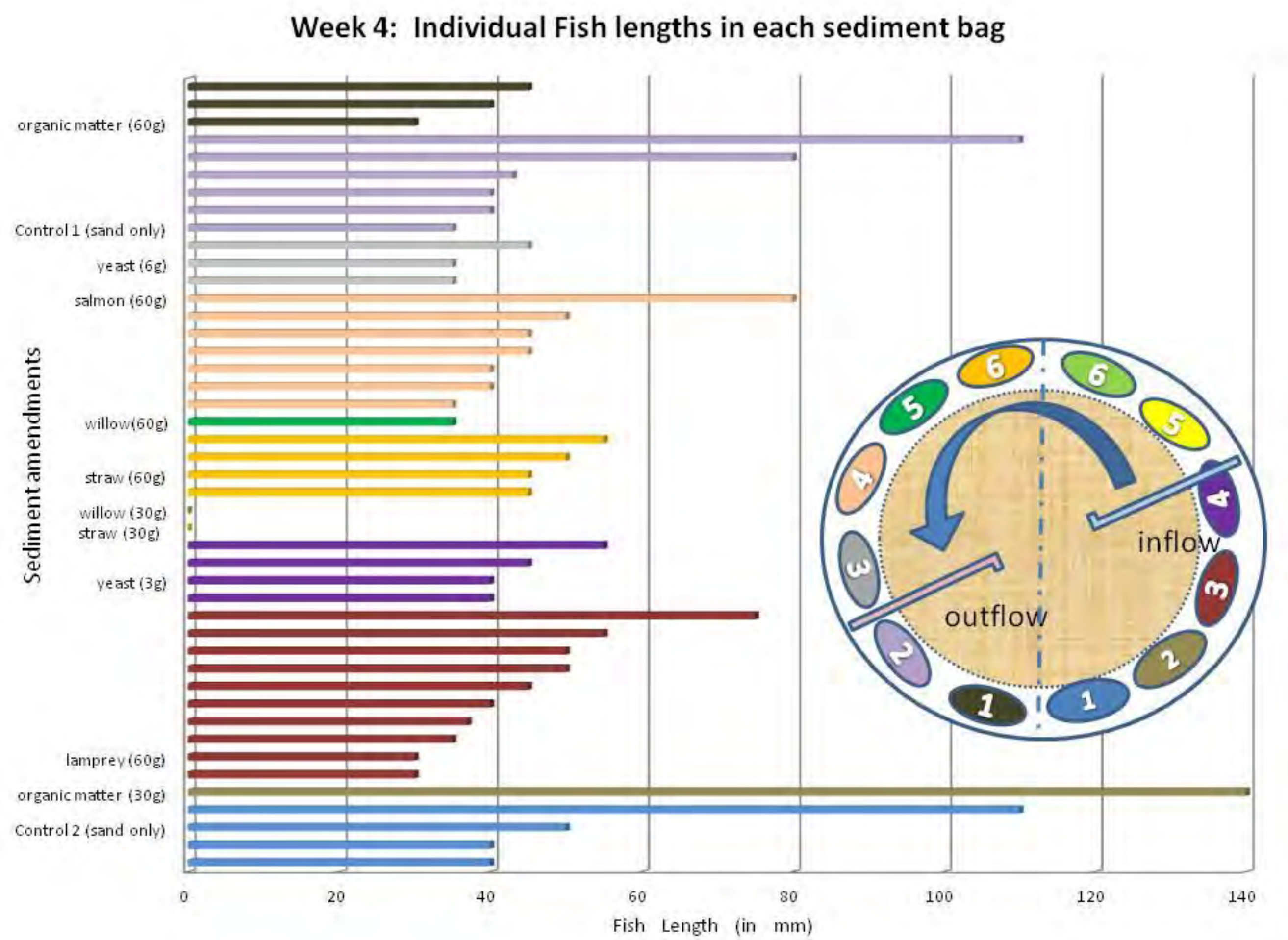


Figure 13 (d): Individual Fish lengths (in mm) of the lamprey which entered each sediment bag in Week 4 (n=43) of the W2 Tank experiment. The sediment bag positions (alternating two blocks) are shown (inset schematic on the right).

The Organic matter (30g) sediment bag had the largest lamprey caught up until Week 4, at 140mm, and also the second largest lamprey found in all bags across all five weeks of the feeding experiment. The second and third largest lamprey, each 110mm, collected in Week 3 were both found in the "sand only" Control 1 and Control 2 sediment bags, (both towards the front of the W2 tank); the fourth and fifth largest lampreys caught, each 80mm, were found in the Salmon (60g) sediment bag, (Position 4, back left side of the W2 tank), and the Control 1 sediment bag. Ten fish were found in the Lamprey (60g) sediment bag, ranging from 30mm up to 75mm (five fish between 30-45mm and another three fish between 50-55mm), with the 75mm lamprey being the sixth largest lamprey collected from all of twelve bags in Week 4. Seven lamprey were found in the Salmon (60g) sediment bag and six lamprey were found in the Control 1 sediment bag. Four fish were found in the Straw (60g) sediment bag, (Position 6, back left of the dashed block line) and the Yeast (3g) and the Control 2 sediment bags, adjacent to one another on the front left of the W2 tank.

In Week 5, we collected the highest number of lamprey, 60 fish total, from all bags over the five weeks of the feeding experiment. Eleven sediment bags contained fish in Week 5.

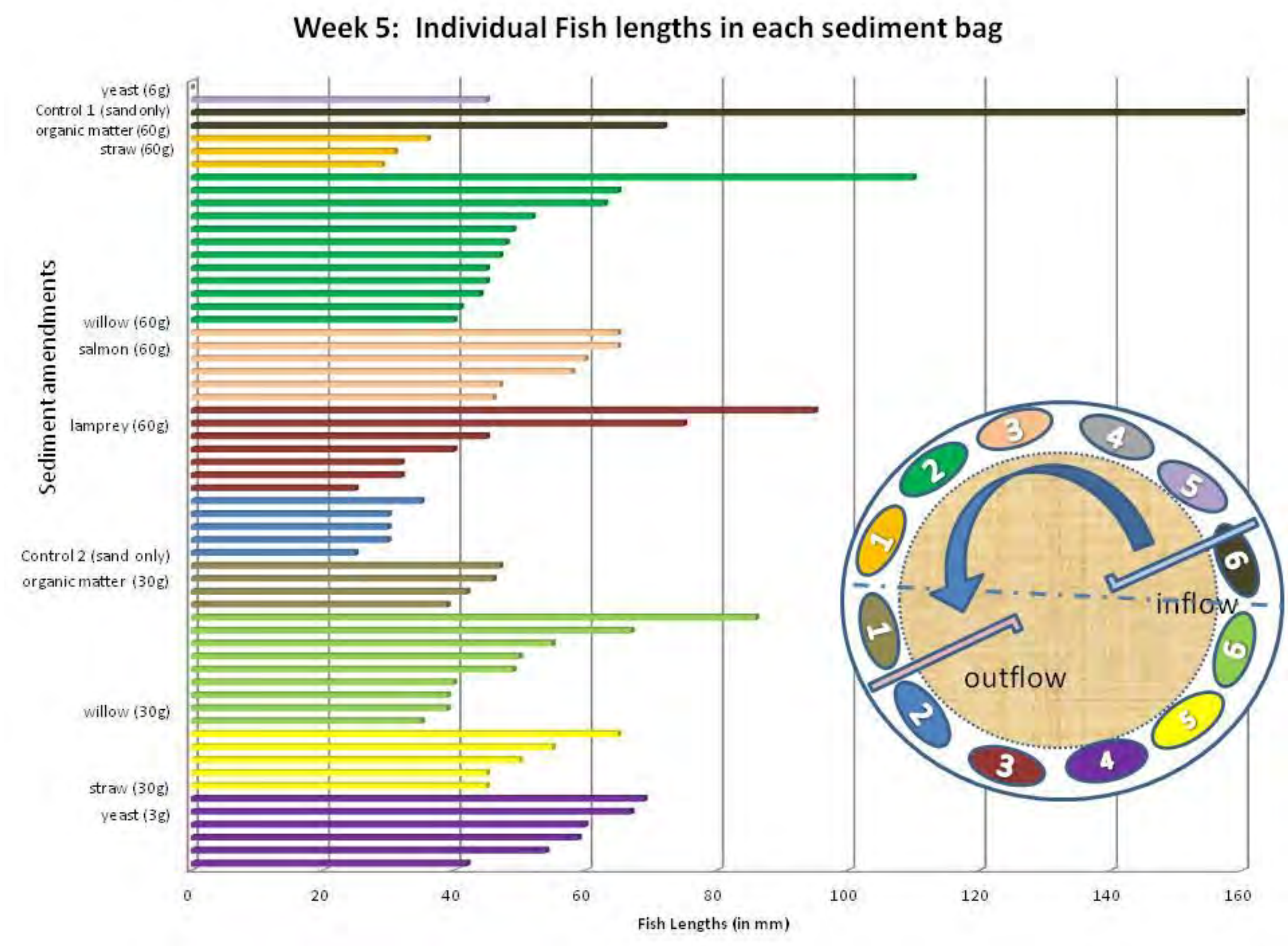


Figure 13 (e): Individual Total lengths (in mm) of the lamprey which entered each sediment bag in Week 5 of the W2 Tank experiment. The sediment bag positions (alternating two blocks rotated 90 degrees) are shown in the schematic on the right.

Only the Yeast (6g) sediment bag was found without any lamprey burrowed into the sediment bags to feed. The largest lamprey found in a sediment bag, in all five weeks of this experiment, was 160mm in length. This 160mm lamprey was in the Organic matter (60g) sediment bag alongside the third largest lamprey caught in Week, at 72mm in length; the second largest lamprey found in Week 5 was 100mm in length and was found in the Willow (60g) sediment bag. Interestingly, the highest number of lamprey were found in the sediment bags amended with Willow (60 g versus 30 g). The Willow (60g) sediment bag, (Position 2 for the 90 degree rotated block in Week 5, or back left of W2 above), also contained the second largest lamprey which entered into a bag in Week 5, at 110mm; nine of the lamprey collected ranged between 40mm to 52mm; and another three lamprey ranged between 52mm to 65mm. The Control 2 sediment bag had smaller sized lamprey ranging from 25 mm to 35 mm in length.

Recommendations

We saw an increase in the total number of lamprey entering our sediment bags each week. The increase can possibly be attributed to 1) lamprey needing some acclimation time to get used to rearing in the mesh bags or 2) lamprey slowly starving over time from limited amount of feed that was added. The W2 tank still received weekly feedings of active dry yeast, albeit at a reduced rate (5g / week). Since the availability of tank space and larval lamprey were limited, we could only conduct this feeding experiment in the W2 tank for five weeks during the summer. We recommend conducting a trial like this for eight to ten weeks that follows what was attempted in Week 5 of our experiment. Thus, we recommend that the experiment follow a two block design (for the high and low treatment strengths in relation to the inflow and outflow pipes of the tank) that also includes 90 degree rotation each week for the random placement of the sediment bags.

ii. Petri Dish Experiments

Approach and Methods

From July 22, 2013 through August 27, 2013, at the hatchery in Prosser Washington, we initiated a 5-week petri dish feeding trial with hatched larval Pacific lamprey, or ammocoetes, similar to a prior feeding trials conducted in the summer of 2012 (Farias *et al.* 2012). The larval lamprey utilized in this pilot experiment originated from adults collected from the Willamette River, and propagated at the hatchery. Larval lamprey had been reared to a size class of approximately 8-10mm at the Yakama Nation hatchery in Prosser, Washington. Initially, we started an experiment in two independent 10-gallon aquaria in the culture room at the hatchery, but an unforeseen leak from one of the tank led to a loss of larvae at the start of this study. We then relocated the petri dish experiments to two sections (each approximately 32x 16 x 14 inches) of a large flow-through trough (83-gallon trough tanks measuring 180x16x14 inches in total) in the larval rearing room at the Prosser hatchery.

A rotating two block design was selected to test food amendments (or feed) to the sediment at two concentration strengths, a high or low feed 'dose' (a block design similar to the W2 tank experiments). We dispersed 45 to 50 healthy (active, normally swimming) larval lamprey into each aquaria/trough compartment and allowed them to swim down towards the bottom of the trough section. A random number generator allowed us to randomly assign positions for each type of feed in each of two blocks (six dishes) in the two trough compartments.

In each section, we coated the bottom of the trough section with fine, sieved sand of a grain size fine enough for larvae of this size class. Twelve petri dishes, of a standard 3-1/2" x 5/8" (or 100mm x 15mm) size, were then placed in rows equal distances from the sides of the trough section's walls and equal distances from one another. The sediment at the bottom of each trough section was smoothed and leveled to match the edge of all twelve petri dishes.
To ensure that the larvae had enough food over the course of the week, each trough compartment was fed a 2.5g yeast solution at least 5 days each week. Larvae were left alone for six to seven days before each dish was removed (to sort for larvae, Figure 14 and Figure 15) and then re-set. After the dishes were reset on August 12, 2013, and due to low recruitment to

the dishes in the trough compartments, we allowed the troughs to sit for 2 weeks before breaking down the feeding trial on August 27, 2013. No larvae were found in any of the dishes upon the break down of the experiment.

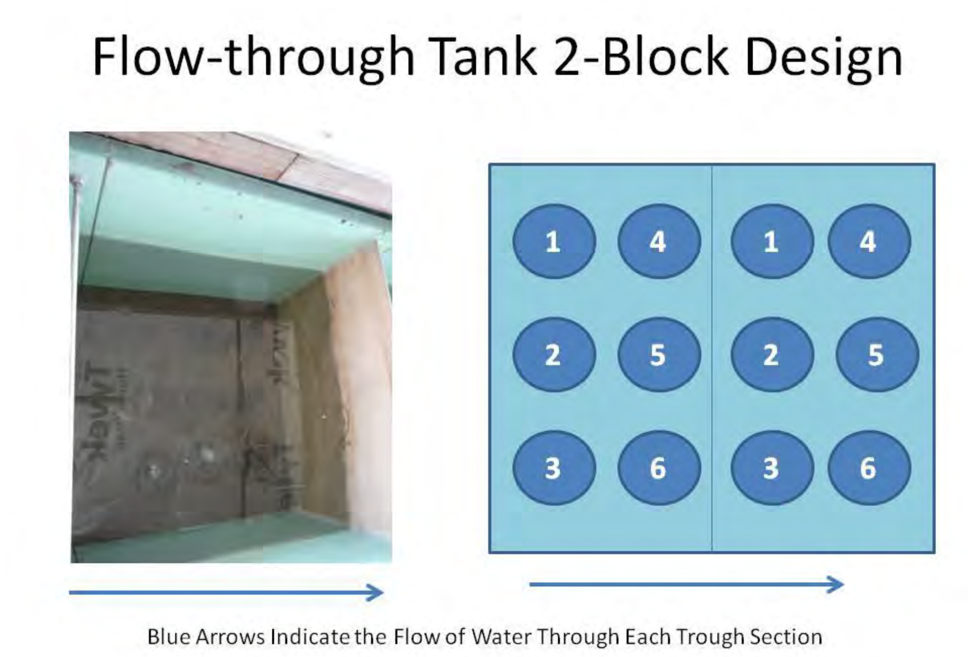


Figure 14: Picture of a set-up trough, on left, with 12 petri dishes and their assigned amendments. A schematic, on right, of the position assignments for each half of the trough. The blue arrows indicate the flow of water through each trough section. Trough 2 was upstream of Trough 3.

Figure 15: Picture of the twelve sediment-filled petri dishes retrieved from a trough, and ready for sorting to find any larval lamprey.

Overall, we saw low recruitment of larvae to the petri dishes in both the 10-gallon aquaria (before the leak was discovered) and the incubation trough. On July 28, 2013, larval lamprey were found in petri dishes amended with willow clippings; a total of 6 larvae, with 4 larvae in the dish with 1g willow cuttings and 2 larvae in the dish with 0.5g willow leaf cuttings. On August 5, 2013, in Aquaria 9 we found 2 larvae total: 1 live larvae in a control petri dish (sand only) and also found what appeared to be 1 dead larval lamprey in a dish amended with 0.5 g straw; the second larval lamprey was found in a dish amended with 0.5g organic matter. We also saw low recruitment of larvae to the petri dishes when we ran the feeding trials in the two incubation trough compartments.

Recommendations

We observed that larvae were not attracted into the petri dishes with the amendments. We recommend that this experiment be attempted again in the Summer of 2014. During the first check of the larvae in Trough 2 and Trough 3, we noticed that larvae were concentrated in the sediment outside of dishes along the screen walls of the trough. It is possible that the flow of the water through the outer sediment was a better environment for larvae of this size, especially for oxygen. As a future recommendation, it would be possible to create small plots of sediment with mesh or screen sides so that better flow occurs within each petri dish. We only checked these dishes once a week. Since it is possible for larvae of this size to die, break down and biodegrade rapidly in the tank, (without leaving a trace), we recommend that a future repetition of these petri dish feeding trials be checked at a different time interval—perhaps on a rotation of every three days.

iii. Formalin Trials

At the hatchery in Prosser, Washington, Yakama Nation FRMP biologists are developing methods for rearing hatched larval lamprey. Developing safe sterilization methods to protect larvae against disease and infections is an important component of rearing methodology. Commonly in aquatic culture systems, hatcheries must sterilize and keep tanks and culturing equipment clean and free of the build-up of harmful fungal and/or bacterial growth. In July, once larvae had successfully been hatched from spawned adult lamprey from the Willamette Falls, we conducted two lethal dose formalin trials to determine what strength of formalin treatment could be safe to lamprey larvae of the approximate size class 8-11 mm.

Methods and Approach

In mid-July (July 17, 2013 and July 23, 2013), two replicates of the lethal dose formalin trials were conducted at the hatchery in Prosser, Washington. Five 5-gallon buckets were used to conduct each trial. Ten liters of well water was poured into each bucket and we then added the appropriate amount of formalin product to test five formalin concentrations, from low to high: 1:24000, 1:12000, 1:6000, 1:3000, and 1:1500 percent solutions. From trough sections with hundreds of newly hatched larvae (larvae produced from Willamette Falls adults), we selected ten healthy, actively swimming lamprey larvae for each concentration. To keep the formalin buckets cool over the course of the trial, we placed each bucket into an empty trough section in the flow through troughs of the lamprey larvae culture room. Once fish were added to each formalin treatment bucket, we observed the swimming behavior of the larvae at 15 minute intervals for a minimum of 1 hour. Notes were recorded on: where in the bucket the larvae were (bottom of the bucket, water column, or at the surface); each larvae's swimming behavior; the swimming behavior; and responsiveness of each larvae when "disturbed." For the first run through of the trial, we recorded short videos to characterize larvae behavior. To observe their swimming behavior, if the larvae were at rest, we would gently sweep a probe (a long zip tie) within a 1 centimeter circumference of each larvae's location within the bucket. We then observed the ability of the larvae to swim and move away from the disturbance. At the end of each of the two formalin trials, we gently rinsed the larvae off and placed them in a recovery bath for 20 min to monitor further changes in lamprey status.

Results

In the 1:24000 and the 1:12000 percent formalin solutions, larvae appeared less agitated, resting and swimming normally when disturbed as well as able to swim for more sustained amounts of time (> 5 seconds, often >8 seconds). In the 1:6000 formalin solution, at the start of the experiment, larvae appeared slightly agitated but swam actively and normally. At the 15 and 30 minute mark, we observed less resting behavior compared to the lower formalin concentrations (1:24000 and 1:12000 solutions). At the 45 minute mark, we observed more resting behavior than at previous observation times. At the hour mark, all larvae were alive and able to actively swim for sustained bursts greater than five seconds. At the recovery observation, all larvae seemed to behave normally.

In the 1:3000 formalin solution, larvae exhibited less resting (at the bottom of the bucket) and appeared slightly agitated at the first observation period (15 minutes). At the 30 minute mark, all larvae were still active with three of the larvae exhibiting a twitching motion of their heads. By 45 minutes, the larvae either exhibited short bursts of swimming activity which we referred to as lethargic swimming—i.e. swimming, coasting and then swimming briefly again. The larvae observed at rest were less responsive (transition from rest to swimming) to the gentle probe. Immediately upon placement into the 1:1500 percent formalin solution, the larvae swam aggressively, seemingly agitated. This highest concentration rendered most larvae sluggish and largely unresponsive within 30 minutes. Within 45 minutes to an hour, the 1:1500 solution proved lethal to all 10 larvae for the first trial (July 17, 2013). After the second formalin lethal dose trial, only one larvae (out of 10) was revived after 20 minutes in a recovery bath of fresh water.

In conclusion, formalin solutions below a 1 percent solution, or strength, do not seem to impair lamprey larvae of the 8-11mm size class. Formalin solutions above 2 percent appear to impact lamprey larvae swimming behavior and responsiveness. Formalin solutions above 4 percent appear to be lethal, at worst, or can strongly anesthetize most larval lamprey under 11mm.

IV. References

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A Mark-Release-Recapture Study in Congdon Diversion (Naches, WA) to Assess Dispersal and Entrainment of Larval/Juvenile Lamprey

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Abstract:

Among the many causes of decline, irrigation diversions may potentially be a major threat to Pacific lamprey (*Entosphenus tridentatus*) as young larval lamprey are small enough to pass through fish screens that meet the NOAA Fisheries guidelines. At Congdon Diversion (Naches, WA), we conducted a mark-release-recapture study on larval/juvenile lamprey, using a total of 190 Western brook lamprey (31-171 mm) and 1,256 Pacific lamprey (7-25 mm). We conducted three types of release tests (trap efficiency release, screen release, and upstream release tests) in addition to the dewatered canal sampling. The main objective of this study was to understand

the mechanism through which larval lamprey pass the fish screens. The second question we pursued was the "fate" of juvenile/larval lamprey that enter a diversion.

The trap efficiency tests indicated that larvae can be effectively recaptured within various areas of the diversion (such as bypass and canal outlet channels). Through the screen tests, we observed and documented a wide variety of behavior in front of the fish screens, which we categorized into six general modes, including "escaped", "averted", "rolled", "impinged", and "passed." These various modes of behavior were strongly dependent on the size classes of the larvae; for example, 85.7% of the large larvae (>85 mm) were able to "avert" the screens whereas 94.1% of the 0+ age larvae "passed" directly through the screens. As a result of the upstream release tests, we discovered that the vast majority of larvae remained inside the diversion and very few larvae actually moved out into the bypass (<3%) or canal outlet channels (<2.4%) immediately after release. The distribution and abundance of fine sediment within the diversion may play a large role in where larval lamprey will disperse. However, over time these larvae appear to be moving out of the diversion; via dewatered canal sampling using VIE tags, we found that only a small portion of larvae (<7%) remained at the diversion after dewatering. Furthermore, many of the VIE tagged larvae were found below the fish screens, regardless of size classes, indicating that even large lamprey (>124 mm) can be vulnerable to entrainment. Although this mark-release-recapture study provided numerous valuable insights regarding lamprey entrainment and dispersal mechanism within irrigation diversions, many critical questions still remain.

Acknowledgements:

First of all, we would like to thank Robert Smoot (Yakima Valley Canal Company) for graciously allowing us to conduct this study at Congdon Diversion on a short notice. Jarod Hutcherson (Bureau of Reclamation) provided much needed expertise and outstanding support from start to end on this project. We also want to thank the three volunteers that helped us during the screen release experiment on September 25, 2013; Gaylord Mink set up and supervised underwater filming to document the lamprey behavior in front of the fish screens (using his own personal equipment); Joel Hubble (Bureau of Reclamation) controlled the position of the underwater camera in front of the fish screens; and David Child (DC Consulting) took detailed notes on the behavior of the lamprey. Al Potter assisted us for the upstream release experiment on September 26, 2013, and supplied many photos he took during the day, some of which were used in this report. Many others provided crucial insights and inputs leading to the study, including Susan Camp, Zackary Sutphin, Eric Best, and Arden Thomas (all Bureau of Reclamation) and Patrick Luke, Bob Rose, Tim Reissue, Ryan Deknikker, and Nathan Longoria (all Yakama Nation Fisheries). Lastly, we would like to thank the Bureau of Reclamation for providing the funding necessary to conduct this research on juvenile lamprey entrainment.

Introduction:

Since the 1960s, Pacific Lamprey (*Entosphenus tridentatus*) populations have been declining throughout the species range and local extirpations are occurring or have occurred in many of the Mid and Upper Columbia River watersheds. Among the many causes of decline, irrigation diversions may potentially be a major threat to the species as young larval lamprey are small enough to pass through fish screens that meet the NOAA Fisheries guidelines. The Yakama Nation Fisheries (YN) had the opportunity to work with Jarod Hutcherson, a Bureau of Reclamation (Reclamation) Fish Biologist from the Denver Colorado office, to conduct a two-week juvenile entrainment study between September 16 and 26, 2013. A meeting was held on September 16, 2013 with the local Reclamation and YN personnel to discuss and determine the best design for this short-term study. We had juvenile Western brook lamprey salvaged from 2012-2013 canal surveys and Pacific lamprey 0+ larvae that were artificially propagated at Prosser Fish Hatchery and hence available for a potential mark-release-recapture study.

Initially, we were planning to conduct the study in Sunnyside Diversion (Wapato, WA), but the sheer size of the facility (approximately 1,300 cfs per day) makes any kind of mark-release-recapture study on a small elusive larval fish extremely difficult, if not impossible. With the current technology, pit tagging of small larvae for remote detection is unfeasible due to their small size and shape. In fact, 0+ age class larval lamprey start off as small as 6 mm (long) x 0.6 mm (wide), which is roughly four times smaller than 3/32" (2.38 mm) – the maximum screen opening size guideline set by NOAA Fisheries. Therefore, it made sense to conduct the study in a much smaller facility than Sunnyside Diversion where monitoring would be more practical and achievable within the time frame we had available.

A list of potential surrogate sites included: West Side (Yakima R.), Taneum (Taneum Cr.), Olney (Toppenish Cr.), Lafortune-Powell (Naches R.), and Congdon (Naches R.) diversions. After visiting each site, we selected Congdon Diversion for the study due to its compact size and its close resemblance to Sunnyside Diversion in the following features: 1) similar woven wire mesh / rotating drum screens, 2) large deposition of fine sediment within the facility, and 3) moderate water velocity rates by the fish screens.

Many of the larval lamprey can pass fish screens due to their skinny and long eel-like body shape as shown by Rose and Mesa (2012) in "Effectiveness of Common Fish Screen Materials to Protect Lamprey Ammocoetes." Since 2010, dewatered canal surveys, performed by the YN in collaboration with the Reclamation, have shown that large numbers of juvenile/larval lamprey (up to several thousands in Wapato and Sunnyside diversions) are entrained below fish screens throughout the Yakima River Subbasin.

To develop a preventative solution to juvenile lamprey entrainment, a key question we pursued was "How are lamprey getting through the fish screens?" Among the many types of fish screens, we focused on woven wire mesh screens on rotary drums as they are one of the most common types of screens for large facilities within the Yakima Subbasin that typically entrain a large number of larval lamprey. The main objective of this study was to understand the mechanism through which larval lamprey pass the fish screens. Do larval lamprey simply swim through the woven wire mesh screens, roll over the rotating drum screens, or use alternate routes we do not yet know about?

The second question we pursued in this study was the "fate" of juvenile/larval lamprey that enter a diversion. What is the proportion of juvenile/larval lamprey that exit through the bypass in comparison to those that swim through the fish screens and migrate down the canal, or simply burrow and hold within the fine sediment available above and below the fish screens? Although conditions can be considerably different at each and every diversion, understanding the general mechanism of lamprey entrainment and their fate within Congdon Diversion will likely provide useful insights to develop preventative solutions and tools to deal with the existing entrainment problems that lamprey currently face within the Yakima Subbasin.

Methods:

Study Area

Congdon Diversion is located on the right bank of the Naches River about 4 miles east of Naches, WA, and adjacent to Eschbach Park (Figure 1). The diversion, owned by Yakima Valley Canal Company, supplies approximately 54 cfs (1.529 m^3/sec) during the irrigation season. During the study period (September 24-26, 2013), discharge was approximately 37.08 cfs (1.050 m^3/sec; 87.5% of the overall discharge) for the canal outlet channel, 5.30 cfs (0.150 m^3/sec; 12.5% of the overall discharge) for the bypass channel, and 42.38 cfs (1.198 m^3/sec; 100% of the overall discharge) for the inlet channel, based on discharge data from Yakima Valley Canal Company and Washington Department of Fish and Wildlife. Water depth was approximately 1.32 m at the inlet (by the trash racks), 1.33 cm by the fish screens and the bypass channel, and 0.92 cm in the canal outlet channel. Width was 6.52 m at the inlet, 12.57 m at the fish screens, 0.46 m at the bypass channel, and 3.62 m at the canal outlet channel. Based on discharge rates and size dimensions, water velocity (m/sec) was estimated to be 0.32 m/sec within the canal outlet channel, 0.25 m/sec within the bypass channel, 0.14 m/sec at the inlet channel by trash racks, and 0.07 m/sec at the fish screens. There are three rotary drum fish screens (each 4 m long), which are equipped with woven wire mesh with an opening of 3/32" (2.84 mm) (Figure 2 and Figure 3). Starting on October 15, 2013, flow was turned down rapidly in preparation to end the irrigation season. Deepest water depth was only 0.25 cm by the upstream side of the fish screen area during the dewatered canal sampling on October 16 and 17, 2013. The study consisted of six major phases: 1) fish tagging, 2) acclimation, 3) trap efficiency release, 4) screen release, 5) upstream release, and 6) dewatered canal sampling.

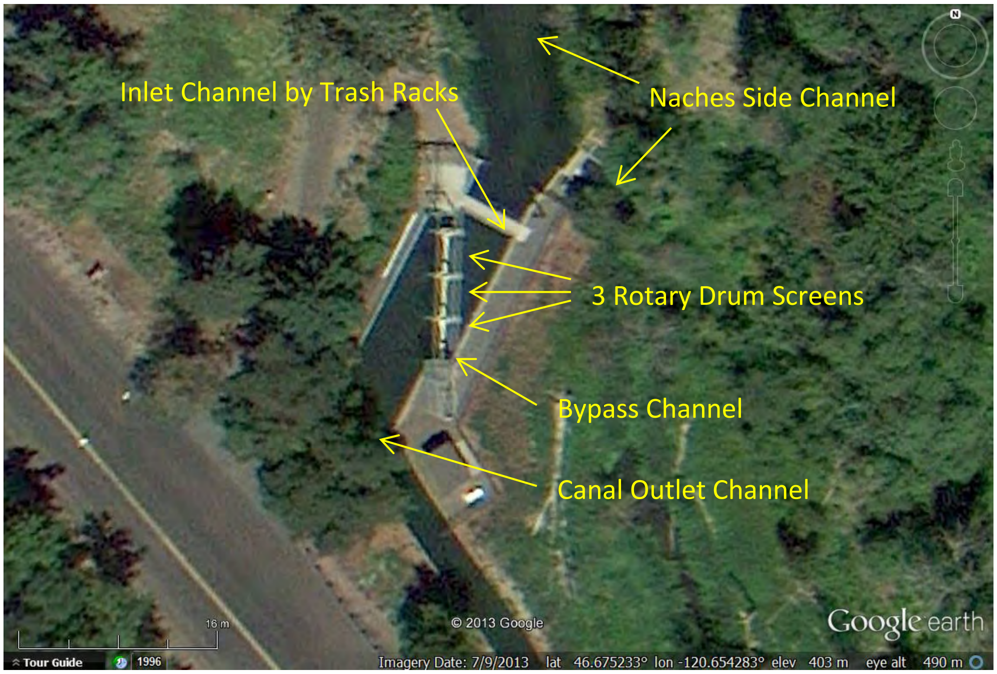

Figure 1. An aerial map of Congdon Diversion with labels for key components.


Figure 2. Looking upstream towards the three rotary drum fish screens at Condon Diversion.


Figure 3. Woven wire mesh with a 3/32" (2.84 mm) opening at Congdon Diversion.

Fish Tagging

All of the larval/juvenile Western brook lamprey that were used for this study were salvaged from dewatered irrigation diversions within the Yakima Subbasin in the winter of 2012-2013 and were subsequently held and reared at Prosser Fish Hatchery before the study. In order to differentiate the larvae/juvenile we release from the potentially naturally occurring larvae/juvenile at Congdon Diversion, we tagged all 172 of the fish with Visible Implant Elastomer (VIE) tags (Figure 4). Yellow colored VIE was used for small larvae (<50 mm), orange for medium larvae (≥50 mm, <85mm), and green for large larvae. All of the VIE tags were implanted on the left side of the body roughly half way between the last gill pore and first dorsal insertion. Pacific lamprey 0+ age larvae used for the study were artificially propagated during the summer of 2013 at Prosser Fish Hatchery (N=1256). These larvae hatched in mid-summer and only began feeding for approximately three months at the time of the study. These fish were left untagged because they were still too small to safely tag with the VIE tags.

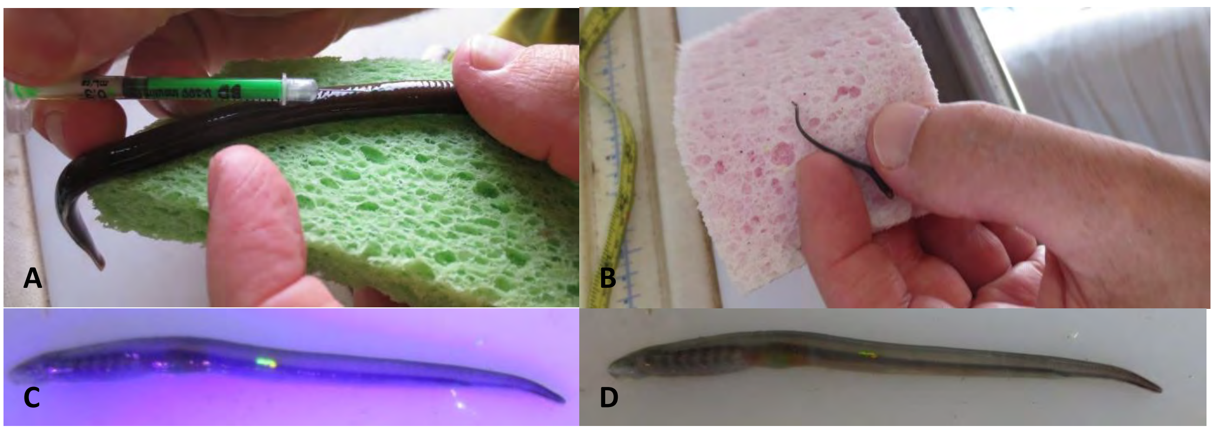

Figure 4. Implanting a VIE tag for a large (A) and small (B) larva. The visibility of VIE tags with (C) and without black light (D).

Acclimation

Because it was discovered that newly hatched larvae are extremely sensitive to changes in water (M. Moser, NOAA Fisheries / CTUIR, pers. comm. 2012), we also conducted an acclimation survival test using 130 Pacific lamprey 0+ age larvae to ensure that the transportation will not cause mass mortality for these fish before the experiment. To test that these small larvae can tolerate the water changes from Prosser Fish Hatchery well water to Naches River water, we transported the fish in a flow-through 5-gallon bucket with fine sediment to Congdon Diversion, and returned the following morning to check on their status. We also acclimated all larvae that were part of this mark-release-recapture study (trap efficiency release, screen release, and upstream release) at the facility as soon as we arrived each day to ensure the lamprey would have some time to adjust to the new water (Figure 5). For the trap efficiency and screen releases, larvae were transported and released without the fine sediment. For the upstream release, we transported and released them with a small amount of fine sediment, imitating a high flow event in which larvae are moving along with the fine sediment.

Figure 5. Larval/juvenile lamprey in flow-through 5-gallon buckets being acclimated below the fish screens at Congdon Diversion.

<u>Trap Efficiency Release</u>

We used primarily 0+ age Pacific lamprey larvae to determine trap efficiency in the bypass and canal outlet channel (Figure 1). A custom made net that fit tightly inside the bypass channel was constructed using 540 micron nylon mesh to trap as many of the larvae moving into the channel (Figure 5). This net had three separate net segments (45 cm long each) to be able to detect which part of the water column the larvae were traveling in (top, mid, and bottom). For the trap efficiency test, we released larvae 1 m upstream of the net using a suction hose (Figure 6). The first group of 25 larvae (Pacific lamprey larvae) was released all on the bottom of the water column, whereas the second group of 25 larvae was all released in the mid-water column to see the difference, if any, in how the larvae will be distributed among the three net segments. We waited at least 15 minutes after the end of release time before we pulled the net out.

Figure 5. Inserting a custom made net for the trap efficiency test in the bypass channel.

Figure 6. Releasing 0+ age Pacific lamprey larvae 1 m in front of the bypass net at the bottom of the water column to test trap efficiency.

Three 0.5 m plankton nets (500 micron mesh) were placed in the canal outlet channel to effectively capture a subsample of the larvae moving further down the canal (Figure 7). The three nets covered roughly 17.8% of the overall canal outlet channel, so we tested whether approximately 17.8% of the released larvae can be recaptured in these three nets. Because we were not certain which part of the water column 0+ age Pacific lamprey larvae would travel in, we tested recapture rates with nets on the bottom for one release group (N=73) and nets in the upper water column for the other release group (N=73). For each release group, approximately half of the larvae were released on the bottom of the water column, and the other half were released in the mid water column, 10 m upstream of the three nets. A trap efficiency test was also conducted using 18 medium size Western brook lamprey. For this release group, all nets were placed in the upper water column. We waited at least 30 minutes after the end of release time before we pulled the nets out. We used 540 micron or finer mesh screen to sift out smaller particles and/or debris from the nets and searched for small larvae meticulously (Figure 8).

Estimates of larvae passing through the bypass channel were calculated based on the mean recapture rate from the bypass channel trap efficiency test. Estimates of larvae passing through the canal outlet channel were calculated based on the percent area covered by the three plankton nets in comparison to the overall area of the canal outlet channel; use of percent discharge was also considered, but based on the trap efficiency tests, we determined that the percent area was the most suitable indicator for the trap efficiency. On September 24, 2013, we also placed the three plankton nets directly downstream of the trash racks near the inlet in the upper water column (30 min) and lower water column (30 min) to monitor for naturally occurring larvae movement in the system, but no lamprey were detected.

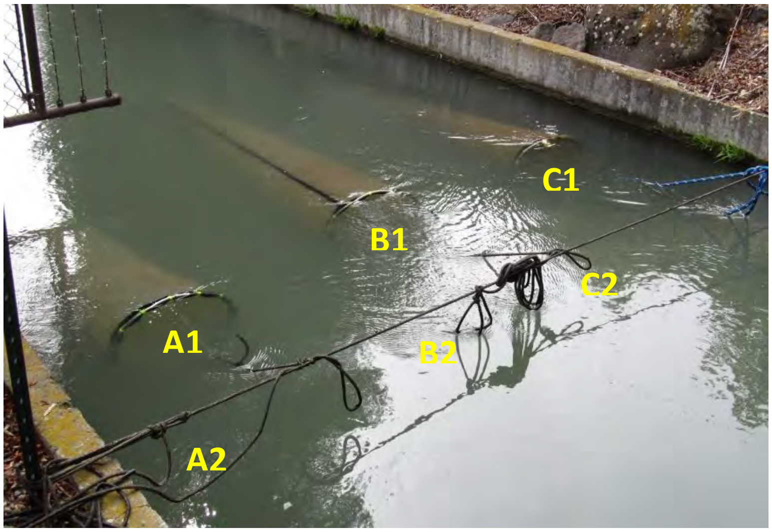

Figure 7. Three 0.5 m plankton nets placed in the upper water column inside the canal outlet channel to test the trap efficiency. "A1", "B1", and "C1" refer to the position of the net in the upper water column. When nets were placed on the bottom of the water, they were referred to as "A2", "B2", "C2."

Figure 8. T. Beals searching meticulously for small 0+ age Pacific lamprey larvae using a 540 micron mesh screen.

<u>Screen Release</u>

We set aside a total of 160 larvae (100 Pacific lamprey 0+ age larvae, and 20 each of small, medium, and large Western brook lamprey larvae) for a screen release test (Figure 9). The objective was to observe and document how the larvae interact with the screens when they are placed right in front of one. We began with the release of 20 large Western brook lamprey. At first, a hand net was used to release the larvae directly in front of the screen. However, a few of the large larvae were able to swim against the current and away from the fish screens, preventing us to observe any interaction with the screens. As a result, we switched the release method to a suction hose method where we can direct the larvae towards the fish screens to ensure some level of interaction with the screens. While trying to find the best angle and distance from the screen for the suction hose release point, several larvae were released too close to the screen (especially at the beginning with the large larvae), forcing the larvae to come into direct contact with the woven wire mesh. As a result, this may have affected and influenced the behavior of some of the tested larvae. On the other hand, if the larvae were released too far away from the screens, the chances of observing screen interaction was considerably reduced, so we made the best effort to balance these two undesirable scenarios. We attempted to release one fish at a time for all Western brook lamprey larvae (small, medium, and large), but for the Pacific lamprey 0+ age larvae we were forced to release them in groups (approximately 15 each) due to their extremely small size. Therefore, the observation notes for the Pacific lamprey larvae were more of an "impression" of how the overall group of larvae was behaving rather than an actual documentation of behavior by each individual fish. After the last larva was released, we monitored the net in the bypass (30 minutes afterwards) and the nets in the canal outlet channel [upper water column] (60 minutes afterwards) to document recapture rates.

Figure 9. Screen release test with G. Mink (bottom) checking on the underwater camera monitor, J. Hubble (left center) controlling the position of the underwater camera, D. Child (top) documenting observation notes, R. Lampman (right) controlling the suction hose for the release of larvae, and J. Hutcherson (in water, unseen) directing the other end of the suction hose where the larvae come out.

Upstream Release

We released a total of 942 larvae directly below the trash racks (Figure 1 and Figure 10) at Congdon Diversion. The objective was to assess the fate of lamprey once they enter the diversion by examining the bypass and canal outlet screens and searching for them three weeks later after the diversion was dewatered. We released them in three groups (Table 1) to ensure we did not overload the downstream monitoring nets with too many recaptured larvae. After the last larva from each release group was released, we monitored the net in the bypass (60 minutes afterwards) and the nets in the canal outlet channel [upper water column] (90 minutes afterwards) to document recapture rates.

Figure 10. Releasing larvae directly downstream of the trash racks at Congdon Diversion using suction hose.

Table 1. The number and composition of larvae used for each of the three upstream release tests.

Release Group	# of 0+ Age Pacific Lamprey	# of Large Western Brook Lamprey	# of Medium Western Brook Lamprey	# of Small Western Brook Lamprey
1	230	57	0	0
2	300	0	68	0
3	300	0	0	47

<u>Dewatered Canal Sampling</u>

After dewatering started on October 15, 2013, we surveyed the diversion for larval/juvenile lamprey with an electrofisher on October 16 and 17, 2013. Because our normal electrofishing gear was defective on October 16, 2013, we only conducted a partial survey on October 16, 2013, using a Smith Root electrofisher; however, we were unsuccessful in reducing the burst rate to the appropriate settings and only captured one larva and observed three others downstream of the screens. On October 17, we used an AbP-2 backpack electrofisher (Engineering Technical Services, University of Wisconsin, Madison, Wisconsin), which we normally use for larval sampling. Three pulses per second (125 V direct current) at 25% duty cycle with a 3:1 burst pulse train (three pulses on, one pulse off) was delivered to elicit larvae/juvenile to emerge from the substrate. After emerging, larvae/juvenile were stunned with a current of 30 pulses per second for collection. All Type I (preferred) and II (acceptable) habitat that remained wet was surveyed above and below the fish screens. Overall Type I and II habitat area (both under and above water), survey area, and high density area were mapped and converted to square meter. Total length of all captured lamprey was measured and fish were identified to species if they were large enough (generally >50mm). A black light was used to find and identify the ones that were previously VIE tagged. We also estimated the total length (in 10 mm increment) of those that we observed underwater, but could not capture.

Results:

Fish Measurements

A total of 172 larval/juvenile Western brook lamprey, two of which were transformers (147 mm and 139 mm), were tagged with VIE for this study. The proportion of the three size classes (small, medium, and large) was roughly equal; 27.3%, 39.5%, and 33.1%, respectively (Figure 11). Larval Pacific lamprey (0+ age) ranged between 7-25 mm in size with a mean size of 12 mm (N=1256), representing an even smaller size class than the small Western brook lamprey group.

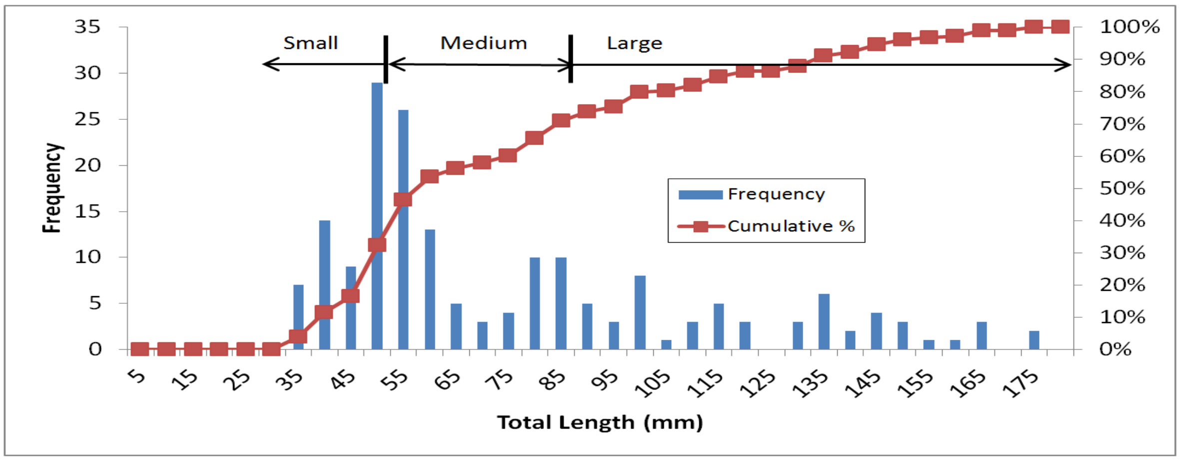

Figure 11. Frequency histogram of the larval/juvenile Western brook lamprey that were VIE tagged and used for the mark-release-recapture study.

Site Acclimation

We transferred 130 of the 0+ age Pacific lamprey larvae from Prosser Fish Hatchery to Congdon Diversion on September 23, 2013, and acclimated them overnight inside the diversion in a flow-through 5-gallon bucket with sand to monitor survival. When we examined them the following morning, we did not see any mortality on the sand surface or in the process of carefully sifting through the sand (all appeared alive and healthy).

Flow Measurements

Flow rate was measured on September 24 and 26, 2013. Based on three replicate samples, each of the 0.5m diameter plankton net in the canal outlet channel passed between 1.1 and 6.8 % of the overall canal outlet channel discharge depending on the position in the water based on three samples for each position; Position A1 (upper left position) had the least discharge while Position B2 (lower right position) had the highest discharge (Figure 7). Each of the three nets covered approximately 5.9% of the overall cross sectional area of the canal outlet channel; three combined represented approximately 17.8%. Placing the three plankton nets in the upper water column passed approximately 12.5% of the overall discharge, while placing them on the canal bottom passed approximately 14.8% of this overall discharge. Estimated mean flow rate in the canal outlet channel was 0.32 m/sec, 0.21m/sec in the bypass channel, 0.14 m/sec in the inlet channel, and 0.07 m/sec in front of the drum screens, based on discharge and cross sectional areas. Flow rates within the plankton nets ranged between 0.06 and 0.36 m/sec depending on the position.

Trap Efficiency Monitoring

We conducted trap efficiency tests at Congdon Diversion within the bypass and canal outlet channel on September 24 (using 0+ age Pacific lamprey; N = 196) and September 25, 2013 (using medium size Western brook lamprey; N = 18). Based on two releases of 0+ age Pacific lamprey larvae within the bypass channel (25 larvae per release), we recaptured 84.0 – 88.0% of the original released larvae in our custom made net (Figure 12). One group was released at the bottom of the channel (recapturing 84.0%) and the other group was released in the mid-water column (recapturing 88.0 %).

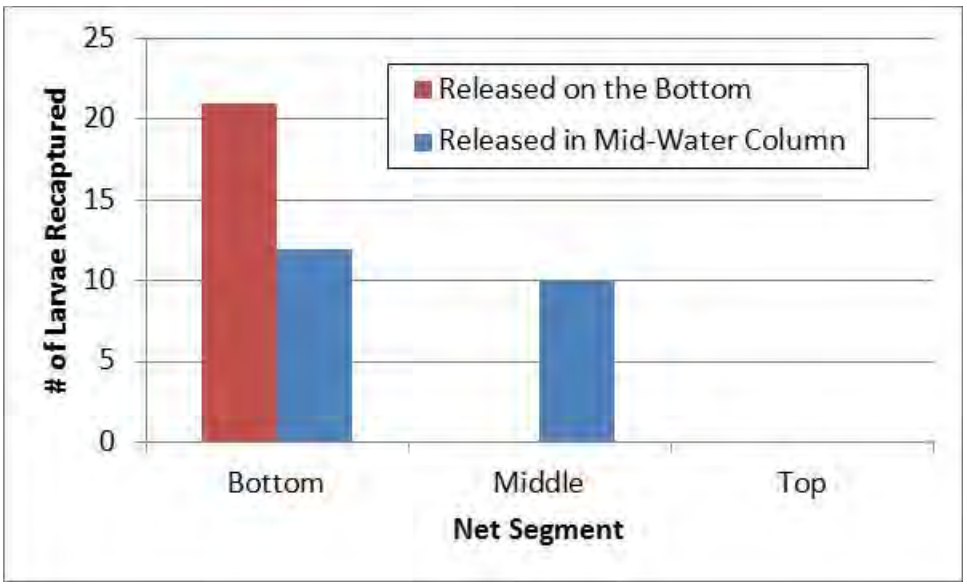

Figure 12. Number of larvae recaptured in the bypass channel within the custom made net with three net segments (Bottom, Middle, Top) (see Figure 5) depending on whether the larvae were released on the bottom or mid water column (25 larvae released for each trial).

Based on two releases of small Pacific lamprey larvae (0+ age; 73 larvae per release) within the canal outlet channel, we recaptured between 9.6 - 19.2 % of the original released larvae in the three plankton nets that cover approximately 17.8% of the channel cross sectional area (Figure 13). The nets were placed at the bottom of the channel for one release group (recapturing 9.6%) and in the upper water column for another (recapturing 19.2%) (Figure 14). Based on a single release of medium size Western brook lamprey (18 larvae) within the canal outlet channel, we recaptured 22.2% of the original released larvae in the three plankton nets set in the upper water column.

Figure 13. Example of the 0+ age Pacific lamprey larvae that were recaptured in the canal outlet channel nets (total length approximately 8-13 mm in this photo).

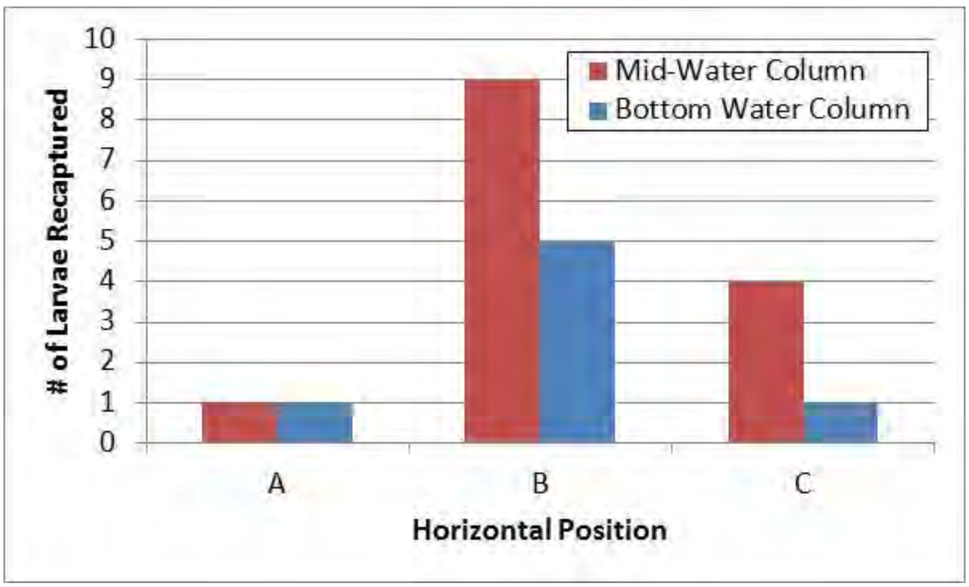

Figure 14. Number of larvae recaptured in the canal outlet channel within the three plankton nets located at position A, B, and C (see Figure 7) in the upper water column or bottom water column (73 larvae released for each trial).

These results confirmed that 1) in the bypass channel, we were able to recapture the majority of larvae (mean of 86%) floating down the bypass channel, and 2) in the canal outlet channel, we were able to recapture approximately 17.8% (percent area covered by the three plankton nets within the overall area of the canal outlet channel) or more of the larvae floating down the canal channel area when the plankton nets were set in the upper water column (Figure 7). In the bypass channel, some of the larvae released in the mid-water column moved to the bottom, suggesting downward movement during their migration (Figure 12). On the other hand, in the canal outlet channel, more larvae were found in the upper water column although half the larvae were released on the bottom water column, suggesting some upward movement during their migration (Figure 14).

Screen Release

A total of 160 larval/juvenile lamprey (100 of 0+ age Pacific lamprey and 20 each of small, medium, and large Western brook lamprey groups) were released directly in front of the fish screens to monitor fish behavior (through direct observation and underwater filming) on September 25, 2013. We observed a wide variety of behavior, which we categorized into six general modes (Table 2, Figure 15). Figure 16 shows the summary of responses for all lamprey (regardless of their sizes). Because of the difficulty in controlling the exact release point of the larvae, some of the larvae were released too close to the screen (to the point of coming into direct contact with the screen) while others were released too far away (increasing the chances of larvae simply swimming away), and this has likely influenced the results to some extent. See "Methods" and "Discussion" sections for more discussion on this topic.

Table 2. Definition of the six modes of behavior that juvenile/larval lamprey displayed at Congdon Diversion.

Behavior Category	Definition
Unseen	Unseen or disappeared before we could identify what behavior it displayed
Escaped	Swam away from the screen without approaching the screen
Averted	Approached the screen at one point, but actively swam away from it before disappearing
Rolled	Approached the screen, became impinged, and rolled over above the water line as the screens rotated
Impinged	Approached the screen, became impinged at one point, but slithered through the mesh screen before rolling above the water line
Passed	Approached the screen and swam through the screen without any impingement

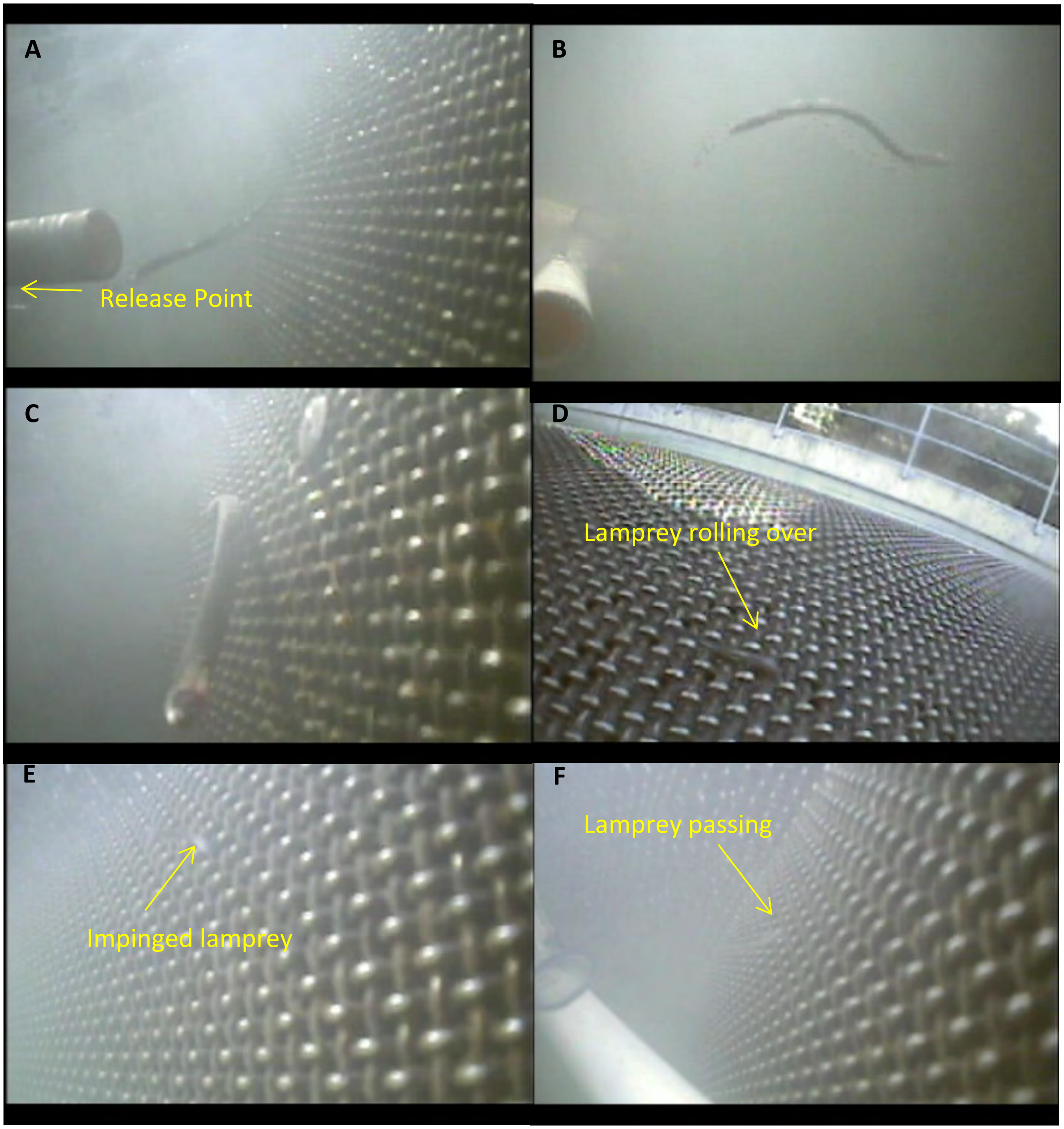

Figure 15. Still images from the underwater filming of screen release test, depicting various modes of behavior: typical release through the suction hose (A); "escaped" (B); "averted" (C); "rolled" (D); "impinged" (E); and "passed" (F).

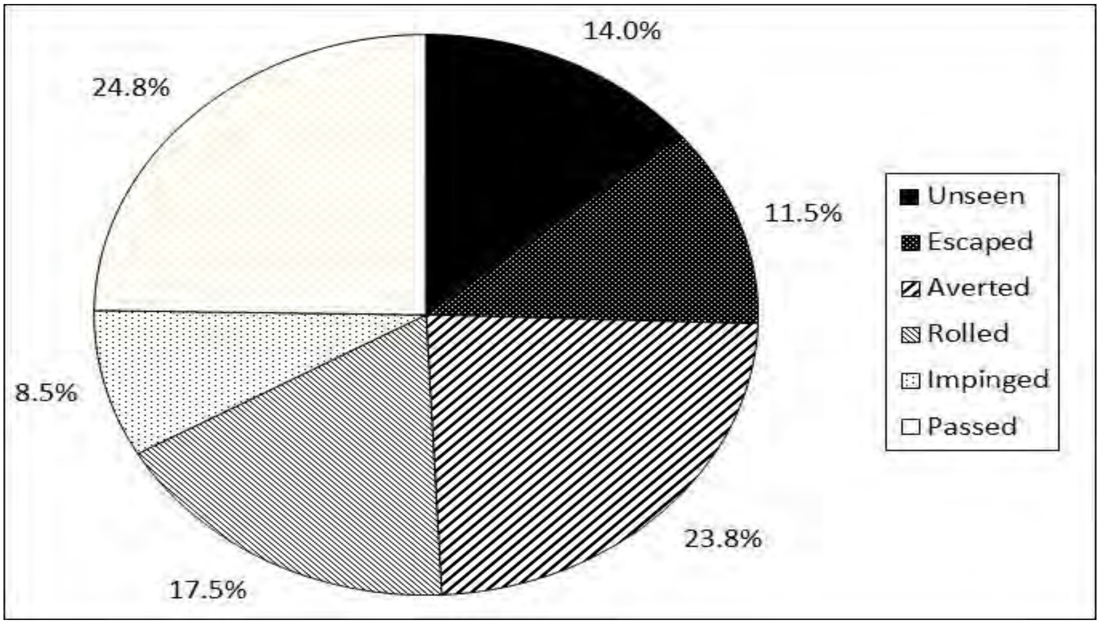

Figure 16. Pie chart summarizing the six modes of behavior displayed by larval/juvenile lamprey at Congdon Diversion after releasing them in front of the rotary drum screens. See Table 1 for the definition of the modes of behavior.

Although we tried to document and monitor each and every fish we released, as the size got smaller, inevitably the number of missed fish ("unseen" category) increased (Figure 17). On the other hand, the number of lamprey that swam away before interacting with the screens ("escaped" category) increased when the size of lamprey was larger, potentially indicating that larger fish are capable of swimming faster and can swim against the current more so than the smaller fish. The other modes of behavior were also heavily influenced by size classes. When we exclude the "unseen" and "escaped" categories from the analysis (due to the lack of direct interaction with the screens), 85.7% of the large Western brook lamprey effectively averted the screens, while 14.3% (N=2) rolled over the screens. However, one of the roll over may have been caused by the fish being released too close to the screens. For medium size Western brook lamprey, approximately half (46.7%) averted the screens, one-third (33.3%) rolled over them, 13.3% were impinged initially before passing, and 6.7% (N=1) passed right through them. None of the small Western brook lamprey averted the screens, while 41.2% rolled over them, 23.5% were impinged initially before passing, and 35.3% passed right through them. Finally, the majority (94.1%) of the 0+ age Pacific lamprey passed right through the screens and the remainder (5.9%) were impinged initially before passing. Many of the larvae that interacted with the fish screen, regardless of the size classes, displayed "burrowing" instinct where they tried to burrow inside the woven wire mesh screen (Figure 18).

We placed the nets in the bypass and canal outlet channel (upper water column) during the entire duration of this screen release test, but only 1 larva (150 mm) was captured in the bypass net, suggesting that 0.7% of the overall group and 5.8% of the large Western brook lamprey group was passing through the bypass channel. It also indicates that very few larvae (<3.5%) were passing through the canal outlet channel.

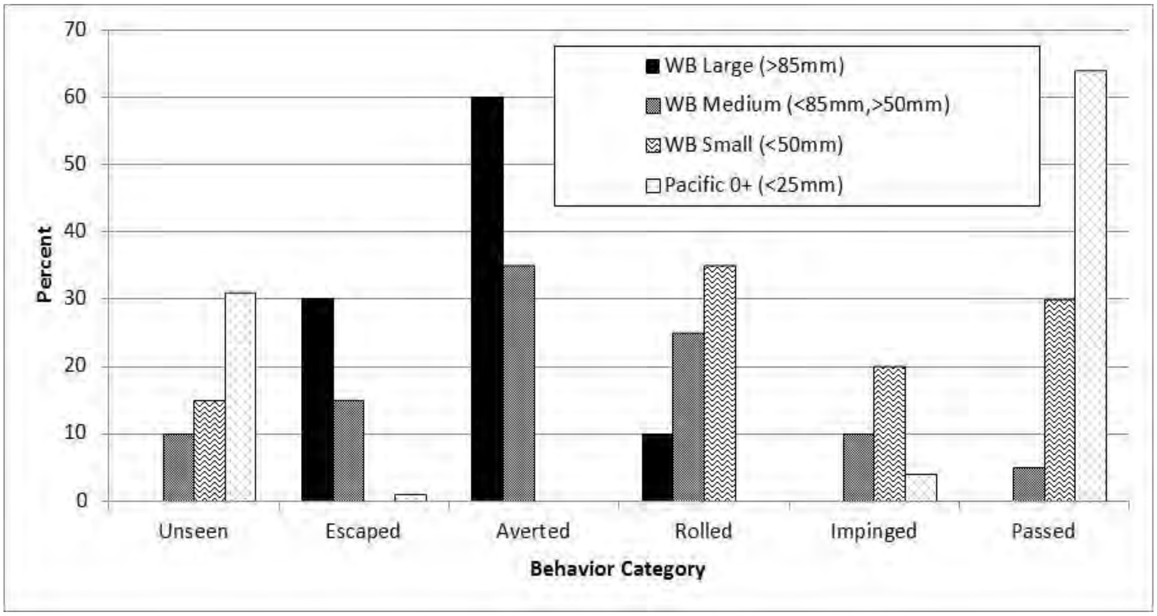

Figure 17. Percent histogram of the six modes of behavior displayed by four size classes of juvenile/larval lamprey at Congdon Diversion after releasing them in front of the rotary drum screens. See Table 1 for the definition of the modes of behavior.

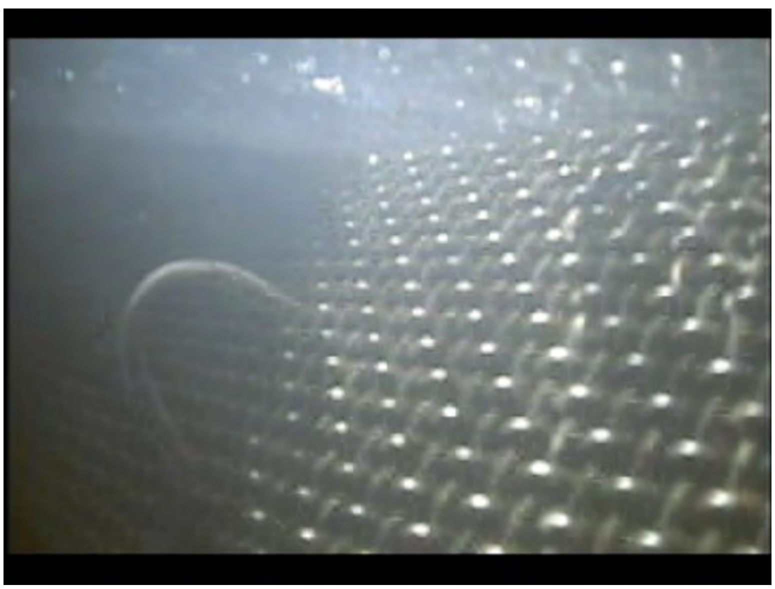

Figure 18. A still image from the underwater filming of screen release test, showing a large Western brook larva trying to burrow into the woven wire mesh by wiggling its tail.

Upstream Release

A total of 942 larvae (830 of 0+ age Pacific lamprey, 47 of small, 68 of medium, and 57 of large Western brook lamprey) were released directly below the trash racks (see Figure 10) at Congdon Diversion on September 26, 2013, for the overall mark-release-recapture component of this study. None of the small, medium, and large Western brook lamprey were recaptured in the bypass and canal outlet channel nets from all three releases, indicating that very few of these lamprey moved past the bypass (<0.7%) and/or canal outlet channel (<3.3%), at least directly after the release.

Pacific lamprey 0+ age larvae were the only ones we recaptured in the monitoring nets (Table 3). From the first release, which consisted of 230 Pacific lamprey larvae, we recaptured 2.6% in the bypass channel net and 0.4% in the canal outlet channel nets, suggesting that approximately 3.0% passed the bypass channel and 2.4% passed the canal outlet channel. From the second release, which consisted of 300 Pacific lamprey larvae, we recaptured 0.7% in the bypass channel net and 0.3% in the canal outlet channel nets, indicating that approximately 0.8% passed the bypass channel and 1.9% passed the canal outlet channel. Finally, from the third release, which consisted of 300 Pacific lamprey larvae, we recaptured 2.0% in the bypass channel net and none in the canal outlet channel nets, indicating that approximately 2.3% passed the bypass channel and very few (<1.9%) traveled through the canal outlet channel. Therefore, on average, we estimate that 2.0% and 1.4% passed through the bypass channel and canal outlet channel, respectively, for Pacific lamprey 0+ age larvae directly after the release. During and shortly after the release, we also monitored the upstream side of the three fish screens from above water to see if we could observe any larvae interacting with the screens, but none were spotted.

Table 3. Number and rates of recapture and estimated "true" passage for 0+ age Pacific lamprey larvae based on three release tests in Congdon Diversion.

Release Sample #	Location	# Released	# Recap.	% Recap.	Estimated #	Estimated % Passage
1	Bypass	230	6	2.6	7	3.0
2	Bypass	300	2	0.7	2	0.8
3	Bypass	300	6	2.0	7	2.3
1	Canal Outlet	230	1	0.4	6	2.4
2	Canal Outlet	300	1	0.3	6	1.9
3	Canal Outlet	300	0	0.0	<6	<1.9

Dewatered Canal Sampling

Type I habitat was abundant above the screens, and consisted of fine sand (Table 4; Figure 19). The water level was very low, with stagnant pools by the trash racks. Water level was deepest directly upstream of the drum screen. Some organic matter and aquatic vegetation was present amongst the fine sediment. Below the screens was primarily Type I habitat as well (Table 4; Figure 20). The Type I habitat ranged from silt (near the canal outlet and directly downstream of the vertical screen on the north end) to fine sand (in the remaining area). Aquatic vegetation was present on patches of silt, but otherwise the sediment was bare. Animal tracks were present below the screens in exposed sediment areas, indicating potential fish predation. Small larval fish, other than lamprey, were also observed both above and below the screens.

Table 4. Summary data on larval habitat and sampling from the dewatered canal survey on Congdon Diversion (October 16 and 17, 2013).

Survey Location	Total Habitat Area (m^2)	Total Survey Area (m^2)	Max Sed. Depth (cm)	Estimated Volume of Fine Sed. (m^3)	# of Lamprey Captured	# of Lamprey Missed	# of Lamprey Observed
Above Screen	24	8	35	4.2	9	3	12
Below Screen	62	14	40	12.4	9	13	22

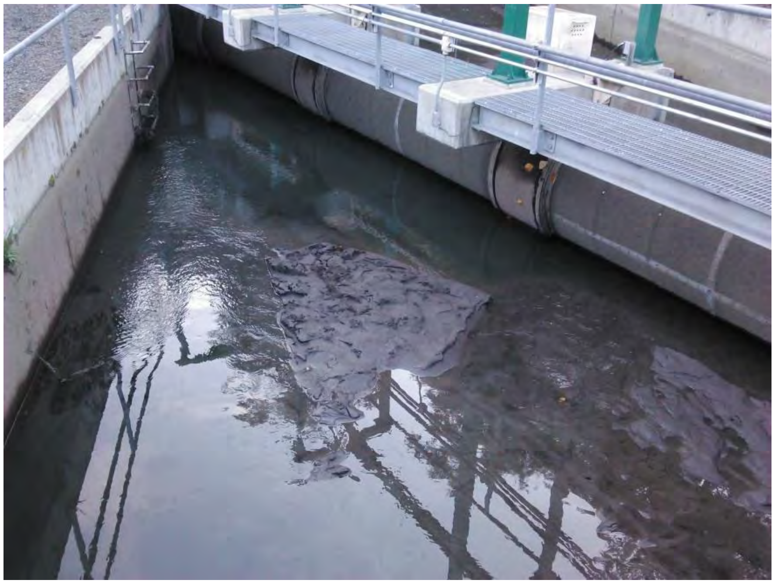

Figure 19. Condon Diversion after dewatering (looking downstream towards the three rotary drum fish screens). An abundance of fine sediment and organic matter is available upstream of the screens.

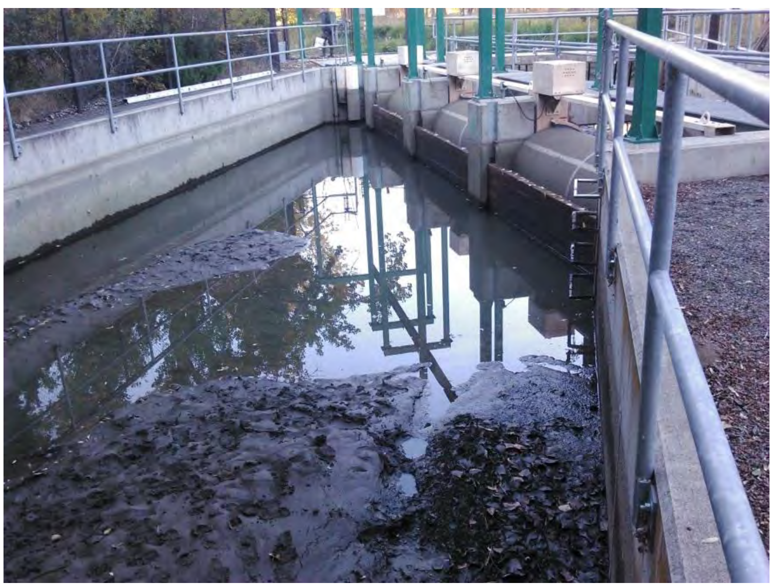

Figure 20. Congdon Diversion after dewatering (looking upstream towards the three rotary drum fish screens). An abundance of fine sediment and organic matter is available downstream of the screens.

We sampled both above and below the screens to record any lamprey that held in the above screen area or passed through the screens. On the first survey date, October 16, 2013, we used a Smith-Root Electrofisher because our other electrofisher equipment was being repaired at the time. Because we were unable to set the Smith-Root Electrofisher to the desired settings for lamprey, we only captured one larva (total length 60 mm) and observed three larvae (~20 mm for all) below the fish screens and nothing was observed above the fish screens.

On October 17, 2013, we returned with our ETS electrofishing gear. Timing of this survey was perfect because of the low water level. Above the screens, we captured one small (45 mm), two medium (54 mm and 63 mm), and three large (94 mm, 105 mm, and 112 mm) VIE tagged Western brook lamprey, and three untagged larvae (91 mm, 95 mm, and 108 mm), resulting in 66.7% VIE tag rate. Three other larvae (~70 mm for all) were only observed and not captured (hence, could possibly have been VIE tagged medium size Western brook lamprey). The highest density of lamprey above the screens was along the concrete wall across from the drum screens in the water moving swiftly towards the bypass (Figure 21).

Figure 21. An aerial map of Congdon Diversion, showing larval habitat area (fine sediment and/or organic matter) [grey highlight], electrofishing survey area [green highlight], and high density area where larvae were captured [red highlight].

Below the screens, we captured one small (43 mm), two medium (68 mm and 71 mm), and two large (92 mm and 124 mm) VIE tagged Western brook lamprey, and three untagged larvae (25 mm, 60 mm, 79 mm, and 111mm), resulting in 55.6% VIE tag rate. Ten other larvae (~30 mm for nine larvae and 60 mm for one larva) were only observed and not captured (hence, could possibly have been VIE tagged medium size Western brook lamprey or Pacific lamprey 0+ age larvae). The highest density below the screens were near the canal outlet channel, where we found mostly small larvae (~ 30 mm), and in the small gate section above the upstream drum screen, where we found the largest tagged larvae (124mm) (Figure 21).

The main difference in the size classes of larval lamprey above and below the screens was that all the 0+/1+ age larvae were found below the screens (Figure 22). Otherwise, the size distribution was fairly similar; even large larvae (111 mm and 124 mm) were able to find their way through the screens, possibly using alternate routes within the fish screens. This was also true for the larvae we released as part of this study (Figure 23). Compared to the number of larvae we released, very few larvae were recaptured during the dewatered canal sampling, ranging between 0.4% for Pacific lamprey 0+ age larvae to 6.0% for large Western brook lamprey (Figure 24).

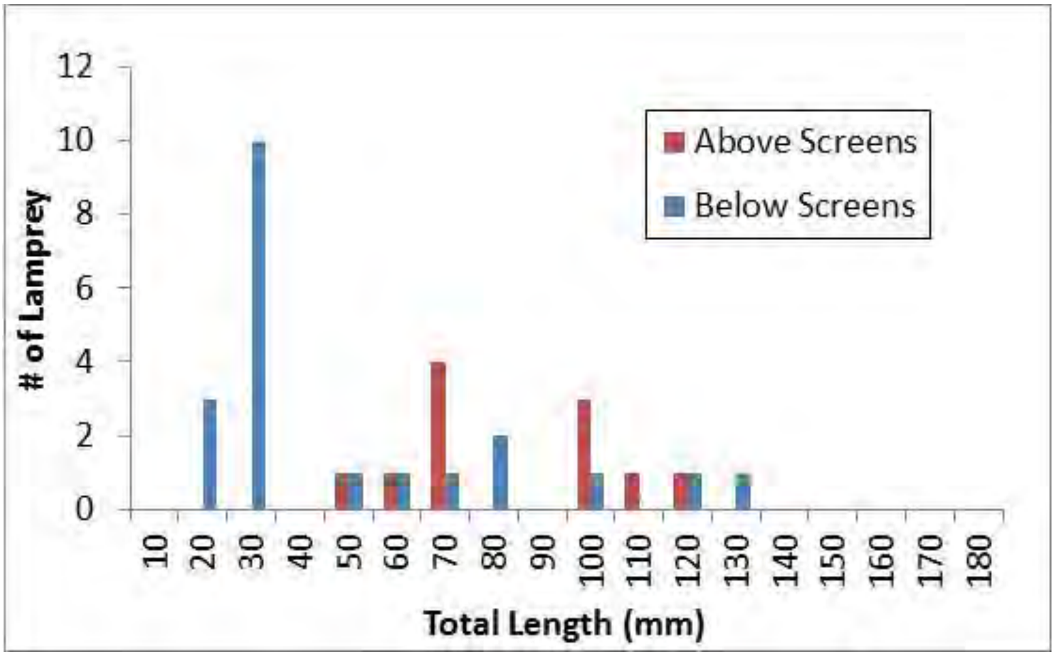

Figure 22. Size class distribution of all larval lamprey observed during the dewatered canal sampling in Congdon Diversion above and below the fish screens.

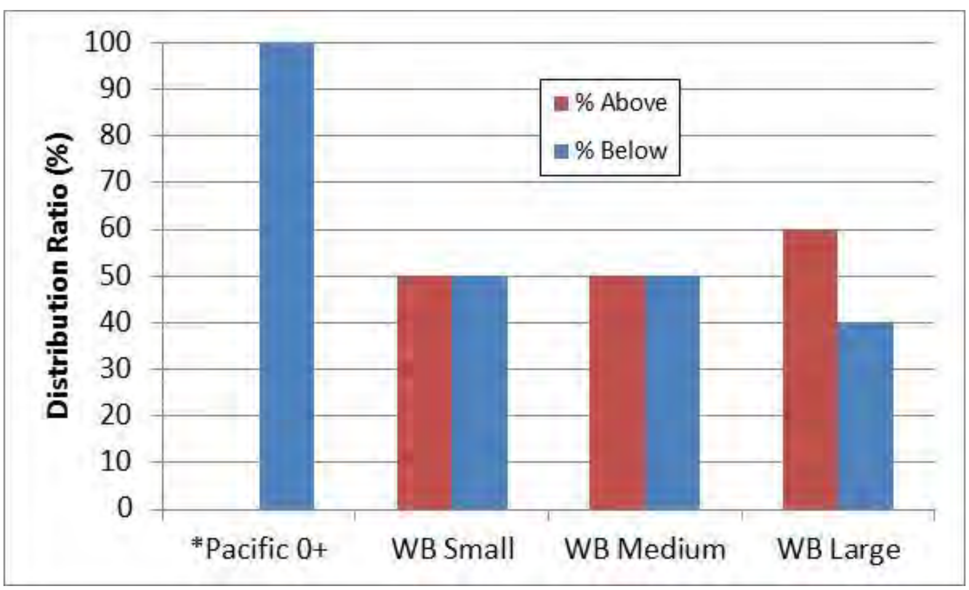

Figure 23. Distribution ratio of lamprey used in the mark-release-recapture study above and below screens during the dewatered canal sampling. ("Pacific 0+" = Pacific lamprey 0+ age larva; "WB" = Western brook lamprey). *Although none of the Pacific lamprey 0+ age larvae were tagged, <35 mm size lamprey were only found below the screens, so we speculated that their distribution was 100% below the screens.

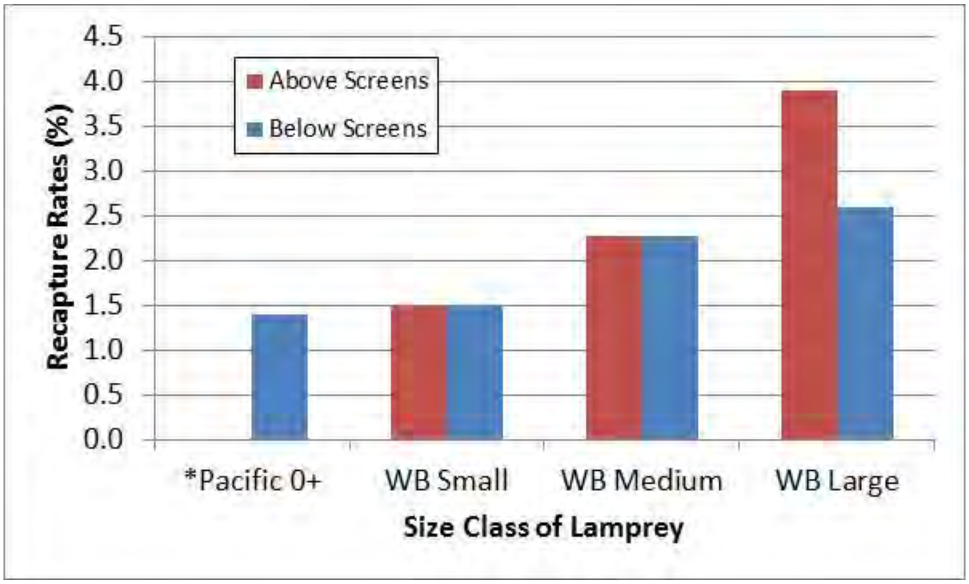

Figure 24. Recapture rates for lamprey used in the mark-release-recapture study above and below the fish screens at Congdon Diversion. *This rate is based on the assumption that all 30 mm or less larvae we observed were larvae we released during our study (hence, a high estimate).

Discussion:

Flow Measurements

The flow rate was the fastest in the canal outlet channel (0.32 m/sec), followed by the bypass channel (0.25 m/sec), inlet channel (0.14 m/sec), and fish screen (0.07 m/sec). Because of the slow flow rate in front of the fish screens, many of the medium and large Western brook larvae were able to swim against the current, if desired. We also saw this tendency in the inlet channel for large larvae (Figure 25). Past research on swimming speed of juvenile lamprey suggests that macrophthalmia on average can swim at a speed of 5.2 body lengths / sec for burst speed and 2.4 body lengths / sec for critical swimming speed (Dauble et al. 2006 from "Swimming behavior of juvenile Pacific lamprey, *Lampetra tridentata*"). However, literature on larval lamprey swimming speed is very limited, if not absent. If we suppose that the swimming speed equation from Dauble et al. (2006) can apply to larval lamprey, this suggests that large Western brook lamprey may be able to swim against the current in all four locations (canal outlet, bypass, inlet, and fish screens) (Table 5). Although they may not be able to sustain their swimming in the mean canal outlet flow (0.32 m/sec), they can probably find slower water within the channel to sustain their swimming. The estimated burst speed for medium size lamprey is also faster than all four channel routes, suggesting they can potentially swim against the current at least for a limited time period. It seems unlikely, however, that small Western brook lamprey can swim against the canal outlet or bypass channel; swimming against the inlet flow may potentially be possible, nevertheless. The 0+ age Pacific lamprey are most likely susceptible to all of the flow rates in these four channels.

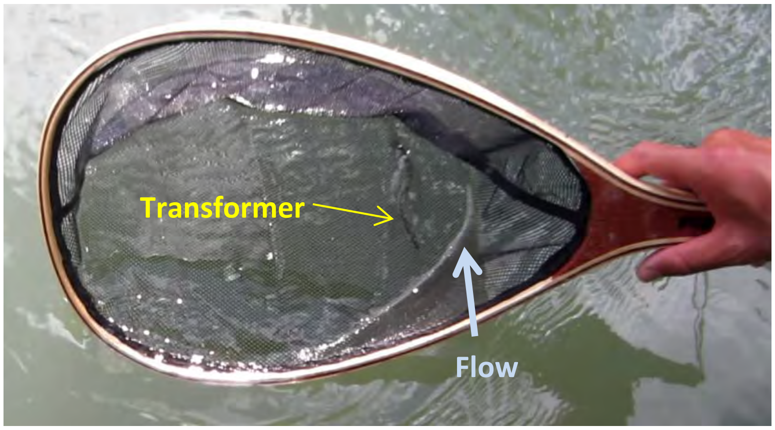

Figure 25. A Western brook lamprey transformer capable of swimming against the current in the inlet channel.

Table 5. Approximated burst and critical swimming speed of various size classes of larval lamprey based on Dauble et al. (2006) data, and summary of inferred ability to pass various areas within the diversion (O = passable, Δ = potentially passable, x = not passable).

Size Class	Mean Length (mm)	Burst Speed (m/sec)	Critical Swimming Speed (m/sec)	Canal Outlet Channel	Bypass Channel	Inlet Channel	Fish Screen
WB Large	119	0.62	0.29	Δ	O	O	O
WB Medium	63	0.33	0.15	Δ	Δ	O	O
WB Small	43	0.22	0.10	x	Δ	Δ	O
Pacific 0+	12	0.06	0.03	x	x	x	x

Trap Efficiency Monitoring

Instead of always migrating in a particular area of the water column, Pacific lamprey 0+ age larvae appeared to move with the strongest current in the canal outlet channel as evidenced by the recapture numbers and the discharge rates (Figure 26). Because larvae were only released in the center of the channel (position B), that may have influenced the higher numbers in the center net (B1 and B2). In Position C2 (Figure 7), larvae recapture rate was low despite the high discharge, but this may be due to the distinct upward current we sensed near the release site (the gradient rises sharply going into the canal outlet). In the bypass channel, the larvae appeared to show up in net segments closets to the water column from which we released the larvae.

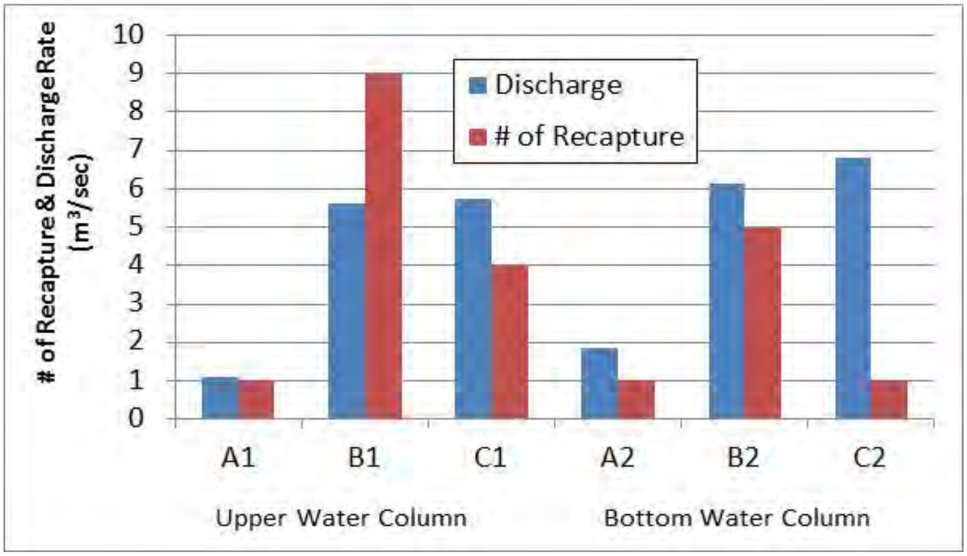

Figure 26. Number of recaptured Pacific lamprey 0+ age larvae and the mean discharge rate in each of the three plankton nets placed in the upper and bottom water columns.

Due to the limited number of Western brook lamprey available, we were not able to conduct trap efficiency tests for the larger size classes except for one test within the canal outlet channel using medium size Western brook lamprey. Although medium size larvae are potentially able to swim against the current (Table 5), we saw a considerably high recapture rate (22.2%). This may be because when there is lack of larval habitat (i.e. fine sediment), larvae may be more inclined to move downstream till they encounter their preferred habitat.

Screen Release

As described in the methods section, the release method was primarily through a suction hose, but some of the larvae were released a little too close to the screen, thereby forcing them to occasionally come into direct contact with the screens. Some of the modes of behavior was likely influenced to some extent by this factor, and thereby overestimated as a result (especially, "Rolled" and "Impinged" behavior). This occurred especially at the beginning when we were testing the appropriate distance between the screens for large and some of the medium size Western brook lamprey. Also, during the release study period, the fish screens have not been cleaned for some time, indicating that more surface area was plugged up by debris/algae, etc. This may cause flow rates to increase locally (although compared to large diversions, the flow rate is still much lower and considerably below the NOAA Fisheries guideline set for the screen approach area (0.40 ft/sec).

However, when larvae had the chance to interact directly with the screen, we consistently saw multiple types of behavior, such as gliding along the screen, attempting to burrow into the screen, impinging their head or tail partially into the screen, and rolling over the screen. Especially, as the drum screen rolled up, shifting its mesh screen angle to be more and more horizontal, more larvae attempted to burrow down into the screen (possibly because of their natural instincts to borrow "down"). As some of the larvae rolled over the water line, many reacted to the direct sunlight (became active again) and slithered through the screen mesh. Some larvae waited from slithering through till they rolled over all the way to the waterline on the downstream side to burrow back into the screen. It is not clear how larvae behave once they burrow into the mesh screen; they may move out of the drum screen by swimming to the sides (where there is opening in the rubber cover), burrow down through the mesh screen to the downstream side, or borrow down through the mesh screen to go back to the upstream side, going in circles.

We found very few larvae in the bypass (0.7%) and canal outlet (0.0%) channel nets. This seems to suggest that the majority of larvae, regardless of whether they pass the screen or not, are staying inside the diversion (most likely burrowing in the fine sediment), at least for the short term.

Upstream Release

The recapture rates from the upstream release tests, similar to the screen release test, was extremely low (mean value of 2.0% in bypass channel and 1.4% in canal outlet channel), indicating that the majority of larvae stayed inside the diversion, at least for the short term. Although it is possible that some of the larvae may have swum against the current and moved outside the diversion during the release, the more typical behavior of larvae is to swim directly down towards fine sediment to look for cover and habitat. Because fine sediment was very abundant both above and below the screens, we can postulate that most larvae, including 0+ age larvae, were able to find some rearing habitat before they ever tried to move outside the diversion. If we hypothesize that the emigration rate was somewhere between 2-3% for both the bypass and canal outlet channels, this means that approximately 95% simply stayed within the habitat available in the diversion.

Dewatered Canal Sampling

Given the fact that the majority of larvae (~95%) appeared to reside within the diversion immediately after the release test in late September, 2013, we wanted to examine how many of those would still be present in the diversion after dewatering. Two days after dewatering began on October 17, 2013, the YN surveyed the entire extent of Congdon Diversion to assess how many larvae we could recapture from the release study above and below the fish screens. Based on the recapture of VIE tagged larvae, the overall recapture rates only ranged between 1.4% and 6.5%, depending on the size class of the larvae.

The VIE tagged larvae were equally distributed above and below the fish screens, indicating that 1) screens have minimum influence on larval dispersal, and 2) potentially alternate passage routes may exist for the larger lamprey. All of the small larvae (<31 mm) were found below the screens. Although electrofishing efficiency can sometimes vary widely, it is unlikely that the electrofishing efficiency was less than 50%, especially given the dewatered conditions, making it considerably easier to find the remaining larvae. On the other hand, if we were able to conduct more dewatered canal surveys over time, we may have been able to find more larvae (and potentially more VIE tagged larvae). Although recapture rates were considerably low during the dewatered canal sampling (1.4-6.5%), given all these uncertainties, the true recapture rates could have been somewhat higher (~20%). Even if we suppose that the recapture rate from the dewatered canal survery was higher (~20%), a large portion of the released larvae are still unaccounted for within Congdon Diversion (~75%).

Because the ratio of VIE tagged larvae (vs. untagged larvae) was 61.1% overall and we used a total of 172 VIE tagged larvae (between 31 mm and 171 mm), this suggests that approximately 109 untagged larvae of the same size range may have been present in the diversion while we conducted the release study.

<u>Conclusion</u>

The mark-release-recapture study provided valuable insights regarding lamprey entrainment and dispersal within irrigation diversions. Information regarding the movement pattern within irrigation diversions has been extremely limited for larval lamprey in general, let alone 0+ age larvae. We were able to demonstrate that 1) larval lamprey can be marked and recaptured successfully within the diversion, and 2) interactions with the fish screens can be documented and analyzed at the site.

Although the results from this study inevitably only portray the outcome from one single site (i.e. Congdon Diversion with a drum screen mesh size of 3/32"), it seems to encapsulate the conundrum of lamprey entrainment. Our screen release tests, similar to the Rose and Mesa (2012) study, demonstrated that many of the small and medium size larvae (<85 mm) can pass through the fish screens, either by passing directly, slithering through, or rolling over.
Our upstream release tests suggest that the majority of lamprey (whether large or small) remained within the diversion and entered neither the bypass nor the canal outflow (at least in the short term). Even 0+ age Pacific lamprey larvae, which appeared to be at the mercy of stronger currents based on trap recapture tests, showed that they can effectively find a place to borrow when fine sediment was available.
Because Congdon Diversion collects voluminous fine sediment upstream and downstream of the screens, lots of habitat exists for the larval lamprey to burrow into. However, only a small portion of these larvae were later detected in the diversion after dewatering occurred. This indicates that the majority of larvae moved out of the fine sediment sometime between the release (in late September) and the dewatering canal sampling (in late October); it could have occurred during the first evening after release, it could have occurred slowly and consistently over the entire month, or it could have occurred mostly during the dewatering process.

Fine sediment in irrigation diversions provides a noteworthy predicament. In a sense, fine sediment in diversions can be both a blessing and a curse for larval lamprey; blessing because we found very few that ventured down the canal outflow (despite the fact that the majority can move through the drum screens) and a curse because larvae will not use the bypass route, either, and will remain within the diversion. Although our study depicts clearly what happens immediately after the release, whether larvae will move out of the diversion through bypass or canal outflow at night time when they are more active and/or days and weeks after the release requires further investigation. The emigration rate immediately after and during the dewatering period merits further research. A release study in spring when fine sediment deposition is minimal (due to facility maintenance during the winter) may provide useful insights for their dispersal behavior.

Our analysis on larval lamprey in irrigation diversions within the Yakima Subbasin at large (see Appendix 2.1 "Assessment of Juvenile/Larval Lamprey Entrainment in Irrigation Diversions and Canals in the Yakima River Subbasin") demonstrates that the amount of fine sediment habitat effectively predicts where the larvae will be distributed, regardless of the presence and type of fish screens. In other words, larvae may simply be moving with the fine sediment and if more fine sediment habitat is distributed above the screens, a proportionate amount of larvae will be found there, and if more fine sediment habitat is distributed below the screens, a proportionate amount of larvae will be found there. Although the screens are effective in reducing the proportion of larger size class larvae (> 85mm) to some extent, they do not appear to influence the overall number of larvae substantially.

As a result, if the goal is to control where larval lamprey move into, the best solution may be to control where the fine sediment transports within the diversion. The big question seems to be "how do we control the fine sediment in a way so that we can make the lamprey do what we want them to do?" Reducing fine sediment input at the head gate may be a potential "long-term" solution, whereas creating effective structures upstream of the fish screens to divert sediment towards the bypass and away from the screens may be a potential "short-term" solution. Based on other dewatered canal surveys, we have noticed that "ecology blocks" placed above and below the screens were effective in trapping fine sediment as well as larval lamprey. Although stop logs placed directly downstream of fish screens do prevent fine sediment collection around the fish screens, if it simply pushes more fine sediment downstream, it is probably not helping deter lamprey entrainment. Although we were not able to evaluate recapture rates from a release study this year, "Farmers Screen" (Farmers Conservation Alliance; Hood River, OR) can potentially be an effective alternative design for screening larval lamprey as water traverses through the diversion rapidly, significantly reducing the chance for fine sediment to deposit within the system.

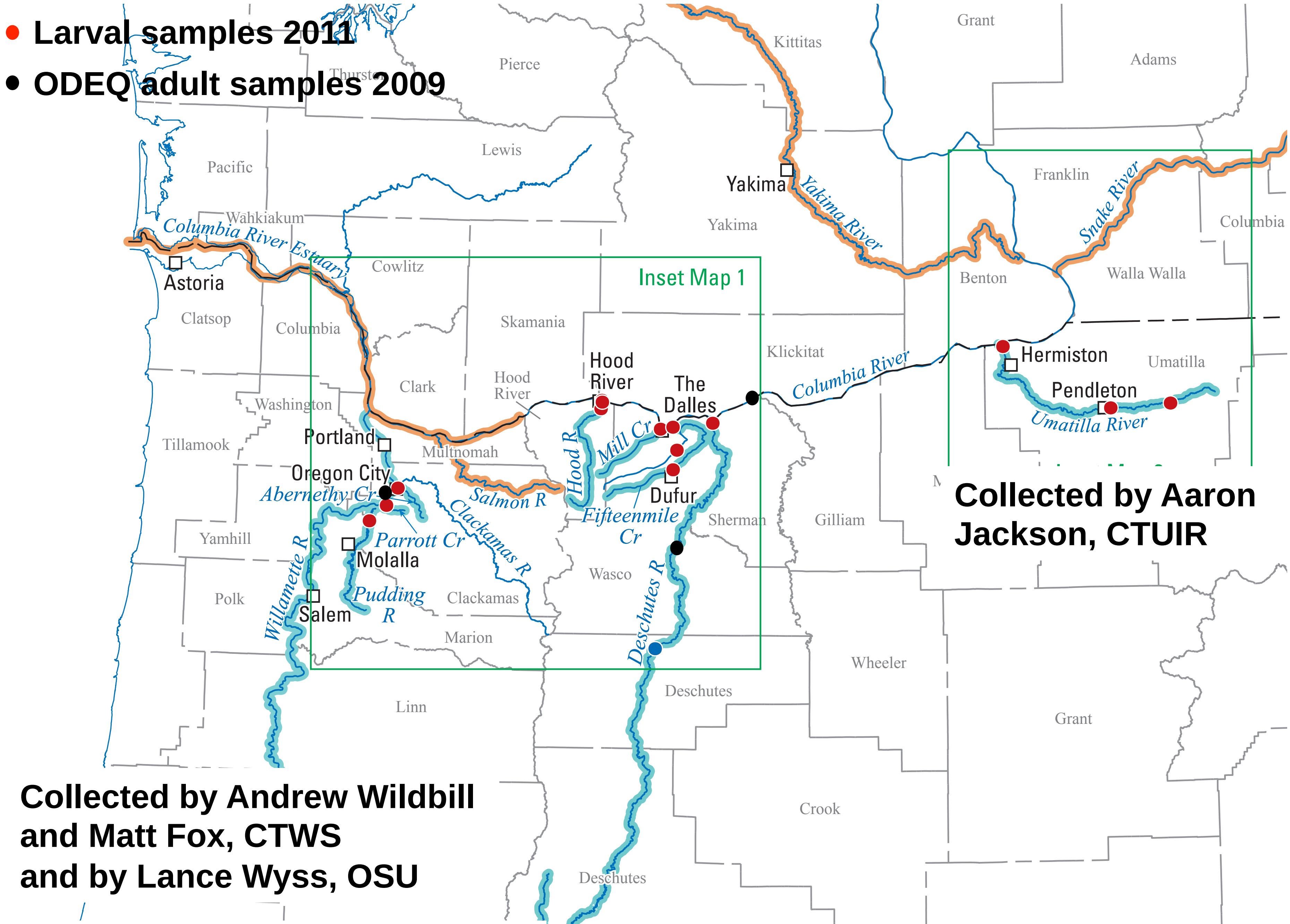

Figure 1. Map of sites sampled in 2011

Table 1. Site information for samples collected in 2011

Date Collected	Time Collected	Coordinates (N/W)	Station ID	Sample Type	Field ID	Basin
8/24/11	13:30	45°36.727 / 121°07.282	4536441210717	Lamprey	15Mi Bridge 1 / Bridge Sample 1	15 mi
	14:10	"	4536441210717	sediment	"	
8/24/11	14:35	45°27.040 / 121°07.143	4527021210709	Lamprey	15Mi Dufur Site 2/ Dufur Site 2	15 mi
	15:15	"	4527021210709	sediment	"	
9/1/11	12:00	45°31.507 / 121°05.956	4531301210557	Lamprey	15Mi 8 Mi Site 3 / 8Mi	15 mi
	12:40	"	4531301210557	sediment	"	
9/21/11	12:00	45°42.681 / 121°30.389	4542411213023	Lamprey	Hood River HR#1 / HR #1	Hood R
	12:40	"	4542411213023	sediment	"	
9/23/11	12:00	45°40.770 / 121°30.673	4540461213040	Lamprey	Hood River Site 2 / Hood River 2	Hood R
	12:40	"	4540461213040	sediment	"	
9/26/11	12:00	45°42.272 / 121°30.282	4542161213017	Lamprey	Site 3 Hood River / Site 3 Hood River	Hood R
	12:40	"	4542161213017	sediment	"	
8/25/11	12:00	45°36.247 / 121°11.310	4536151211119	Lamprey	Sample# 1 Mill Crk / Sample #1 Mill Crk	Mill Cr
	12:40	"	4536151211119	sediment	"	
10/14/11	12:00	45°37.690 / 120°54.396	4537411205424	Lamprey	Deschutes R / Descutes River Mouth	Deschutes R
	12:40	"	4537411205424	sediment	"	
10/27/11	12:00	44°46.297 / 121°12.463	4446181211228	Lamprey	Deschutes R DSC 1 / DSC 1	Deschutes R
	12:40	"	4446181211228	sediment	"	
12/12/11	11:30	45 21 50.848 / 122 35 54.183	4536441210719	Lamprey	Abernethy Creek Oregon City D/S W Falls	Willamette
	10:50	"	4536441210719	sediment	"	
12/12/11	12:30	45°17.853 / 122°39.453	4517511223927	Lamprey	Parrott Creek U/S W Falls	Willamette
	11:50	"	4517511223927	sediment	"	
12/12/11	13:30	45°14.244 / 122°44.827	4514151224450	Lamprey	Pudding River U/S W Falls	Willamette
	12:50	"	4514151224450	sediment	"	
12/13/11	14:25	45°54.829 / 119°19.974	4554501191958	Lamprey	Lower Umatill Basin U/S Pendleton UTM coordinates: 11T 0319080N, 5087121E	Umatilla
	13:45	"	4554501191958	sediment	"	
12/13/11	12:40	45°40.447 / 118°45.267	4540271184516	Lamprey	Mid Umatilla Basin U/S Pendleton UTM Coordinates: 11T 0363354N, 5059339E	Umatilla
	12:00	"	4540271184516	Sediment	"	
12/13/11	9:40	45°41.221 / -118°25.837	4541131182550	Lamprey	Mid-upper Umatilla Basin UTM Coordinates: 11T 0388602N, 5060269E	Umatilla
	9:00	"	4541131182550	Sediment	"	

Table 1. Site information for 2011

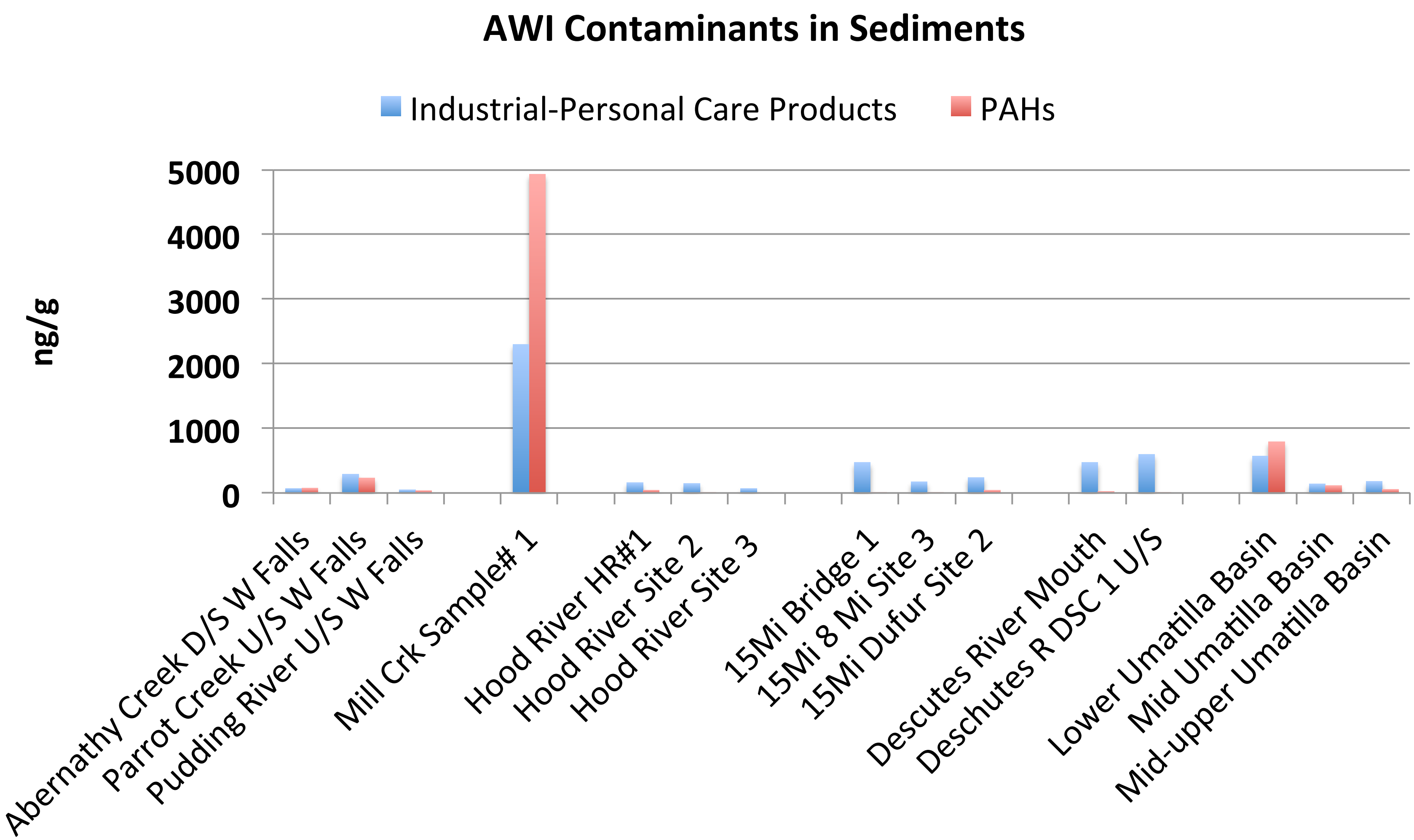

Figure 2. Anthropogenic Waste Indicator (AWI) compounds in sediments.

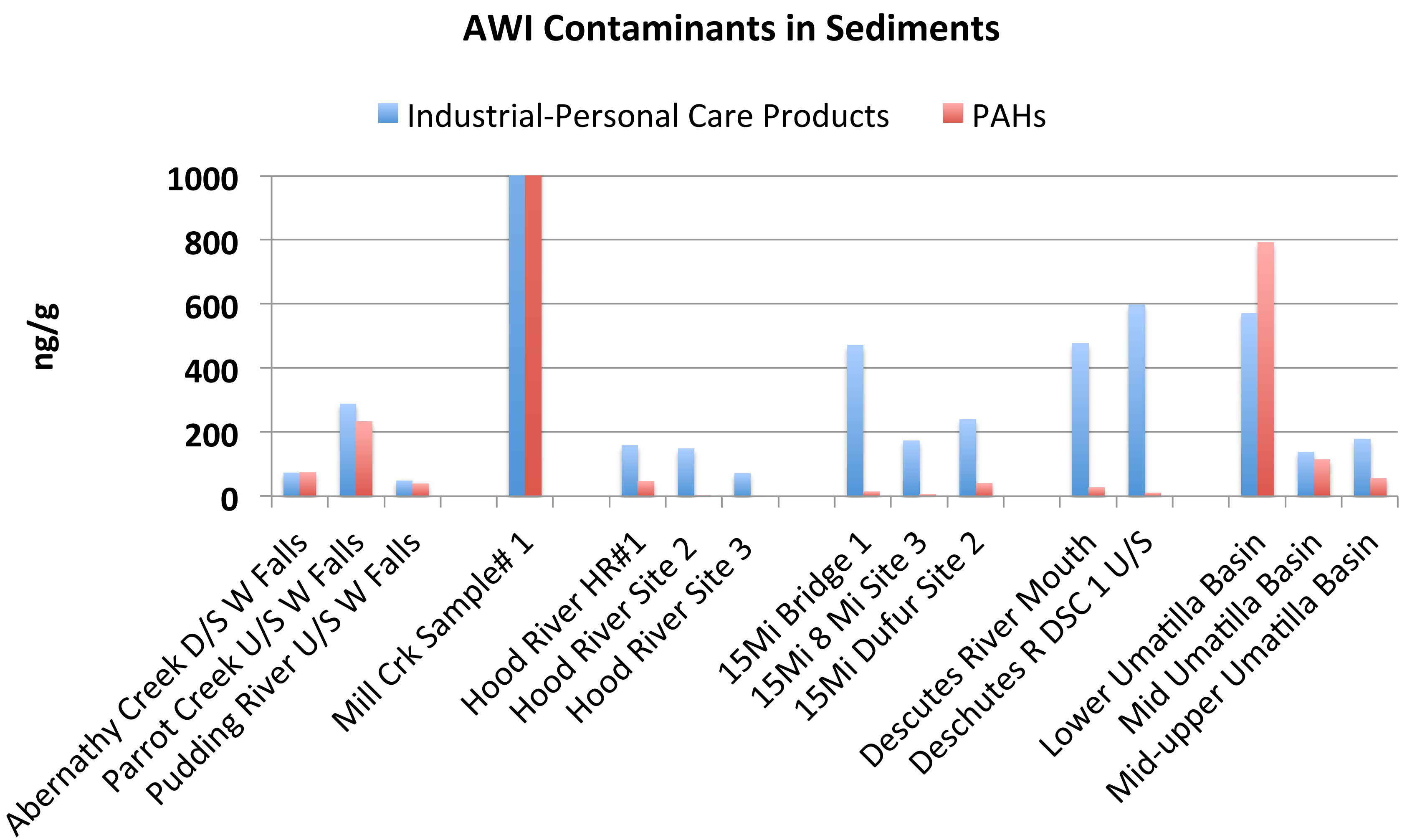

Figure 3. AWI compounds in sediments (same data as figure 1, but with the scale adjusted; Mill Creek concentrations truncated).

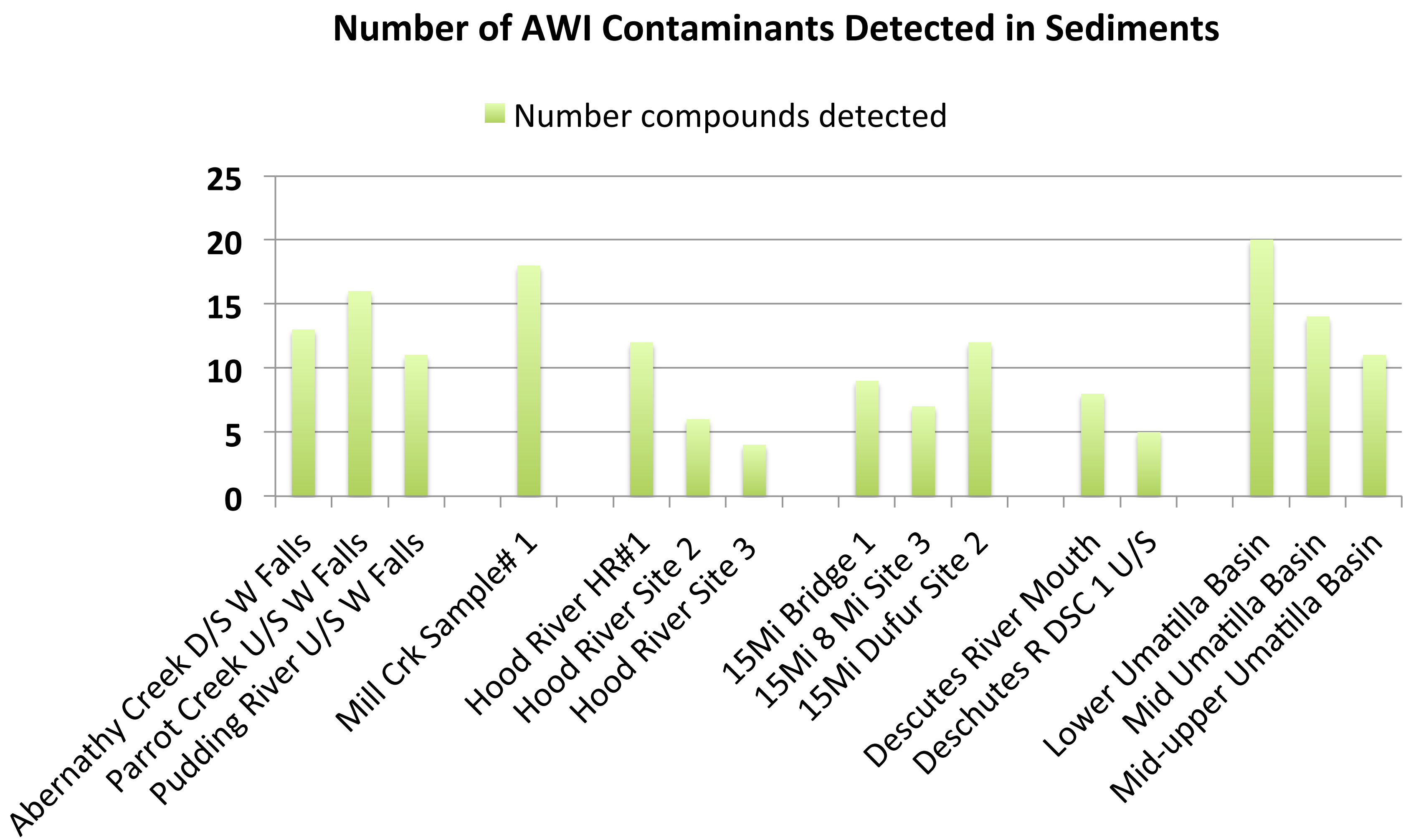

Figure 4. Number of AWI compounds detected in sediments by site.

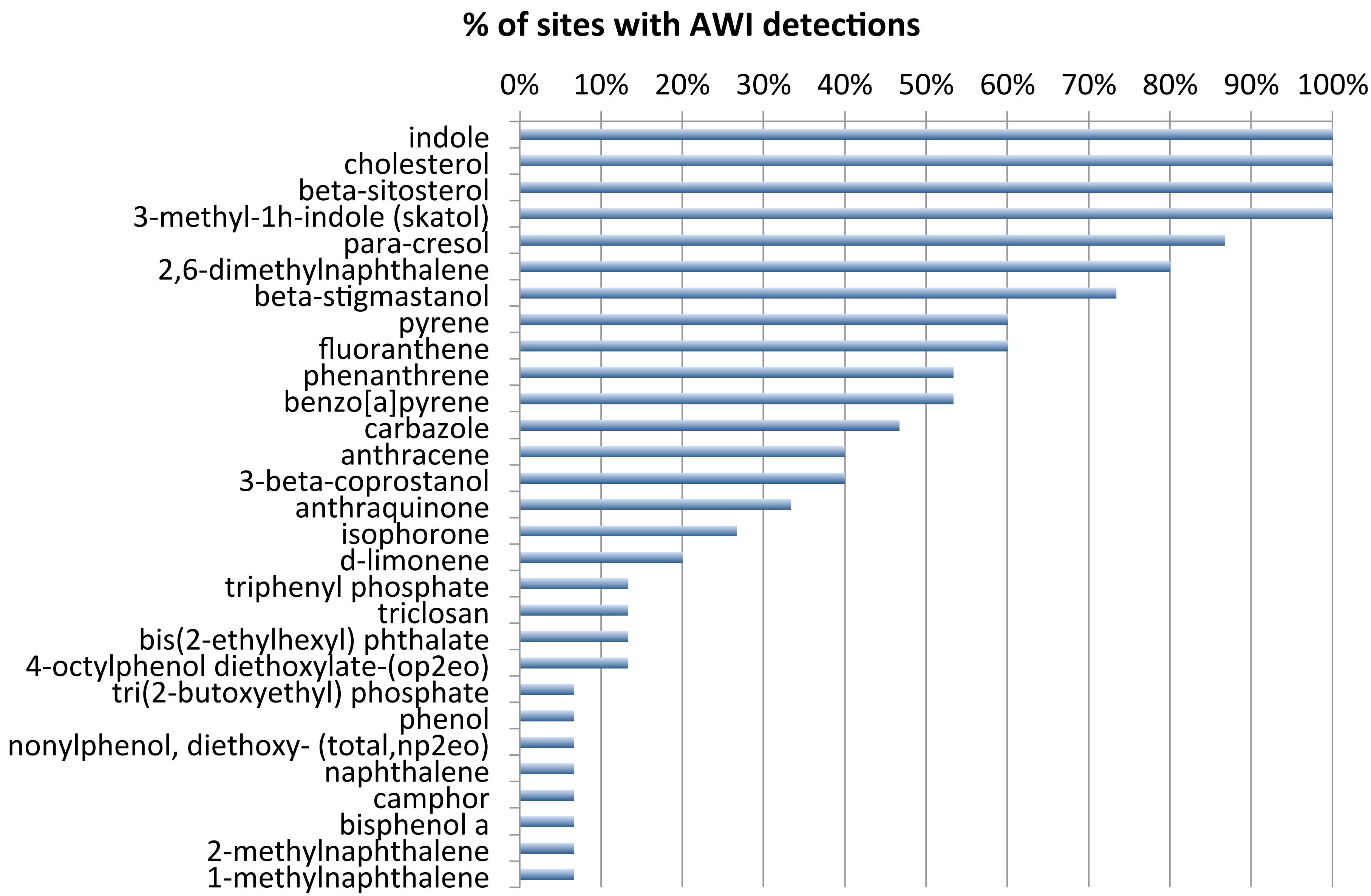

Figure 5. Percent of sites at which each AWI compound was detected.

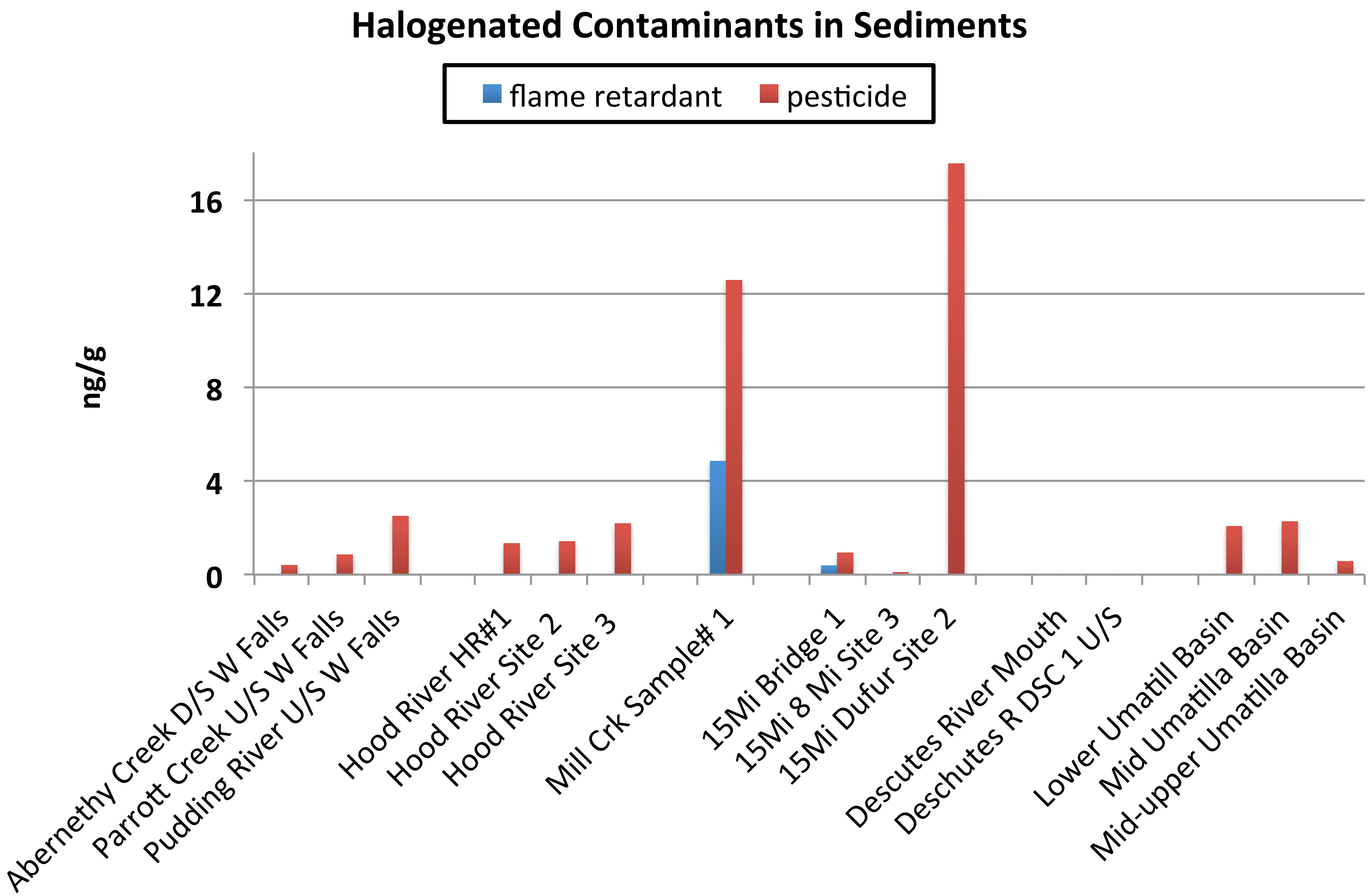

Figure 6. Halogenated compounds detected in sediments.

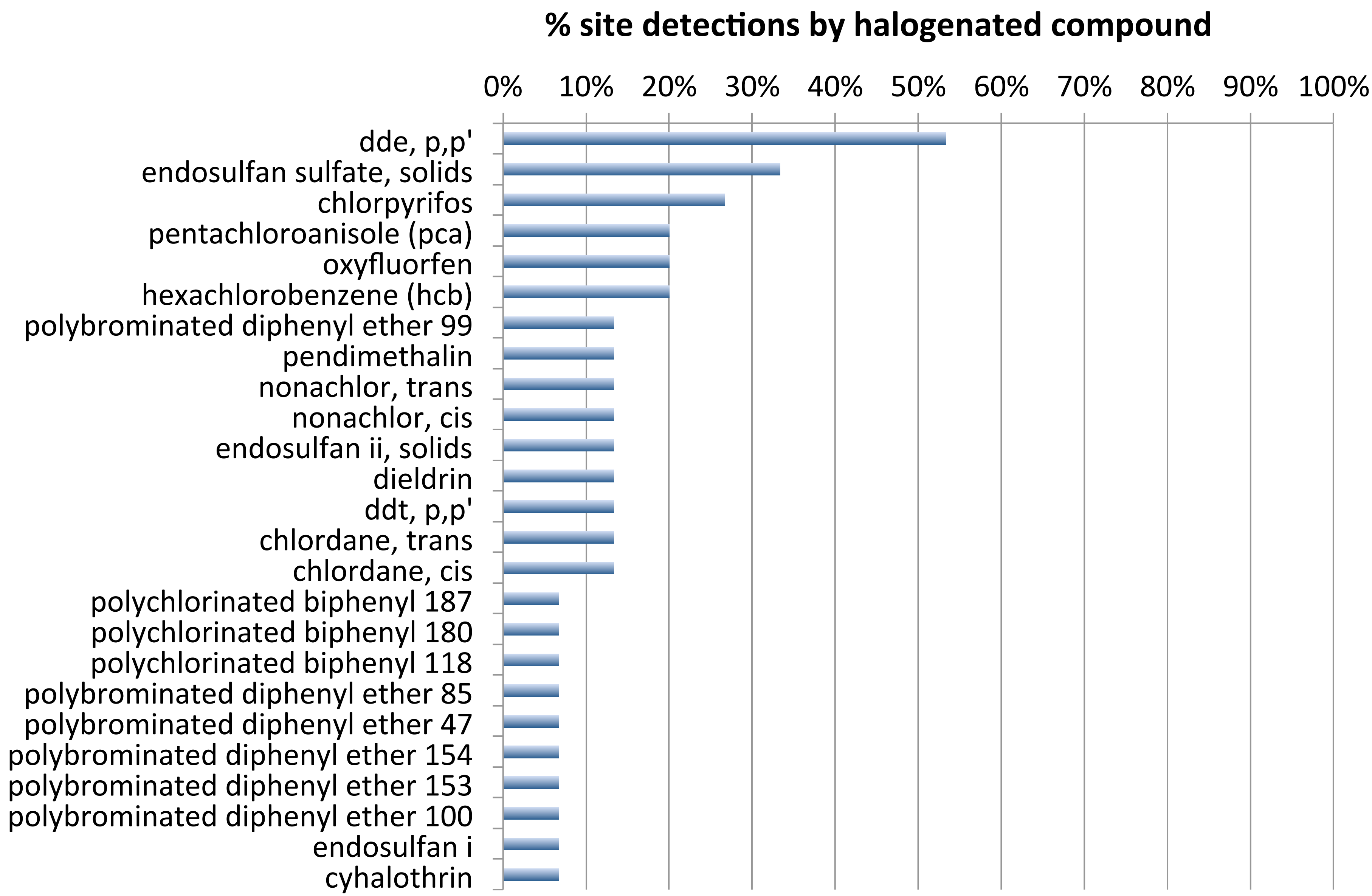

Figure 7. Percent of sites at which each halogenated compound was detected in sediment.

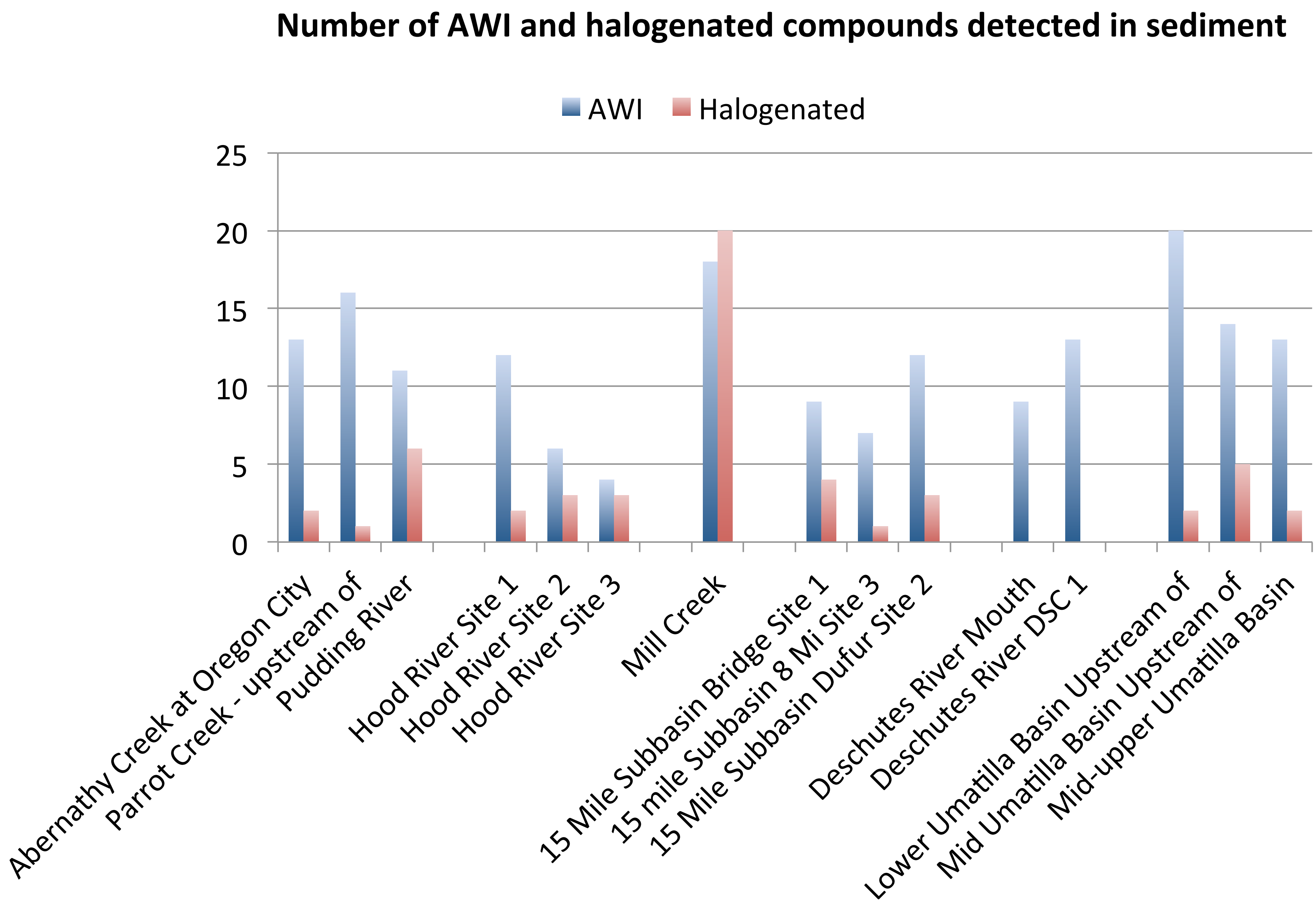

Figure 8. Number of AWI and halogenated compounds detected in sediment

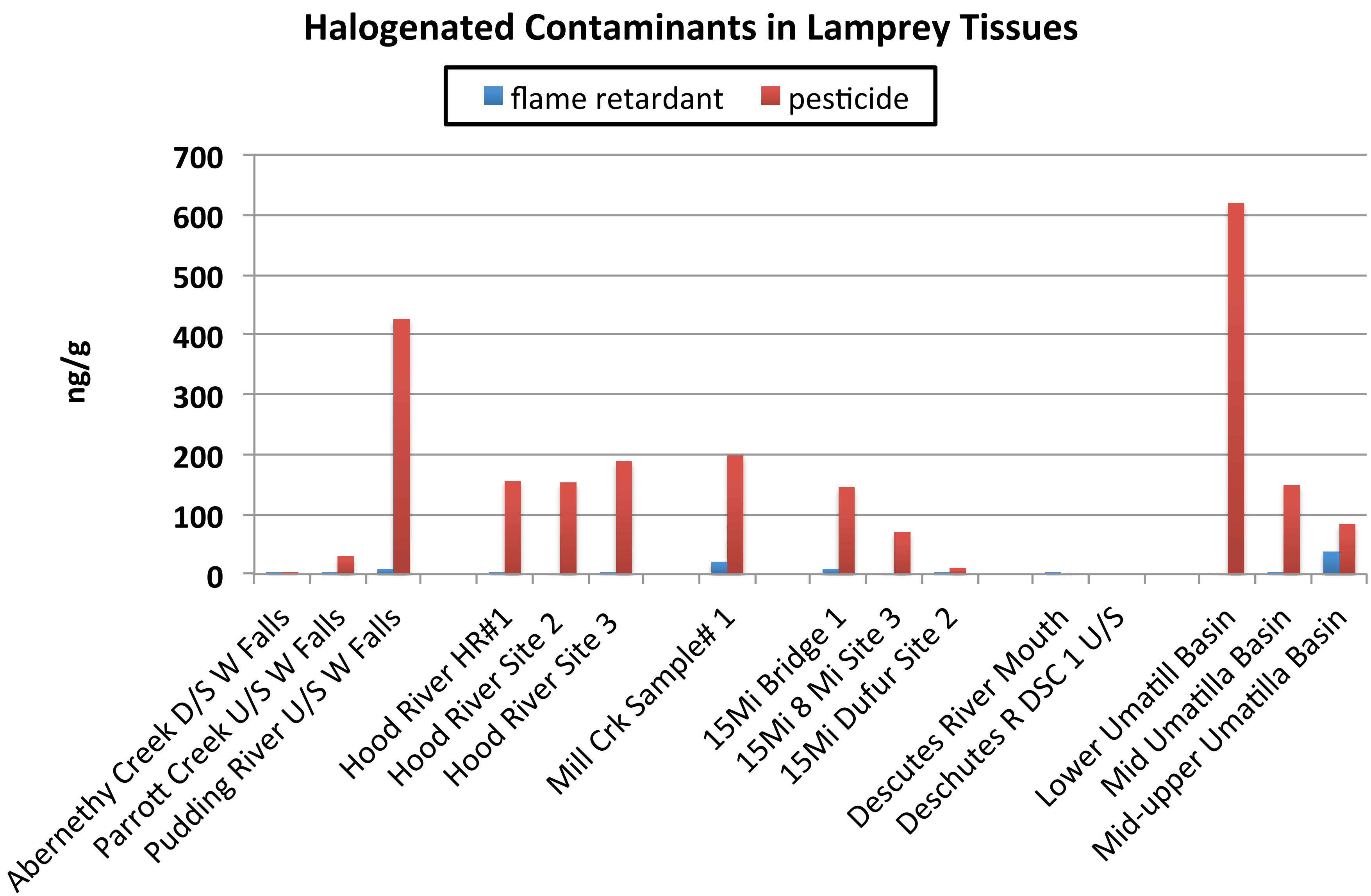

Figure 9. Halogenated compounds detected in lamprey tissues.

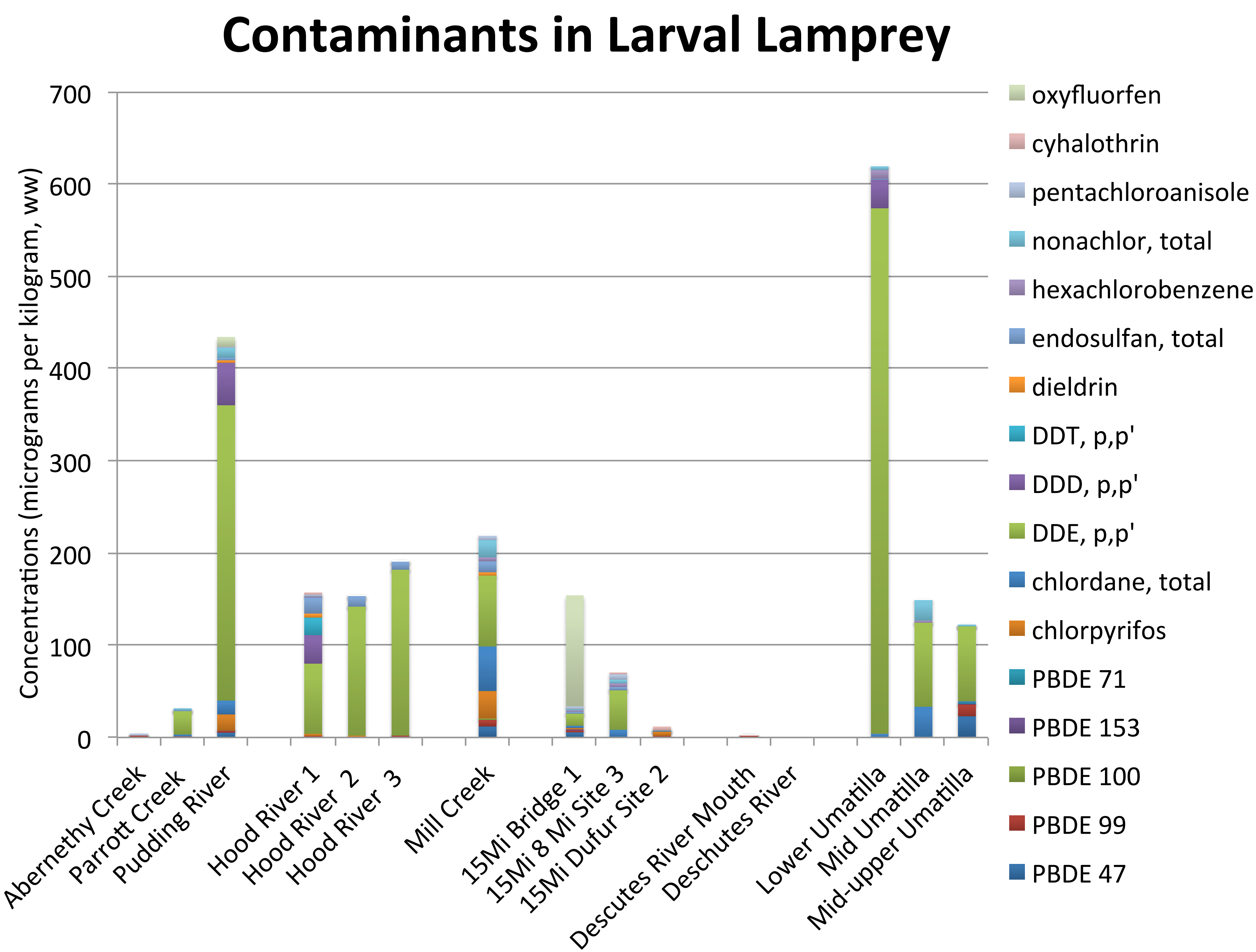

Figure 10. Halogenated compound detection patterns in lamprey tissues.

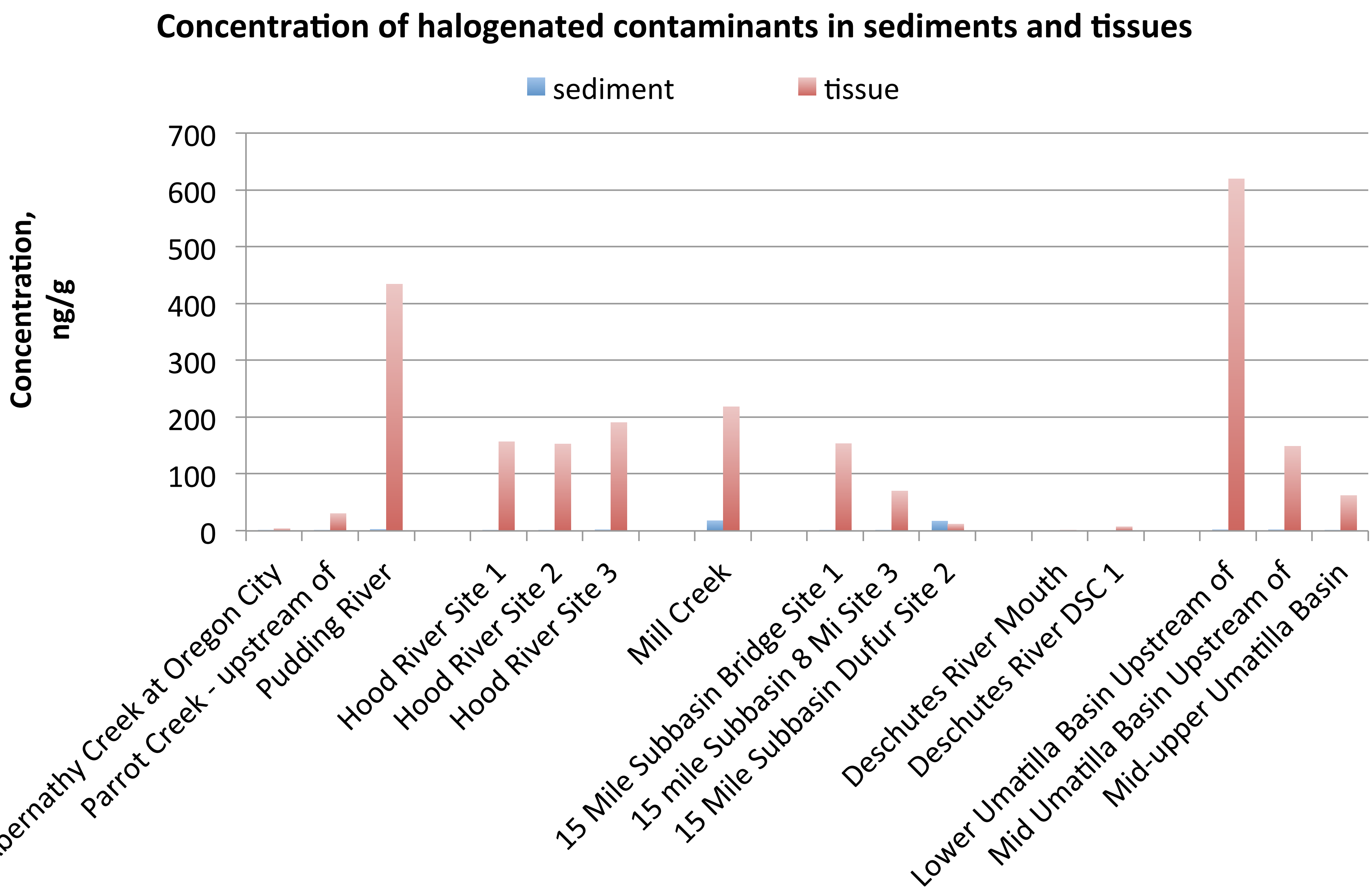

Figure 11. Concentration of halogenated compounds detected in sediments and lamprey tissues.

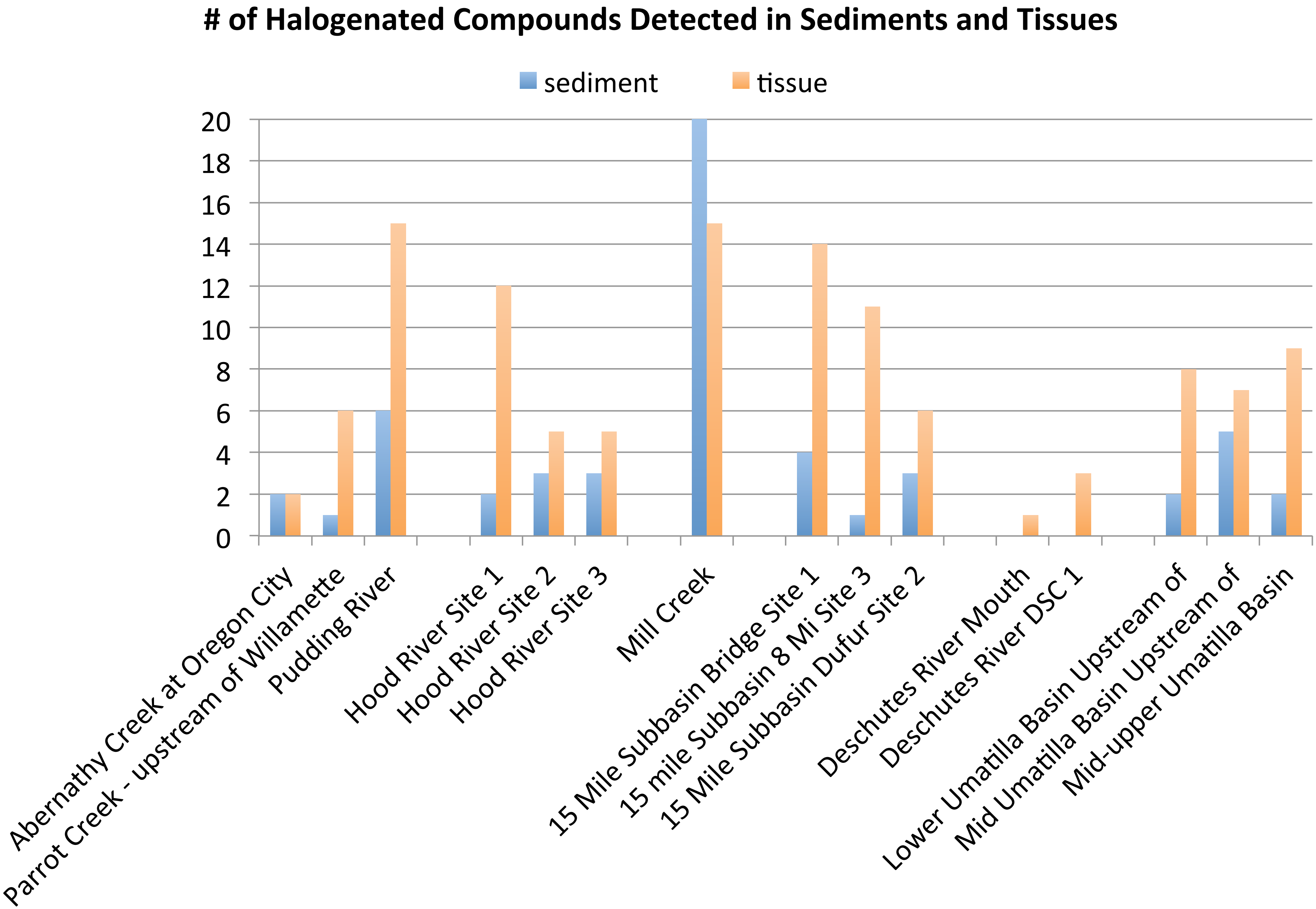

Figure 12. Number of halogenated compounds detected in sediments and lamprey tissues.

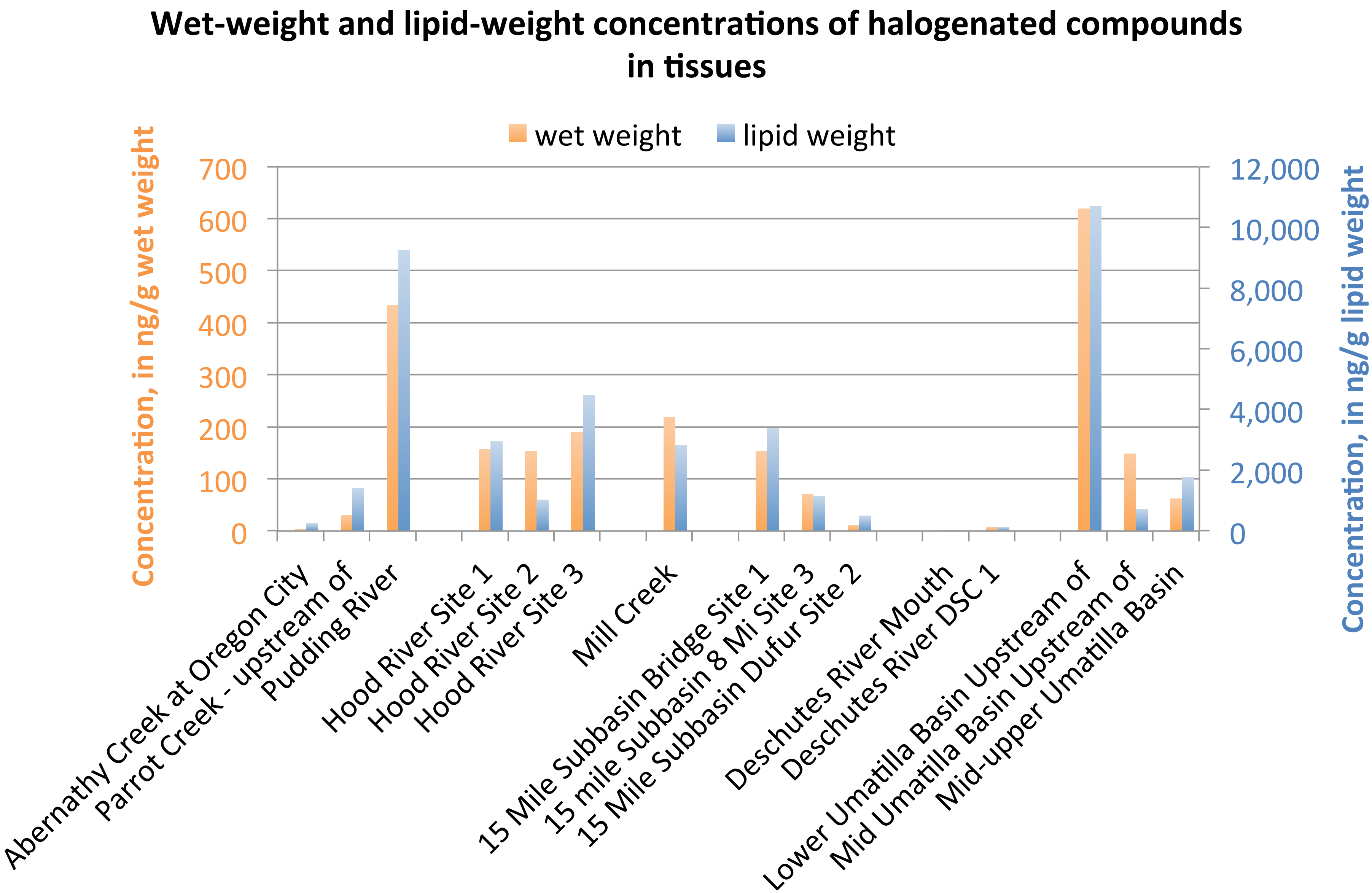

Figure 13. Wet weight and lipid-normalized concentrations of halogenated compounds in tissues

Pesticides in Larval Lamprey Compared to Adults Collected by ODEQ

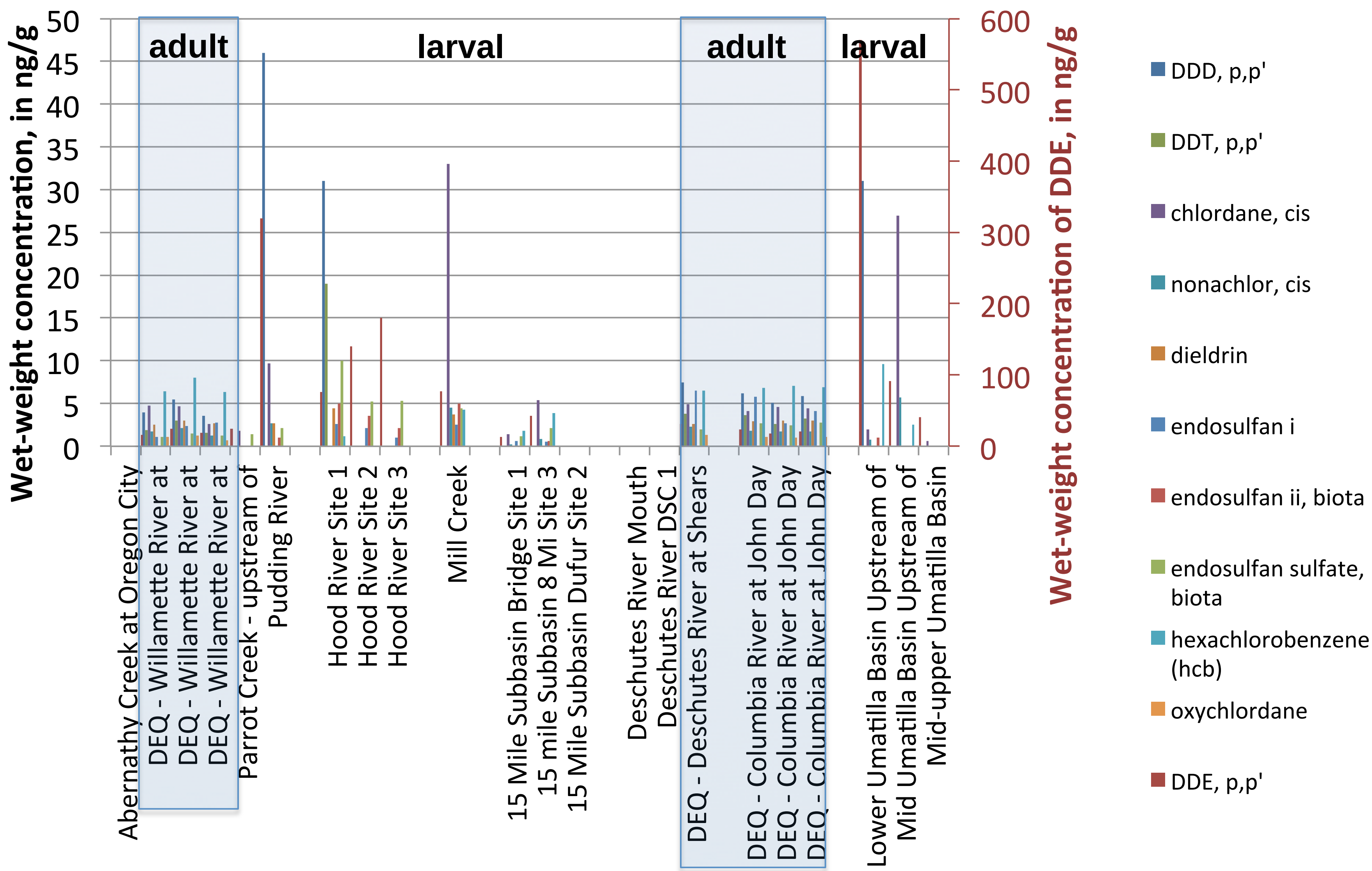

Figure 14. Pesticide concentrations in larval and adult lamprey tissues

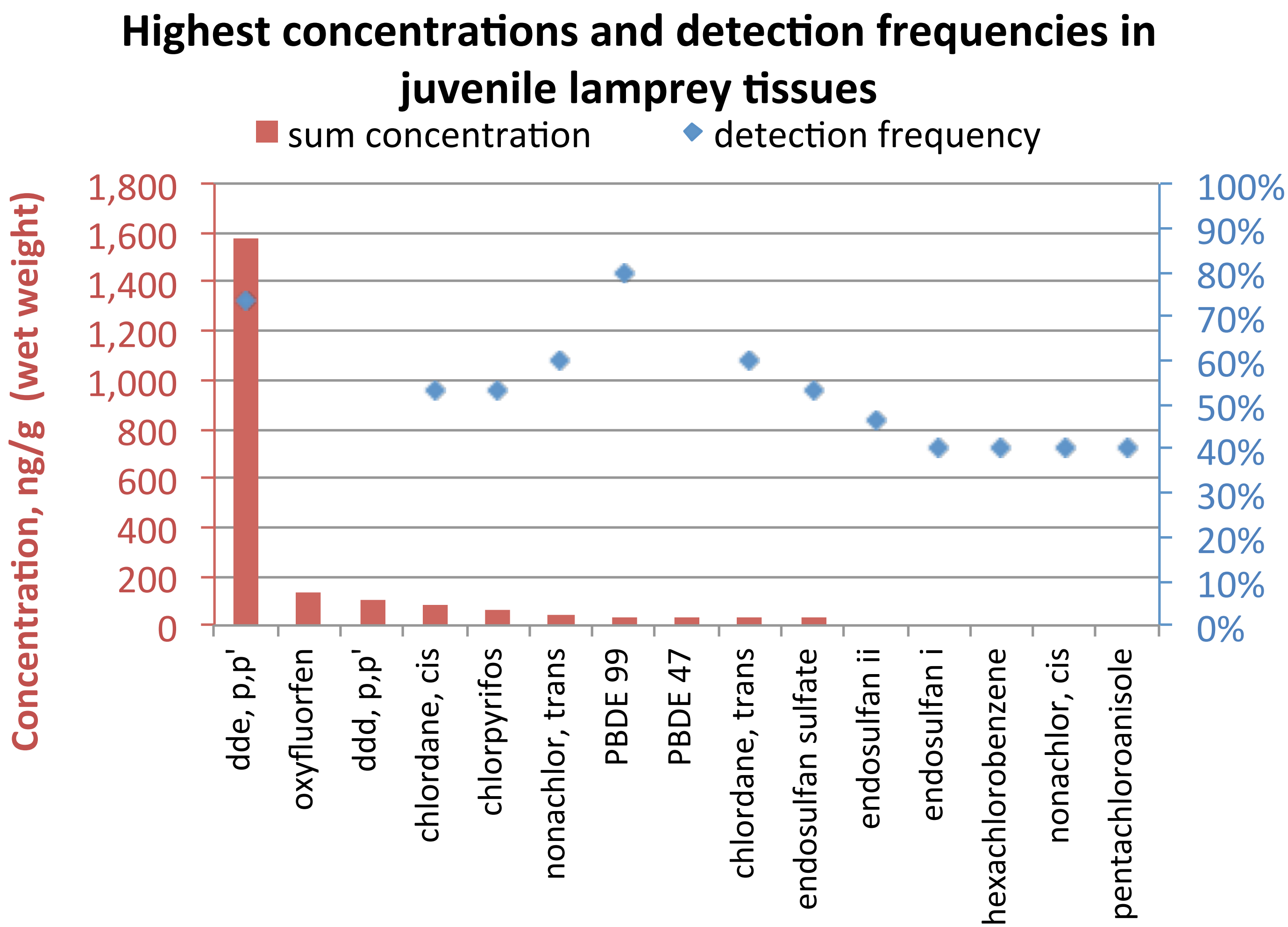

Figure 15. Most prevalent contaminants in juvenile lamprey tissues

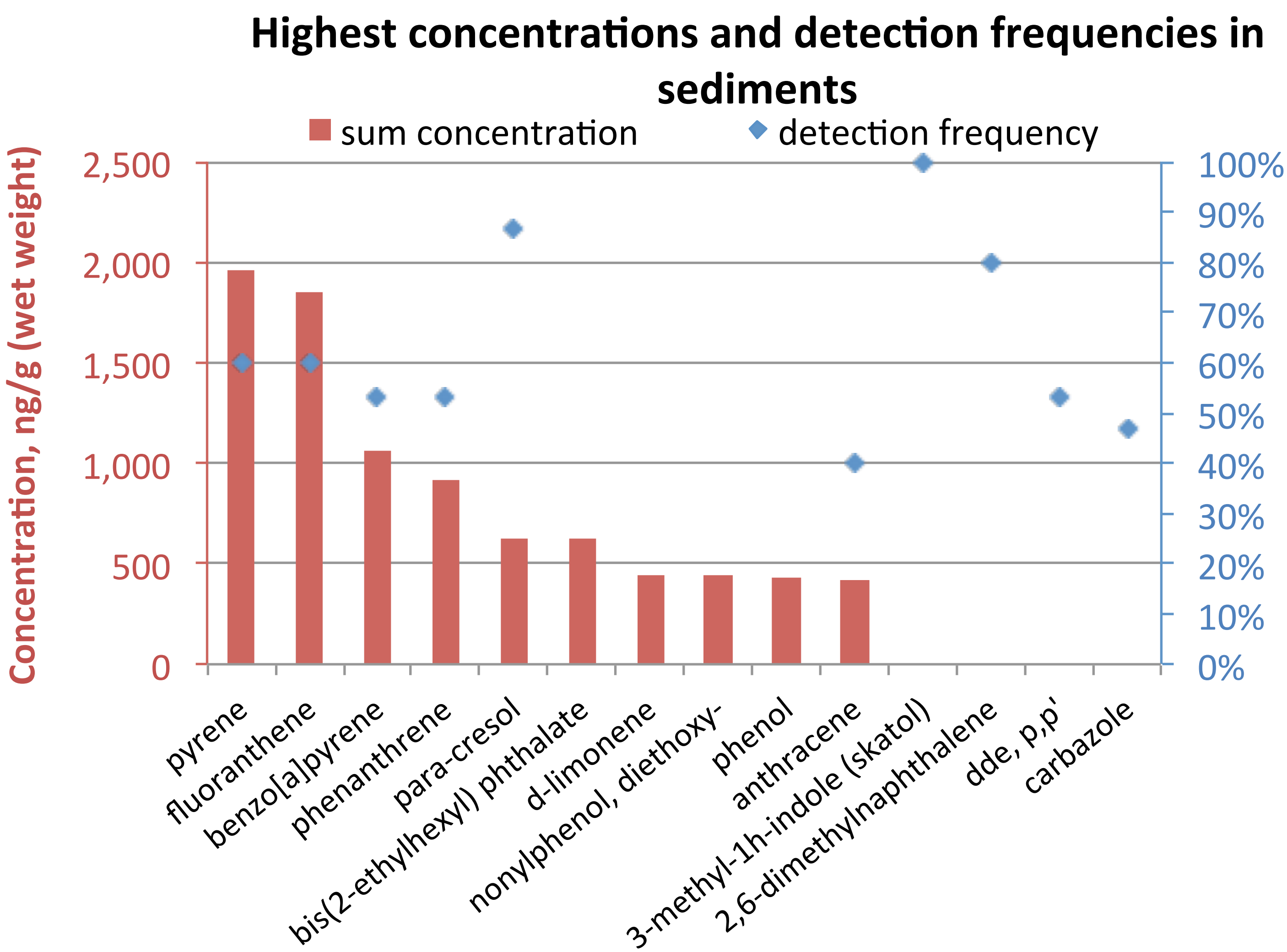

Figure 16. Most prevalent contaminants in sediments

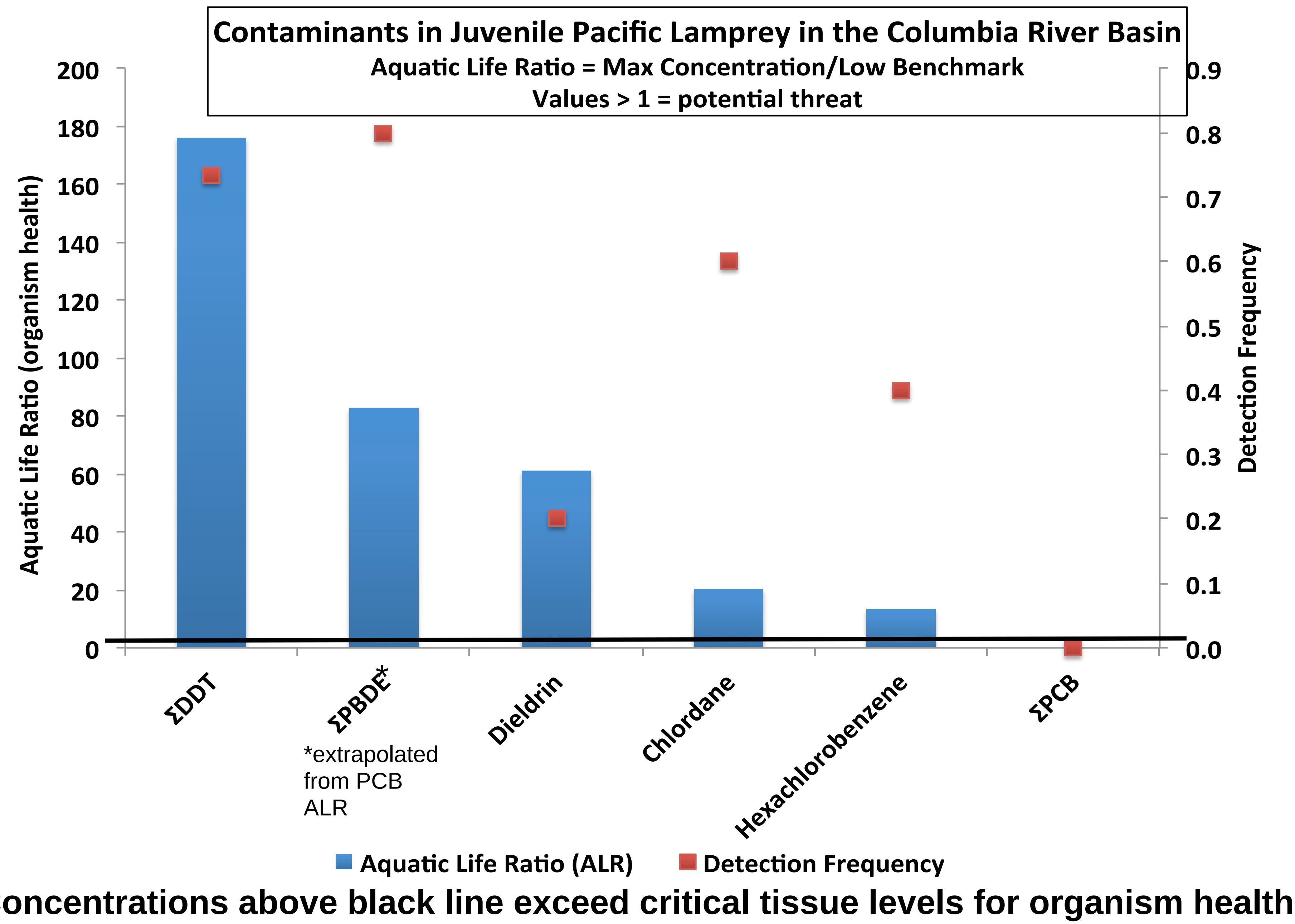

Figure 17. Aquatic life ratios for contaminants in larval lamprey tissues.

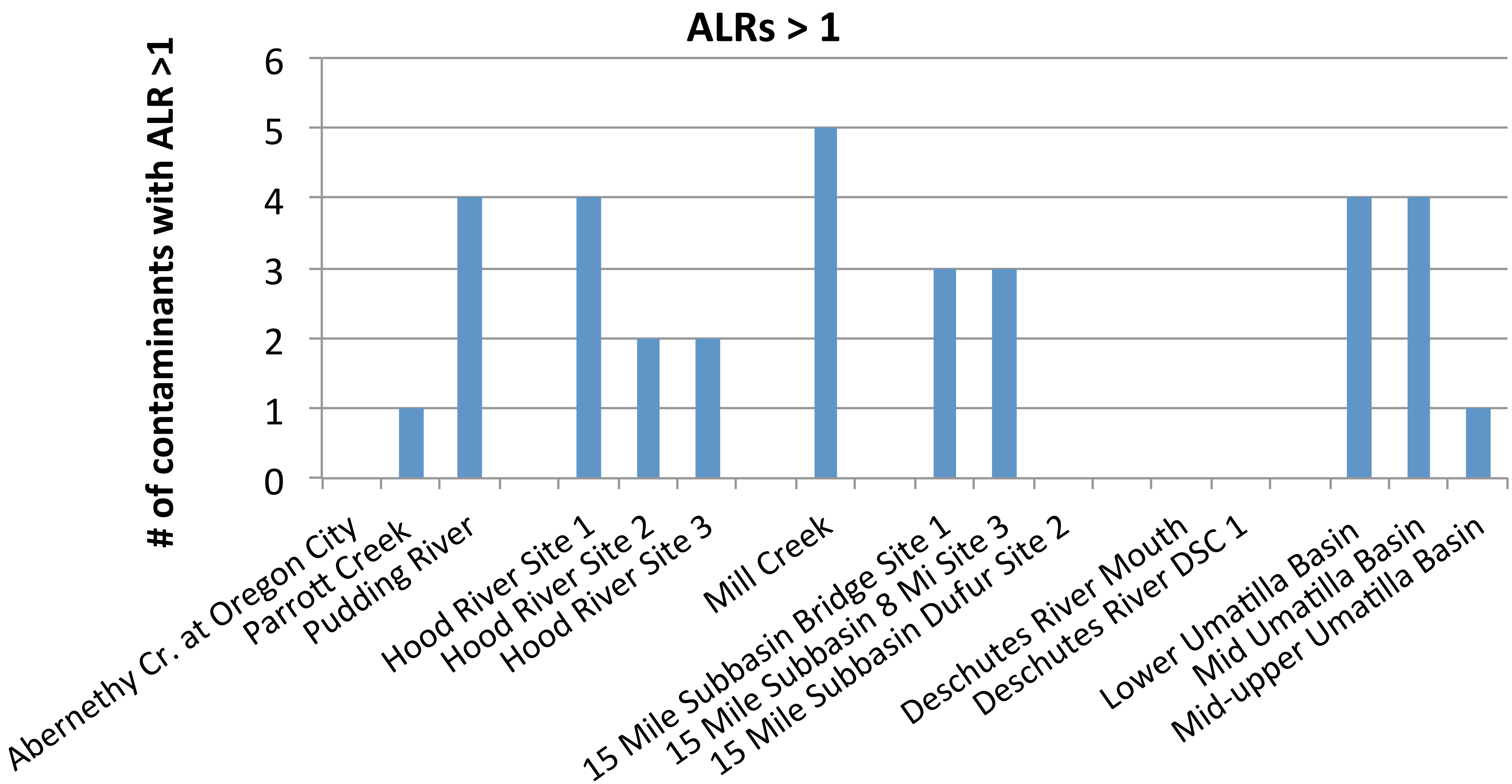

Figure 18. Number of contaminants with ALRs exceeding the threshold of concern

Contaminant	Class	CRITFC sediment		CRITFC juvenile lamprey		ODEQ adult lamprey	
		sediment: high frequency	sediment: high concentration	juvenile tissue: high frequency	juvenile tissue: high concentration	adult tissue: high frequency	adult tissue: high concentration
DDE	pesticide, OC pesticide degradate	x		x	x	x	x
nonachlor, trans	pesticide, OC pesticide degradate			x	x	x	x
PBDE 47	flame retardant				x	x	x
PBDE 99	flame retardant			x	x	x	
DDD	pesticide, OC pesticide degradate				x	x	x
hexachlorobenzene (HCB)	pesticide, OC, banned			x		x	x
nonachlor, cis	pesticide, OC pesticide degradate			x		x	
chlordane, trans	pesticide, OC, banned			x	x		
DDT	pesticide, OC, banned					x	x
dieldrin	pesticide, OC, banned					x	x
endosulfan sulfate	pesticide, OC pesticide degradate, banned			x	x	x	
chlordane, cis	pesticide, OC, banned			x	x	x	x
para-cresol	chemical solvent	x	x				
benzo[a]pyrene	PAH	x	x				
chlorpyrifos	pesticide, CU OP			x	x		
fluoranthene	PAH	x	x				
phenanthrene	PAH	x	x				
pyrene	PAH	x	x				
PCBs	PCB					x	
endosulfan i	pesticide, OC, banned			x			
endosulfan ii	pesticide, OC, banned			x			
3-methyl-1h-indole (skatol)	fragrance	x					
2,6-dimethylnaphthalene	PAH	x					
oxyfluorfen	pesticide, CU				x		
anthracene	PAH	x	x				
pentachloroanisole (PCA)	pesticide, OC pesticide degradate			x			
phenol	chemical manufacture		x				
d-limonene	fragrance		x				
carbazole	pesticide OC pesticide degradate	x					
bis(2-ethylhexyl) phthalate	plasticizer		x				
nonylphenol, diethoxy- (total,np2eo)	surfactant		x				

Table 2. Matrix of the most prevalent contaminants in sediments and juvenile and adult lamprey tissue

DRAFT

Mercury Concentrations in Pacific Lamprey (*Entosphenus tridentatus*) and Sediments in the Lower Columbia River Basin

PRELIMINARY REPORT

Prepared for the Columbia River Inter-Tribal Fish Commission

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Disclaimer: This draft report presents preliminary findings for total and methyl mercury in lamprey and sediment from juvenile the Klickitat, 15 Mile and Wind rivers that are tributaries to the lower Columbia River. The samples were collected in 2013 by the Yakama Nation Fisheries Program and analyzed at the Pacific Northwest National Laboratory facilities in Richland and Sequim, WA. All results are preliminary and may be subject to revision. This report is intended for use by the Columbia Inter-Tribal Fish Commission only and may not be cited or distributed without the consent of the Pacific Northwest National Laboratory and the authors.

Introduction

Pacific lamprey (*Entosphenus tridentatus*) have long represented an important ecological resource in the Columbia River because of their significance to Native Americans, who have harvested these fish for subsistence, ceremonial and medicinal purposes for generations, but also because they have been a major source of marine derived nutrients supporting food webs throughout the basin (Close et al. 1995, 2002). Adult returns to the Columbia River have declined dramatically in recent years in conjunction with hydropower development, and dams have been implicated as an important source of mortality because of obstruction to critical habitat, delayed migration, and entrainment in turbines and on bypass screens. Similar declines, however, have occurred in other rivers on the west coast of North America, suggesting the possibility of region wide effects on recruitment from factors that contribute to accumulation of contaminants such as mercury in river sediments that are essential habitat for juvenile production. As a result, the Pacific lamprey has become a species of concern for federal and state agencies, Native American tribes, and the public (Close et al. 2002; Luzier et al. 2011).

The potential effects of mercury on lamprey recruitment are well established and relate in large part to the early life history of the species. After hatching, larval lamprey (ammocoetes) drift into areas of fine sediment where they burrow and filter feed for approximately 4 to 6 years before migrating seaward (Scott and Crossman 1973; Sutton and Bowen 1994). Studies have shown that in streams with elevated mercury, juvenile lamprey accumulate the element at concentrations well above those observed in the background and surrounding biota. Bettaso and Goodman (2010), for example, found that concentrations of total mercury in Pacific lamprey ammocoetes in the Trinity River (CA) were 12 to 25 times higher than those found in mussels (i.e. an epibenthic filter feeder), whereas Renaud et al. (1998) reported concentrations of mercury in sea lamprey (*Petromyzon marinus*) in the St. Lawrence River (Quebec) to be approximately 2 to 4 times higher than in nearby mussels. Similar concentrations were found by Drevnik et al. (2006) in sea lamprey (*Petromyzon marinus*) ammocoetes from the Connecticut River (MA) and tributaries, which were positively correlated to the mean mercury concentrations in the sediments, but elevated by a factor of 20 to 30. Whether the concentrations of mercury that lamprey accumulate in their natural environment affect survival is not clear, since the samples in these field studies were collected from live specimens. However, laboratory studies have shown that mercury concentrations measured in fish in the wild approach incipient lethal levels for acute mortality from water borne exposure (Mallatt et al. 1986). Moreover, the mortality response to acute mercury toxicity is also highly temperature dependent. Thus, it seems reasonable that chronic exposure to elevated environmental mercury over 4-6 years of juvenile residence could potentially impair physiological function, growth and survival.

We suggested that the accumulation of anthropogenic mercury in the sediments and in benthic biota has contributed to the decline of Pacific lamprey in the Columbia River and associated tributaries and may be constraining recovery through well-known lethal and sub-lethal effects as described by Depew et al. (2012). Our hypothesis is supported by the recent advisory issued by the Department of Public Health in the State of Oregon (http://public.health.oregon.gov/HealthyEnvironments/Recreation/Pages/fishconsumption.aspx) indicating that resident fish in the mid-Columbia River contain elevated concentrations of mercury (as well as PCBs) that can affect human health, and that consumption of these fish should be limited in general and greatly restricted for susceptible demographic groups, particularly pregnant and nursing women, young children. Although this recent advisory did not specifically include Pacific lamprey, their life history is consistent with those species that would likely be highly exposed to mercury given its chemistry in water (i.e. methylation near the sediment – water column interface), the epibenthic and detrital filter feeding behavior of juvenile lamprey and their protracted freshwater residence (4-6 years). Moreover, proposals currently put forth to ship large quantities of coal through the Columbia River corridor have the potential to exacerbate the impacts to lamprey from mercury toxicity through deposition and leaching of mercury from coal particles and coal dust lost during transit and transfer operations. The mercury content of coal planned for shipment along the Columbia River is well documented (i.e.100 ppb, National Institute of Standards and Technology). Assuming an industry estimated loss rate of 3% during transport, the projected shipment of up to 100 metric tons per year could result in approximately 300 kg of mercury entering the environment each year. Although some proportion of this would occur outside the Columbia River basin, this estimate does not include mercury that would be derived from coal lost during loading operations or storage, which can be substantial (Johnson and Bustin 2006).

Managers lack critical information about the effects of mercury that may be impacting Pacific lamprey productivity, particularly the extent and degree of mercury accumulation in important juvenile lamprey habitat. Our understanding of how the concentration of mercury is altered from one life stage to another (such as from an ammocoete to a macrophthalmia and then to an adult) is also limited. If the increased levels of mercury concentration found in ammocoetes continue into their adult life stage, consumption of adult lamprey by Native Americans may pose significant health risks. Identifying these effects will improve our understanding of the mechanisms that contributed to the decline, assist managers in formulating responses to aid recovery, and help protect human health.

As an initial step to assess the impacts of anthropogenic mercury on lamprey in the Columbia River basin, we conducted a preliminary survey in three lower river tributaries to document mercury concentration in ammocoetes and sediments. Our objectives were to measure total and methyl mercury concentrations in ammocoetes among and within multiple streams and compare these findings to published data from other regions in the United State. These analyses were supplemented with a small number of adult samples collected at Bonneville, The Dalles and John Day dams to provide additional baseline information on the potential risks for lamprey reproduction and for human health from consumption.

Methods

Sample preparation and analysis: Juvenile lamprey (ammocoetes) were collected by Yakama Nation Fisheries Program personnel from three tributaries to the lower Columbia River in November 2013: the Klickitat River, Wind River and 15 Mile Creek (Table 1). Sampling effort was focused on Type I and Type II ammocoete habitat as defined by Slade et al. (2003). A total of $n = 10$ ammocoetes were obtained at two sites (river mouth and approximately 5-7 miles upstream) in the Klickitat River and 15 Mile Creek, whereas $n = 5$ were obtained from a single location (river mouth only) in the Wind River. The ammocoetes were collected using a AbP-2 backpack electroshocking unit (Engineering Technical Services, University of Wisconsin, Madison, Wisconsin). The device was set to deliver 3 pulses per second (125 V direct current) at a 25% duty cycle with a 3:1 burst pulse train to induce emergence of ammocoetes from the substrate, which were then stunned with a current of 30 pulses per second for collection. The ammocoetes were wrapped in aluminum foil and placed in zip lock bags on ice for transport to Toppenish, WA where they were measured for length and frozen until shipment to the Pacific Northwest National Laboratory for mercury analysis. Sediment samples were also collected at each sample site and placed in 20 ml acid washed (2% HNO_3) polyethylene vials and frozen. Four adult lamprey were also collected at the Bonneville (1), John Day (2) and Dalles (1) dams in July 2013.

Lamprey samples were analyzed at the PNNL Marine Sciences Laboratory (MSL) in Sequim, WA for total and methyl mercury. Sediment samples were analyzed for total mercury at PNNL in Richland, WA. Total and methyl mercury for lamprey were determined by cold vapor atomic fluorescence spectrometry (CVAFS) developed largely at the MSL and described in EPA Methods 1630 and 1631, respectively. Briefly, for methyl mercury, whole body samples were homogenized and digested with KOH/methanol, ethylated, then purged onto graphitized carbon traps for pre-concentration and interference removal. The mercury species were separated by isothermal chromatography, broken down to elemental mercury by pyrolysis and detected by CVAFS. For total mercury, the tissues samples were digested in a solution of HNO_3/H_2SO_4, heated for 4 hours, and then diluted with 10% BrCl. The mercuric ions in the digested sample were reduced to elemental mercury with $SnCl_2$ and purged onto gold-coated sand traps for pre-concentration and interference removal. Mercury vapor was then thermally desorbed to a second analytical gold trap and introduced into a gas phase fluorescence cell for CVAFS. Preparation and analytical duplicates, standard reference materials and blank spikes were run throughout the analyses for quality assurance and control.

Sediment samples were decanted of water and heated at ~ 35 °C in plastic weigh boats until dry. After drying, 0.5 g was taken from each sample and placed in a Teflon vial with a 13 mL solution of 6 M HCl and 7.5 M HNO_3, heated at 70°C for 3 hours and extracted overnight. The resulting leachate was then filtered and an aliquot was diluted 10X with deionized water for analysis. The diluted samples were analyzed on a Thermo XSeries2 ICP-MS with appropriate calibration standards, blanks and check solutions. Mercury was monitored at masses 199, 200, 201, and 202 to confirm the identity of each peak's intensity as Hg. One sample (Lower Wind River) was run as a total replicate from a separate aliquot of the same leachate.

Data analysis: The effect of body length on methyl Hg concentration was tested by linear regression. Differences in methyl Hg concentration of ammocoetes among and within samples sites were determined using the Kruskal–Wallis rank tests because the site variances were not equal and could not be transformed to meet this assumption for parametric analysis. To compare our results with published values, we converted methyl mercury concentrations in tissue to total mercury using a subset of samples (n = 8) showing that methyl Hg **≈** 0.8 x total Hg. Tissue dry weight was converted to wet using data from Bettaso and Goodman (2010) indicating lamprey tissue moisture content is ~ 73%.

Results and Discussion

We found wide variation in methyl Hg concentrations in ammocoetes, as well as adult lamprey (Table 1). For ammocoetes, methyl Hg concentration differed significantly among ($P \leq 0.02$), but not within rivers ($P \geq 0.08$). The highest tissue concentrations were found in ammocoetes from the Klickitat River, which were approximately 3x greater than those observed in the Wind and 15 Mile rivers. Although most of the large ammocoetes (> 100 mm) were found in the Klickitat River, there was no effect of body length on tissue concentration ($P = 0.36$).

Converting methyl Hg (dry weight) to total Hg (wet weight) shows that the concentrations in the Wind River and 15 Mile Creek ammocoetes are similar to those reported in other studies, which have been conducted in regions of well-known atmospheric Hg deposition (e.g. Great Lakes region, New England, Atlantic Canada), or areas of intense mining operations (e.g. Trinity River, CA) (Figure 1). Whether the total Hg concentrations in the sediments from these study locations are similar to those in the Columbia River tributaries is unknown because other than Drevnik et al. (2006), these studies did not report sediment values. However, the concentrations in river sediments in this study range from approximately 5x to 100x higher than those reported by Drevnik et al. (2006), and show a clear relationship with total Hg concentrations in the ammocoetes, which appears to be asymptotic as the sediment concentration exceeds ~ 1700 ppb (Figure 2). This could indicate a possible upper limit for Hg body burden in ammocoetes, but if so it may mean that Klickitat River ammocoetes are at or above toxicity levels that can have lethal effects. This suggestion is supported by studies of other species showing that lethal effects (e.g. mortality, failure to hatch or spawn, developmental abnormalities) increase rapidly once tissue concentration for methyl mercury exceed 0.1 µg/g (Dillon et al. 2010). The lowest methyl Hg concentrations we found in ammocoetes were 0.22 ± 0.05 µg/g from the lower 15 Mile Creek. At this concentration, approximately 6% of the population would have likely experienced some form of lethal injury (Dillon et al. 2010). For Klickitat River ammocoetes, the calculated lethal injury at ~ 1.5 µg/g of methyl Hg approaches 40%. Early life stage fish, defined as eggs, embryos and fry (Beckvar et al. 2005) are at even greater risk, whereby tissue concentrations of ~ 0.4 µg/g methyl Hg are estimated to produce 50% lethal injury (Dillon et al. 2010). Moreover, sub-lethal effects (e.g. altered behavior, development and growth) have been found to occur consistently above 0.3 µg/g (Beckvar et al. 2005), which suggests that most of the ammocoetes collected this survey may have experienced some adverse effects from mercury. These concentrations may also be problematic for other fish because ammocoetes serve as an important source of prey for a variety resident freshwater species, thus they may be acting as major vectors for Hg transmission into higher trophic levels. As a dietary source, the Hg concentrations in these ammocoetes exceed proposed thresholds that can have adverse growth, behavioral, reproductive and biochemical effects for other fish species (Depew et al. 2012).

For adult lamprey, the mean (± SD) concentration of 0.44 ± 0.46 µg/g (wet weight) was nearly equal to that of ammocoetes in the Wind River (0.46 ± 0.13 µg/g), but much more variable. Two of the four adult lamprey samples had Hg concentrations that were ≤ 0.05 µg/g, whereas the other two samples were ≥ 0.7 µg/g, which were higher than in any of the ammocoetes except those from the Klickitat River. Only limited contaminate sampling has been done on adult lamprey. In 2009 Oregon Public Health Division in conjunction with CRITFC collected adults at Sheras's Falls, Willamette Falls and John Day Dam and found mean mercury levels of 0.21 µg/g (CRITFC 2009). Elevated tissue Hg can lead to reproductive impairment in fish through multiple mechanisms and may be transgenerational as well (reviewed by Crump and Trudeau 2009, Depew et al. 2012). These effects have been shown to occur in organs and cellular systems across the reproductive axis and include alterations of neurosecretion and transmission, disruption of hypothalamic and pituitary endocrine function, and reduced synthesis of reproductive steroids, gamete production and spawning success. Importantly, the concentrations of methyl Hg found in the two adults that were ≥ 0.7 µg/g are well above or within the range of threshold levels reported for reproductive impairment (i.e. range of ~ 0.1 – 1.0 µg/g), and provide further evidence that Pacific lamprey in the lower Columbia River basin are being negatively affected by Hg accumulation in their environment. It is also worth noting that at tissue concentrations of methyl Hg above approximately 0.5 µg/g, the EPA recommends no more than one meal per month (6 oz. cooked) for fish (U.S. EPA, 2000, 2003).

Table 1. Sample locations and dates, sample size and the mean (±SD) length and methyl mercury concentration in ammocoete and adult lamprey from the lower Columbia River basin. Sites without letters in common denote methyl Hg concentrations that are significantly different from each other ($P \leq 0.05$).

Site	Collection Date	N	Length (mm)		Methyl Hg ug/g dry wt.	
Lower 15 Mile	6-Nov	5	88	(22.7)	0.8 z	(0.17)
Upper 15 Mile	6-Nov	5	87	(35.6)	1.0 zx	(0.40)
Upper Klickitat	6-Nov	5	73	(20.5)	5.7 y	(0.91)
Lower Klickitat	6-Nov	5	118	(20.4)	5.1 y	(1.61)
Lower Wind	7-Nov	5	66	(27.5)	1.4 x	(0.38)
Adults	16-26 Jul	4	NA		1.3	(1.35)

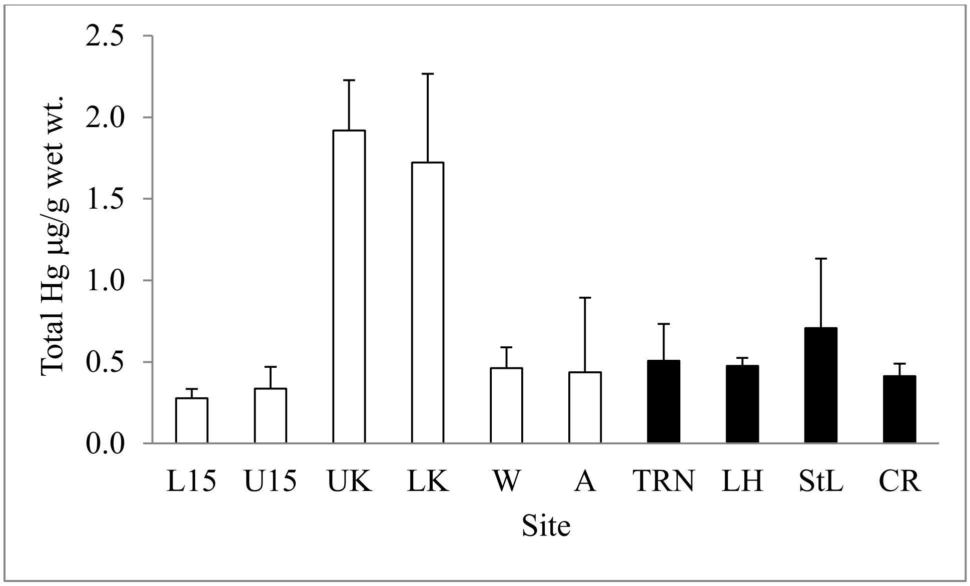

Figure 1. Total Hg concentrations (mean ± SD) in ammocoetes and adult lamprey from the lower Columbia River (open bars) and other North American locations (closed bars). Site designations are: L15 and U15 (lower and upper 15 Mile River), UK and LK (upper and lower Klickitat), W (Wind River), A (adults collected at John Day, The Dalles and Bonneville dams), TRN (Trinity River, CA), LH (Lake Huron), StL (St. Lawrence River, ON) and CR (Connecticut River, MA). All comparative sites are ammocoetes except Lake Huron (adults). Values for comparative sites are means (±SD) for composite groups (e.g. multiple locations, species and sexes combined).

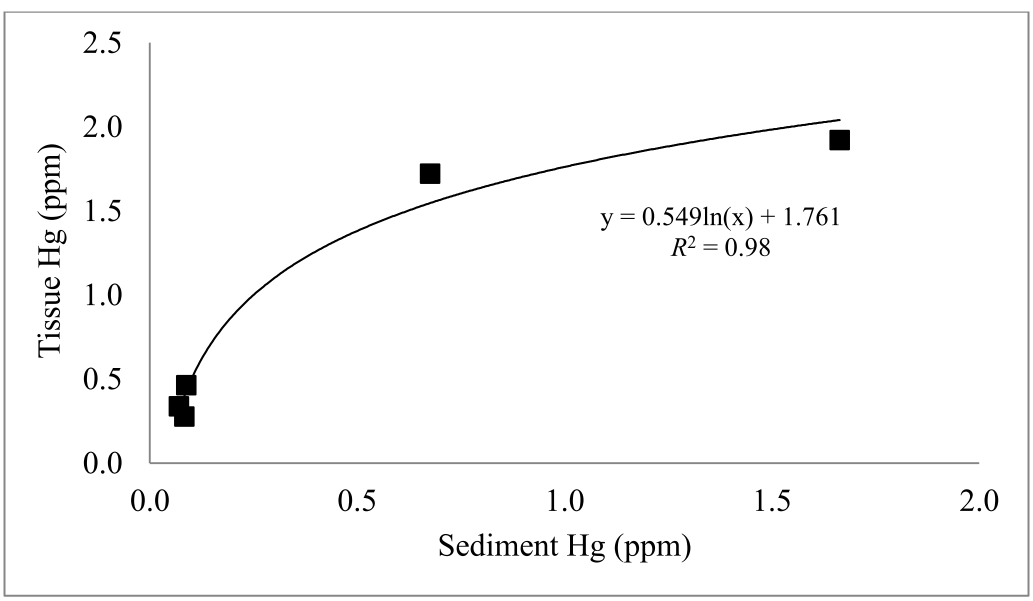

Figure 2. The relationship between total Hg in ammocoetes and stream sediments from the Klickitat, 15 Mile and Wind rivers. Values are means of n = 10 or n = 5 fish from each stream.

Summary and Recommendations

Mercury concentrations in ammocoetes and adults collected for this study approximate and in some cases exceed those reported for lamprey elsewhere in the U.S. When compared with other species where Hg effects have been well studied, the concentrations in ammocoetes from the Klickitat River, 15 Mile Creek and the Wind River suggest that many of these fish may have experienced and (or) continue to experience lethal and sub-lethal adverse effects from Hg that constrain population recruitment. Of particular interest are the extremely high levels of Hg found in the ammocoetes and sediments from the Klickitat River. The reasons for this are unclear and samples collected from higher locations in the watershed may help in answering this question. Analyzing these samples for source attribution may be informative as well. We suggest that a broader and more detailed survey of known Pacific lamprey inhabited rivers in the lower Columbia River basin be conducted to fully document the extent and degree of Hg exposure. Improved understanding of this problem will aid recovery efforts by identifying river systems likely to benefit from reintroduction – transplantation actions, as well as those that might not. Finally, we also recommend that additional analyses of Hg in adult lamprey be undertaken to better characterize the potential impacts to reproduction, and importantly the risk to human health from consumption of these fish.

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Pacific Lamprey Passage Structures Report

November 1, 2012 – March 15, 2013

Fishhead Technology

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The type of Lamprey Passage System (LPS) being proposed is based on previous LPS designs used on the Umatilla River Diversion Dam and Army Corp of Engineers Columbia River Dam Project.

The components to a working LPS

- There are three style of ramps used in a LPS
  - The first being a climbing ramp, which is where Lamprey first enter from the river. These can range in width from 16” to 24” and are 6” deep. The degree of angle should not exceed 60º, a good workable angle would be 45º. Over 60º are passable but would slow down Lamprey travel time.

- The second style of ramps are swim ramps. Swim ramps are ramps that run horizontally. They range in width from 8” to 24” and 6” deep. Swims ramps allows Lamprey to detach from the climbing ramp. Here they swim into rest boxes and through the upwell box to return to the river. There should be at least 24” of swim ramp downstream of rest box for lamprey to enter with ease.

- A transition ramp is the third and last style of ramp. It is a section of swim ramp which is usually 24” long and transitions from 24” to 8” wide downstream of the upwell box.

- Note: All ramps above the water are covered but should provide personnel access. Ramps below the water line are open to provide entrance throughout the water column.

- Upwell box
    - The upwell box is the furthest upstream box in an LPS system. It is where pumped water is introduced which provides water for the entire LPS.
    - Lamprey do not rest in the upwell box, they pass through it on their return to the river.
    - The upwell box allows the Lamprey to travel one at a time through the upwell box to the exit pipe where a counter could be attached to record passage information.

- Rest box
    - The rest box's use is for changing elevation and or direction during Lamprey passage. Once in the box, the design directs the flow of water to guide the Lamprey to the next level or direction.
    - The rest box provides sanctuary. Lamprey usually travels at night. Some may rest in a box during the day and continue through the LPS as night falls.

- Pump System
    - A variety of pump styles can be used depending on power available. 75 to 150 gpm pumps seem to be a good range. Two 75 gpm pumps are usually used to provide

some redundancy in case one pump fails, thus leaving enough water supply for the LPS to operate. Pumps are screened to prevent plugging.

- LPS Support structure and materials
  - The LPS structure is all aluminum, made of 3/16” 5052 aluminum alloy sheeting with the structural components being made of 6061 aluminum alloy.
  - Support design depends on where the LPS is placed on the project. It depends on routing and distance.
  - LPS structures are a semi-permanent construction providing an inexpensive approach to lamprey passage. If damaged caused from high water and/or debris occurs, parts can be easily fabricated and replaced.

Comments and Recommendations

Some smaller modification could be made to spillways at Prosser and Sunnyside dams with the use of a deflector placed upstream of the spillway. This would create a soft flow next to the wall and spillway where the Lamprey like to travel. This design would work well at Sunnyside. At Prosser, a concrete or aluminum flume section would be needed in order to eliminate the overhang spillway design.

Prototype Portable LPS and similar small flumes could be installed in conjunction with spillway deflectors at minimal costs. With the ongoing radio tracking research, US Fish and Wildlife is providing, it would give more insight to where a permanent LPS would work the best. In some cases a deflector or small flume might be all that is needed for Lamprey passage over these diversion dam structures.

For all figures and drawings; please refer to attached PDF. This PDF is made up of all work that has already been sent by email to members of the Expert Technical Team throughout the evolution of this project.

Appendix G2
Collection of Design Drawings for Adult Pacific Lamprey Passage Improvement Structures within the Yakima Subbasin
(Focusing on Prosser and Sunnyside Dams)

Yakama Nation FRMP, Pacific Lamprey Project

December 31, 2013

Prosser Dam Overview

Sunnyside Dam Overview

Engineer Designs by Fish Technology (Jim Simonson): Figure 1-14

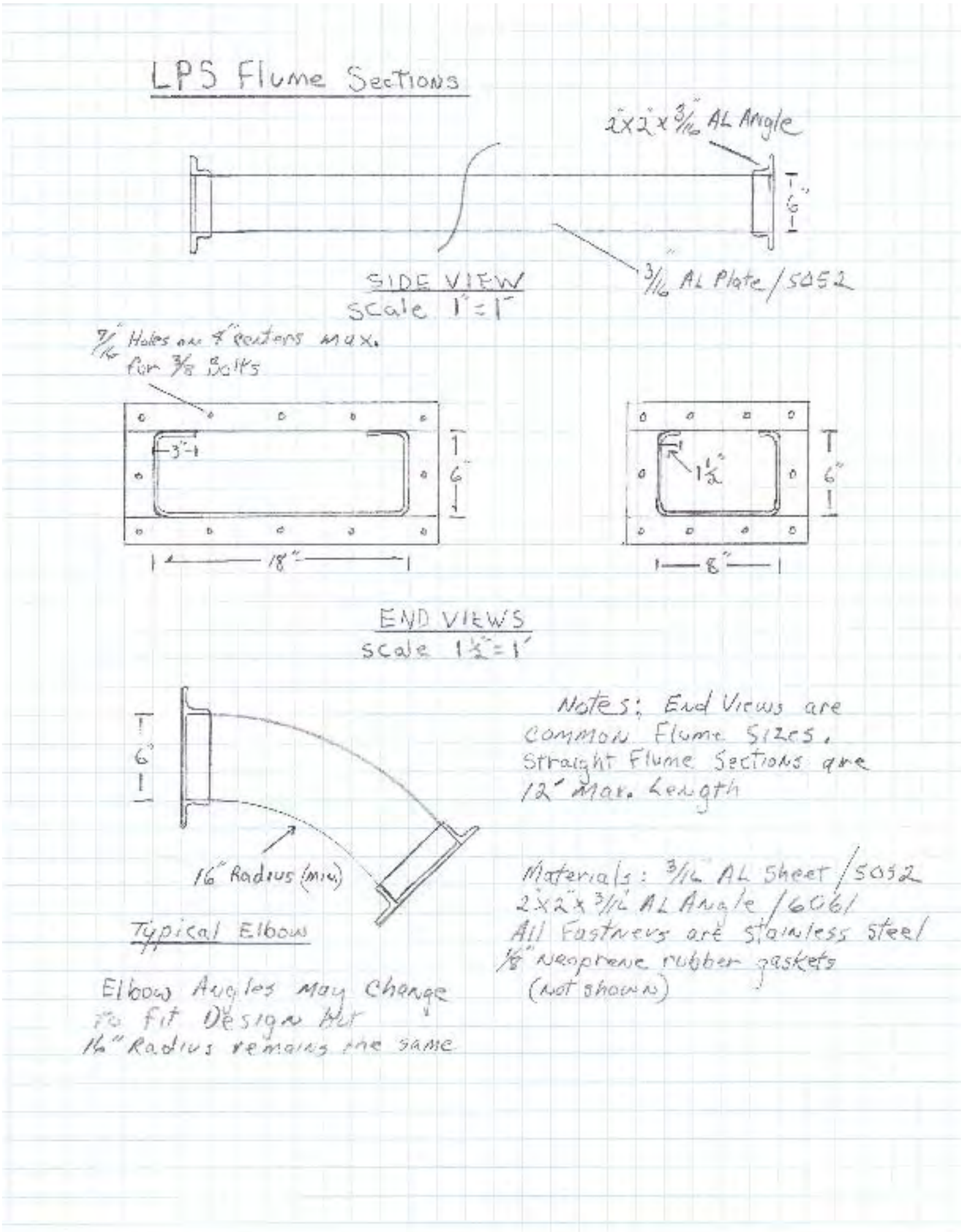

Figure 1. An engineer drawing of the standard lamprey flume design. The flume connects with the rest box and eventually upwell box shown in Figure 2 and 3, respectively, to construct the basic Lamprey Passage Structure (LPS).

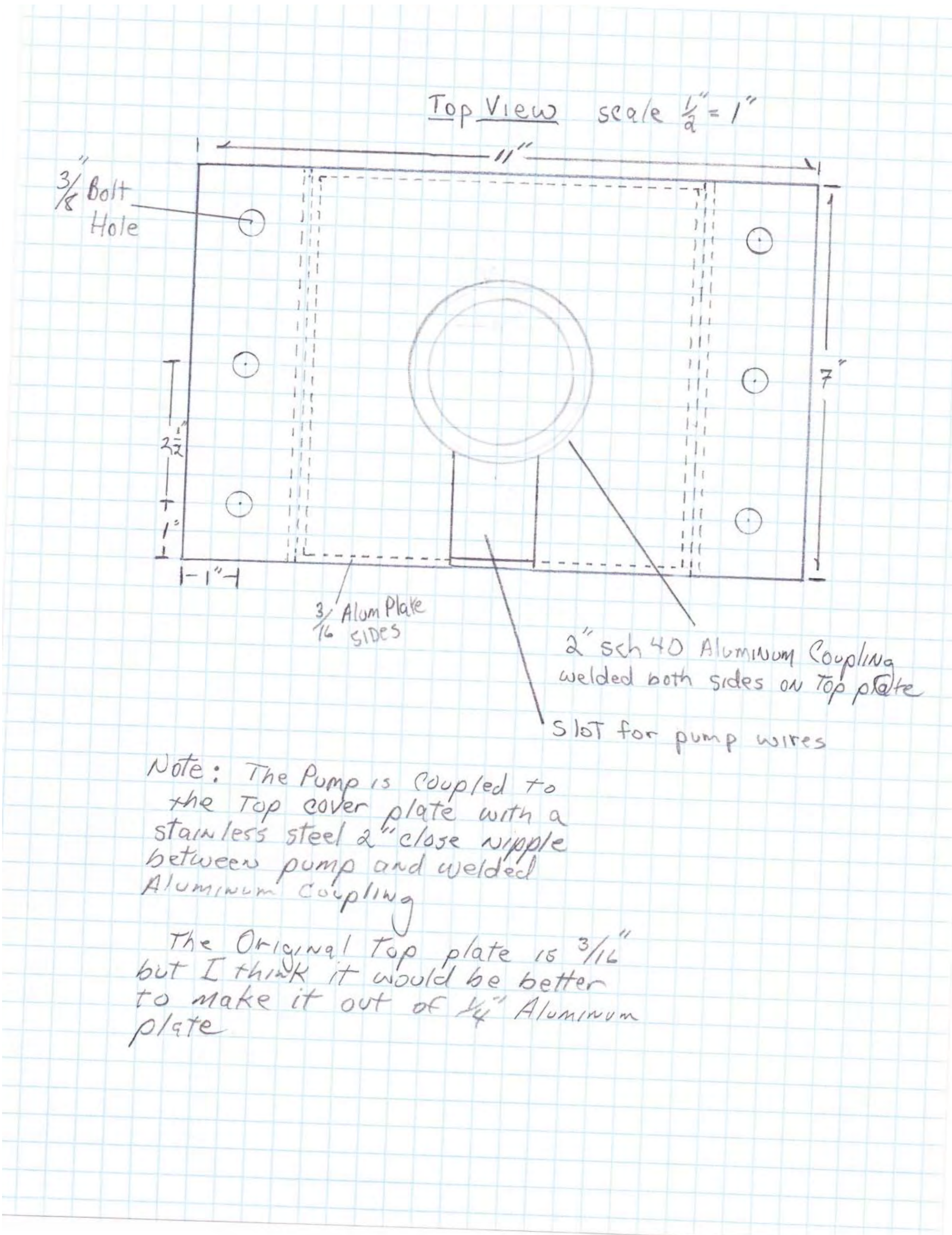

Figure 2. An engineer drawing of the pump connection for the basic LPS (top view). The dimensions can be modified slightly to accommodate the facility specifications. Lamprey pumps and panels require: 2- Goulds 3HP 230v 3ph Submersible Motor, 2- Goulds 3HP 75GPM Submersible Pump, 2- Cutler-Hammer C-H ECN55I2BAE-E14 sizel240v 3ph, Pump Panel HMCP, 2- C-HH20118-3 HTR overload heaters, 2- AcmeT-2A-53329-lS 6kva 3ph 4801240v Transformer, and l0-4 SEAOW water resistant cord.

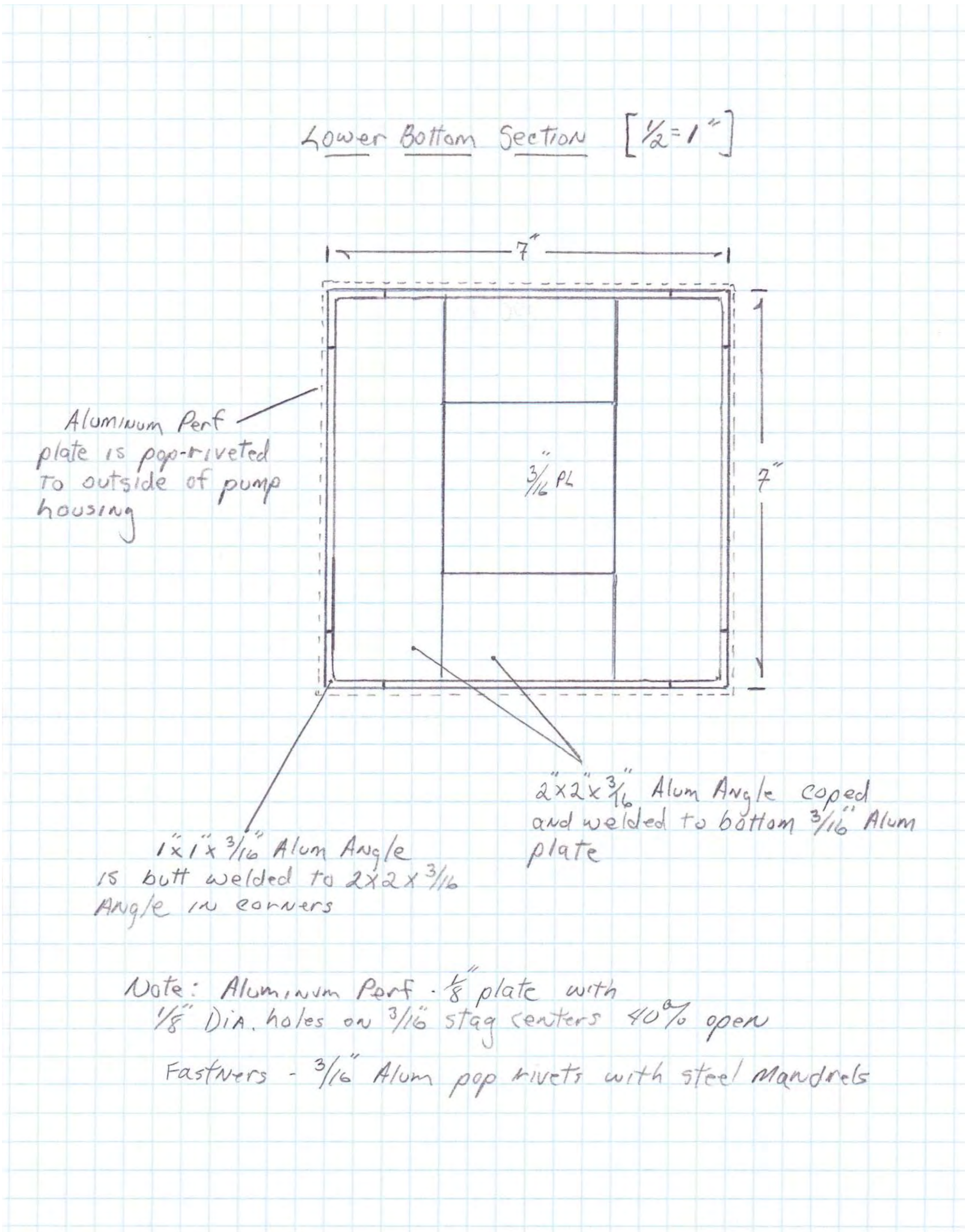

Figure 3. An engineer drawing of the pump connection for the basic LPS (lower bottom section). The dimensions can be modified slightly to accommodate the facility specifications.

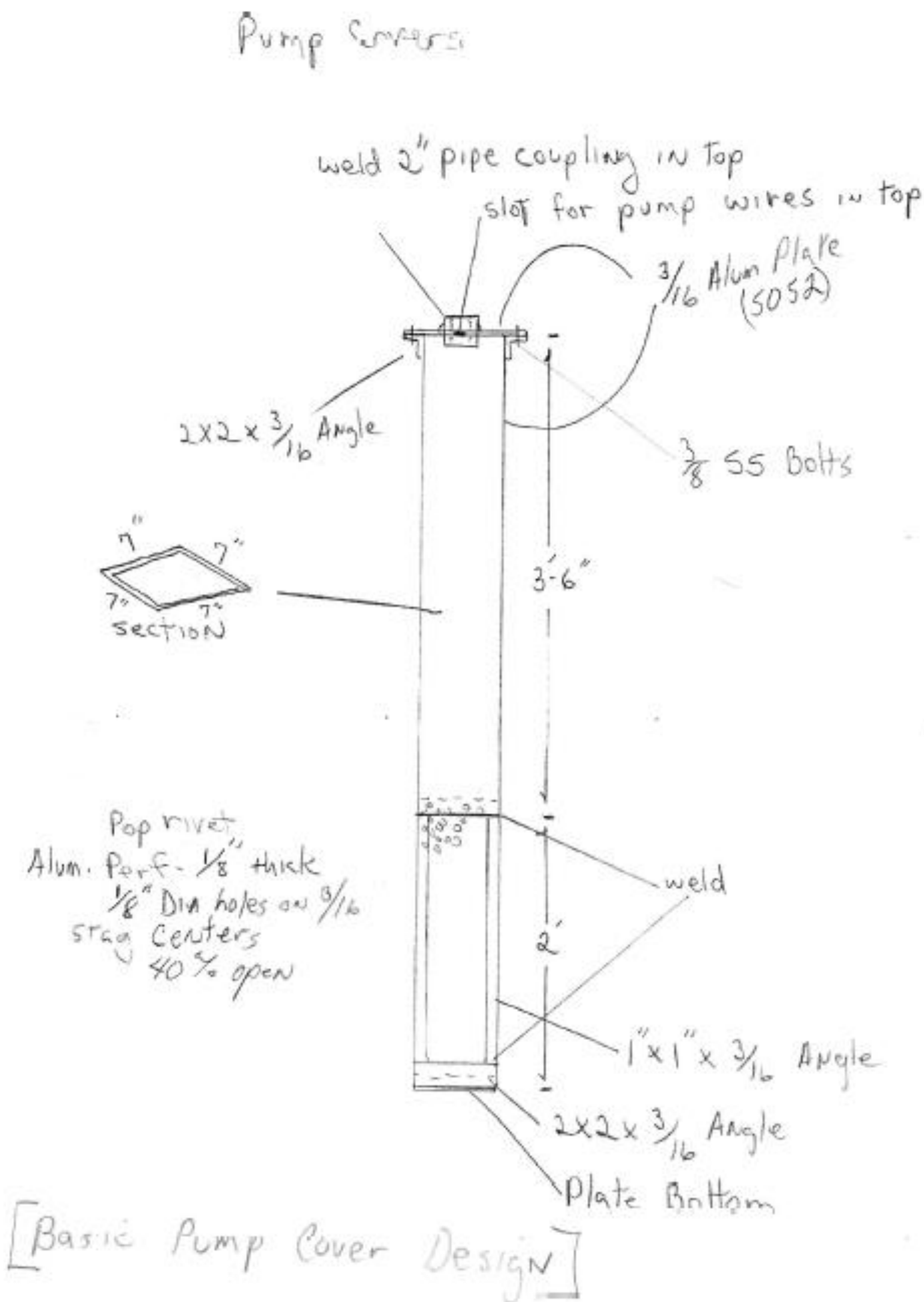

Figure 4. An engineer drawing of the pump covers for the basic LPS. The dimensions can be modified slightly to accommodate the facility specifications.

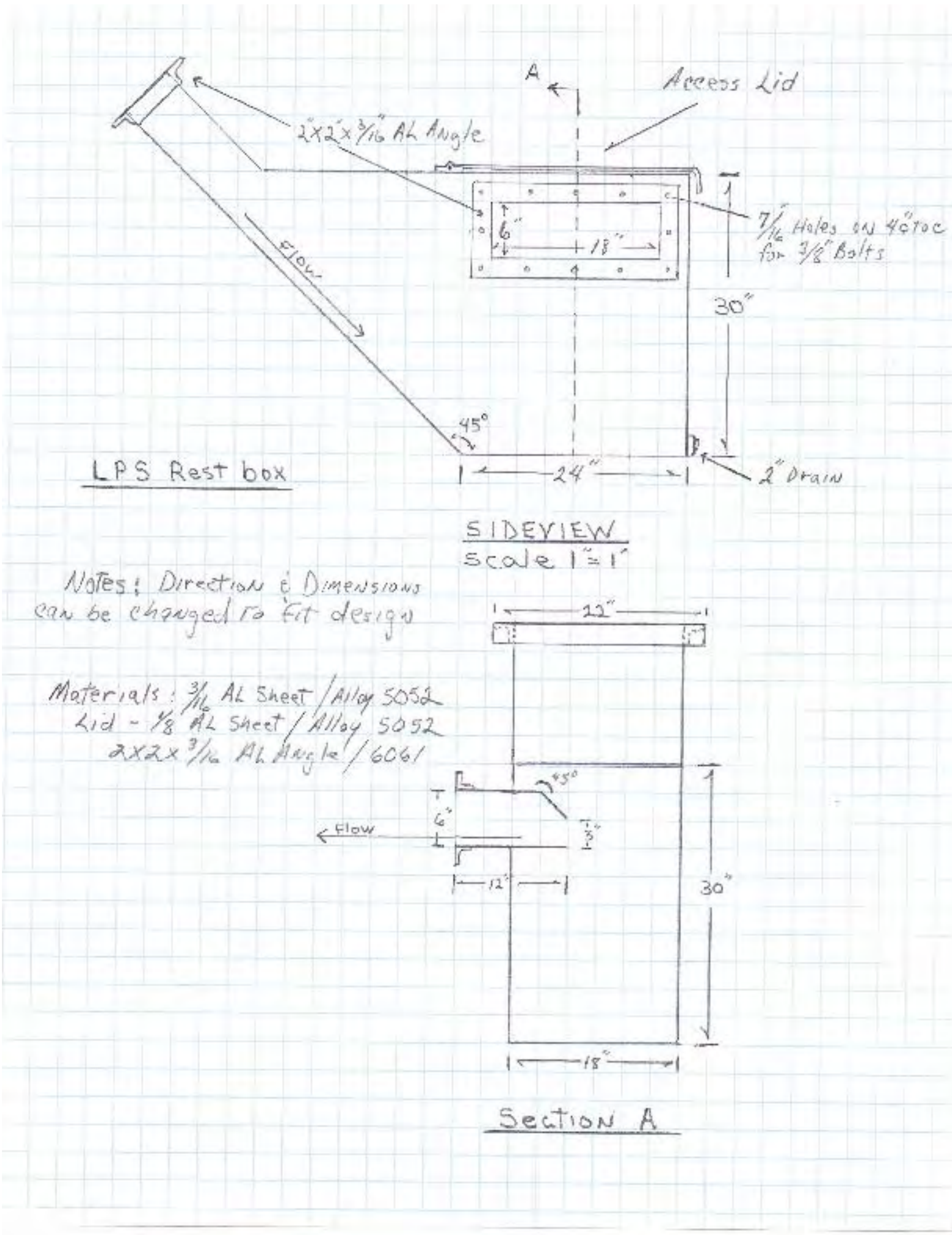

Figure 5. An engineer drawing of the standard rest box for the basic LPS. The dimensions can be modified slightly to accommodate the facility specifications.

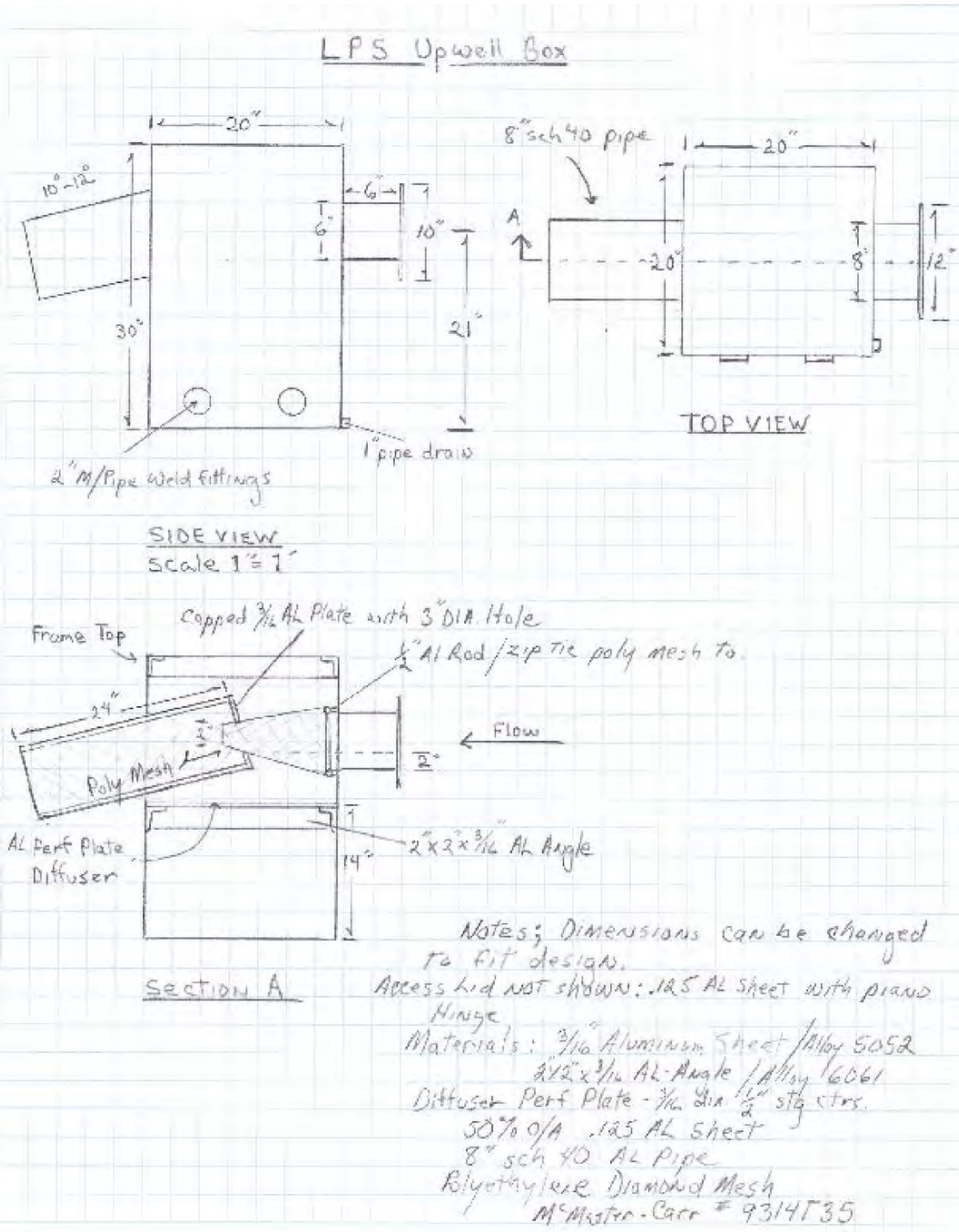

Figure 6. An engineer drawing of the standard rest box for the basic LPS. The dimensions can be modified slightly to accommodate the facility specifications.

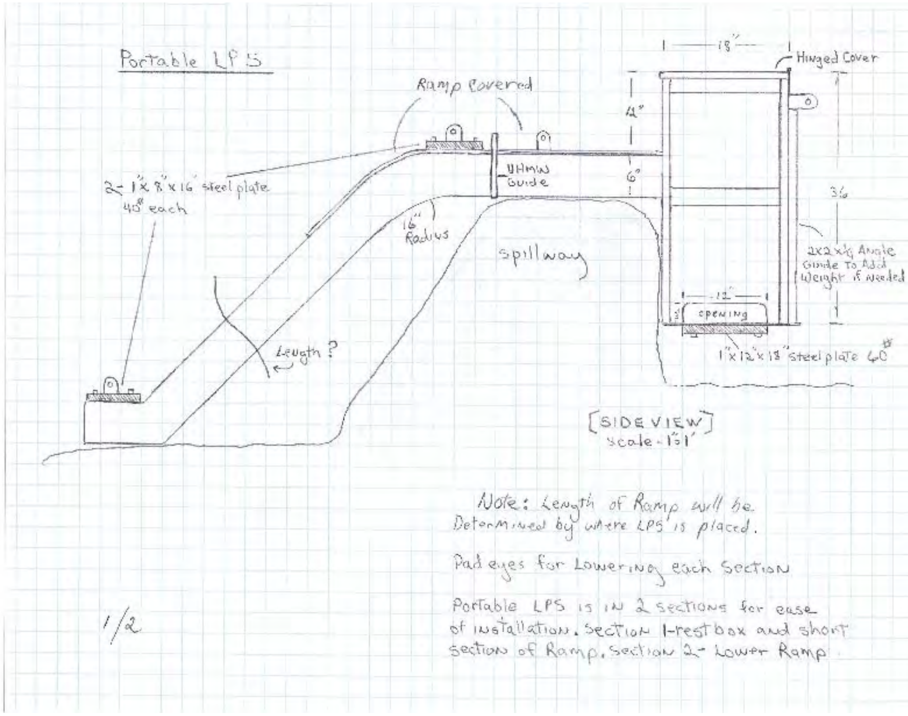

Figure 7. An engineer drawing of a prototype "Portable LPS" looking sideways. The dimensions can be modified slightly to accommodate the facility specifications. A rough estimate for the construction cost is $4200 [material cost = $1200; labor cost = $3000 (40 hrs. at $75.00 /hr.)].

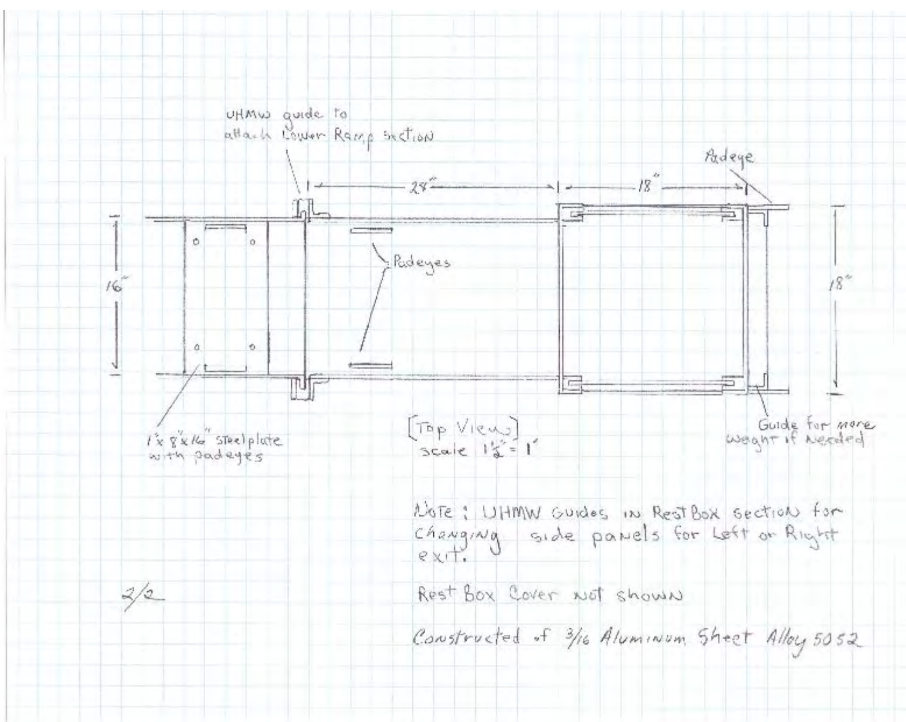

Figure 8. An engineer drawing of a prototype "Portable LPS" looking from the top. The dimensions can be modified slightly to accommodate the facility specifications. A rough estimate for the construction cost is $4200 altogether [material cost = $1200; labor cost = $3000 (40 hrs. at $75.00 /hr.)].

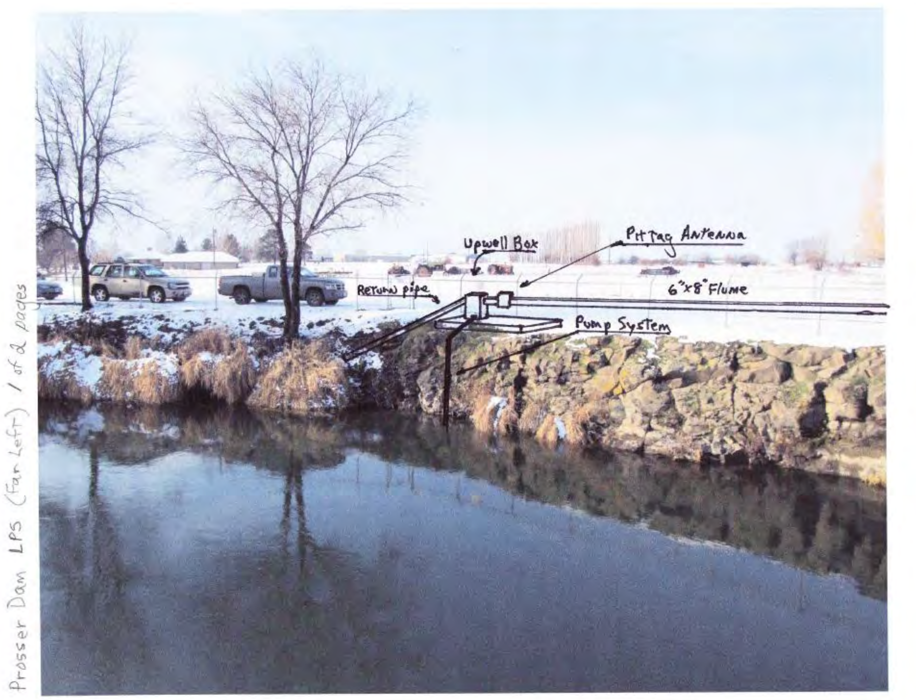

Figure 9. A photo with an engineer drawing depicting the proposed route on the far left LPS site at Prosser Dam (the upstream half). The specific route and dimensions can certainly be modified, but it provides one example of what the LPS would look like.

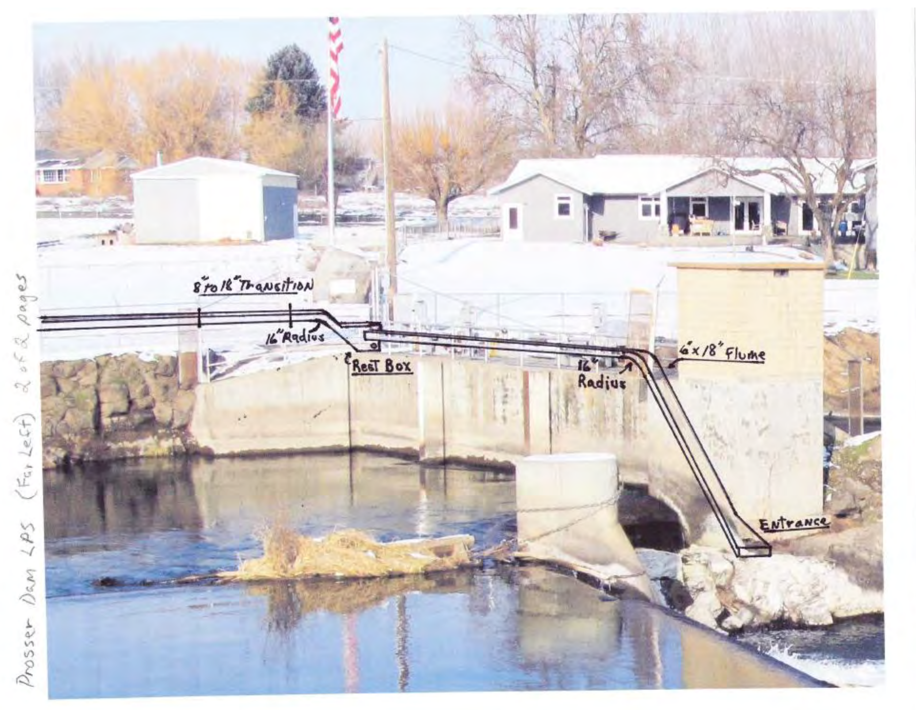

Figure 10. A photo with an engineer drawing depicting the proposed route on the far left LPS site at Prosser Dam (the downstream half). The specific route and dimensions can certainly be modified, but it provides one example of what the LPS would look like.

Figure 11. A photo with an engineer drawing depicting one of the routing options for an LPS structure at Sunnyside Dam (central ladder). This routing option would return lamprey to the centeral fish ladder, providing a short and easy access to enter the fish ladder. Preliminary radio telemetry results from USFWS indicate that many lamprey spent some time just downstream of the central fish ladder, and once lamprey entered and found the fish ladder, most fish were able to successfully pass the dam relatively quickly.

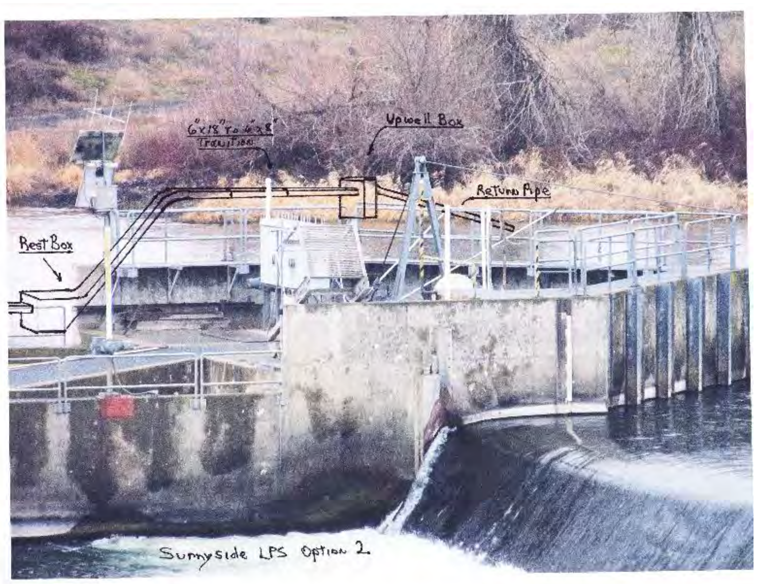

Figure 12. A photo with an engineer drawing depicting one of the routing options for an LPS structure at Sunnyside Dam (central ladder). A photo with an engineer drawing depicting one of the routing options for an LPS structure at Sunnyside Dam (central ladder). This routing option would return lamprey all the way to the upstream side of the dam, using a 6' x 18' flume to the rest box. Although both options (Figure 8 and 9) are viable, if money needs to be spent on a pump system, it may be worth considering a route that takes lamprey all the way to the top, rather than only half way.

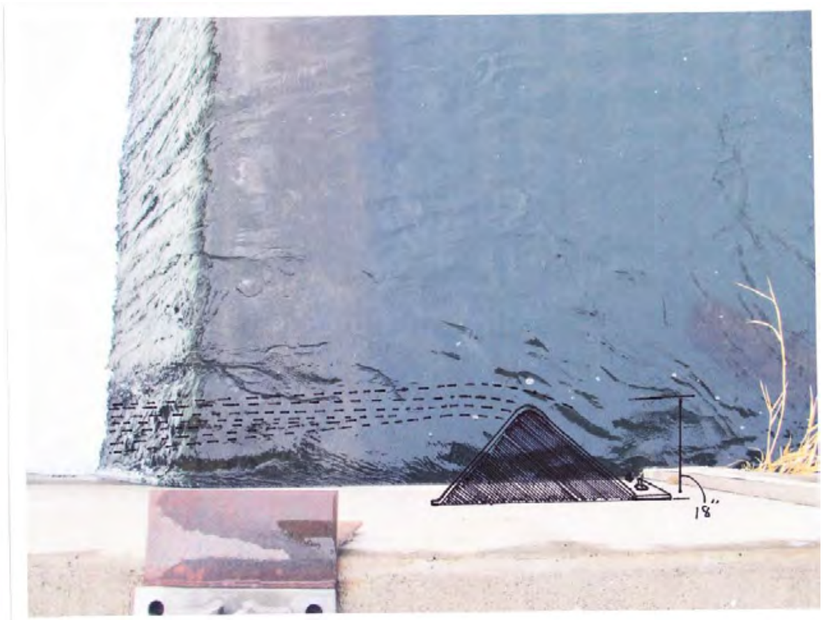

Figure 13. A photo with an engineer drawing depicting a new deflector placed 1.5-2 feet upstream of the spill on the west side of the central ladder, potentially enabling adult lamprey to climb the dam successfully by creating a gentler flow just downstream in the spillway. This structure would be one of the most inexpensive fixes among all the designs contemplated. This structure can be initially tried on the right bank spillway.

Figure 14. A photo showing the existing deflector placed just downstream of the dam. If a declector was placed upstream of the dam (as shown in Figure 9), it may be able to create a gentler flow on the spillway where lamprey could potentially pass.

Google Sketch Drawings by USFWS (Calvin Yonce): Figure 15-21

Figure 15. Entrance to the proposed LPS on the left bank at Prosser Dam. Radio telemetry data suggests that adult lamprey use this area extensively.

Figure 16. The second section for the proposed LPS on the left bank at Prosser Dam, showing the flume extending across the Chandler Diversion headgate.

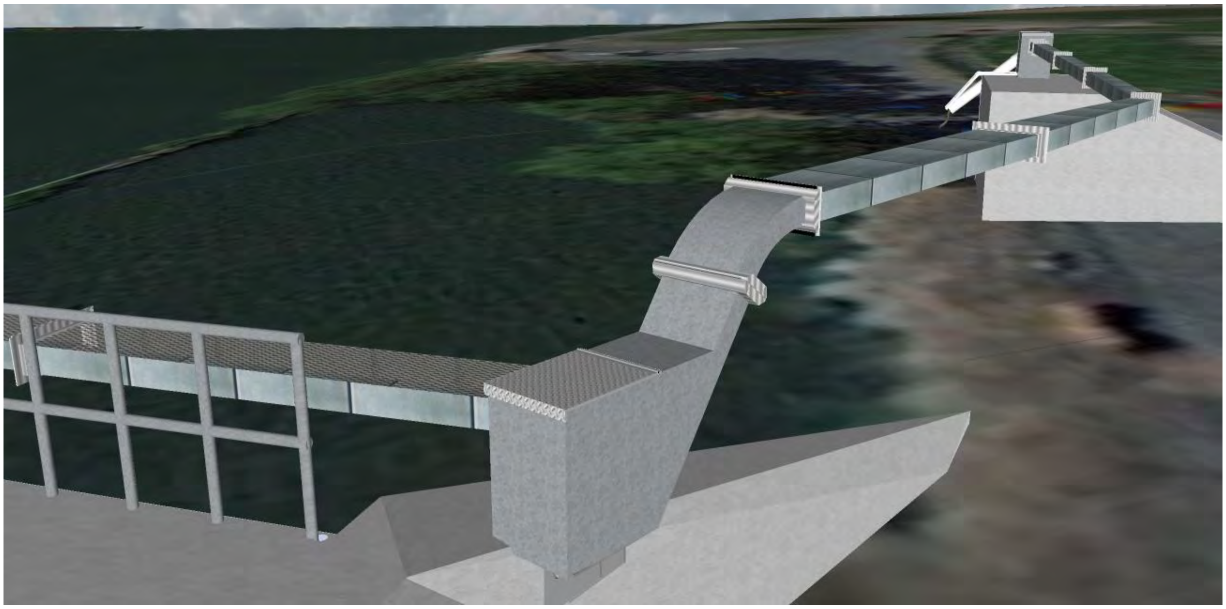

Figure 17. The Third section for the proposed LPS on the left bank at Prosser Dam, showing the rest box and flume extending upstream to the upwell box.

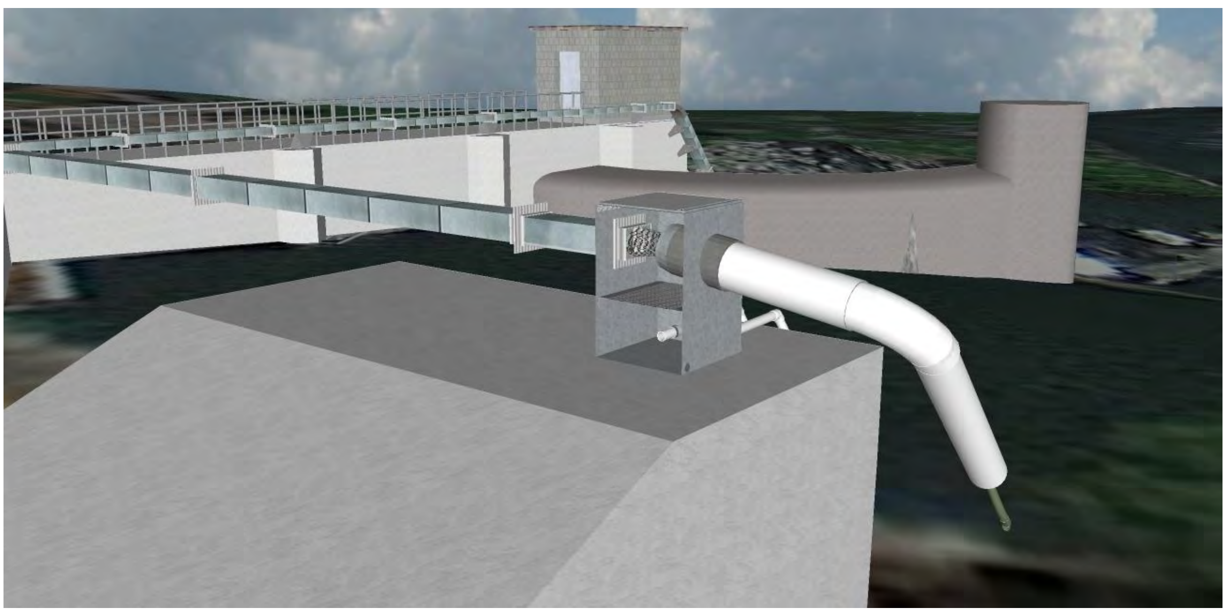

Figure 18. The last section for the proposed LPS on the left bank at Prosser Dam, showing the upwell box and release pipe location.


Figure 19. The overview of the proposed LPS on the left bank at Prosser Dam viewing from upstream.


Figure 20. An alternative view of the entrance to the proposed LPS on the left bank at Prosser Dam.

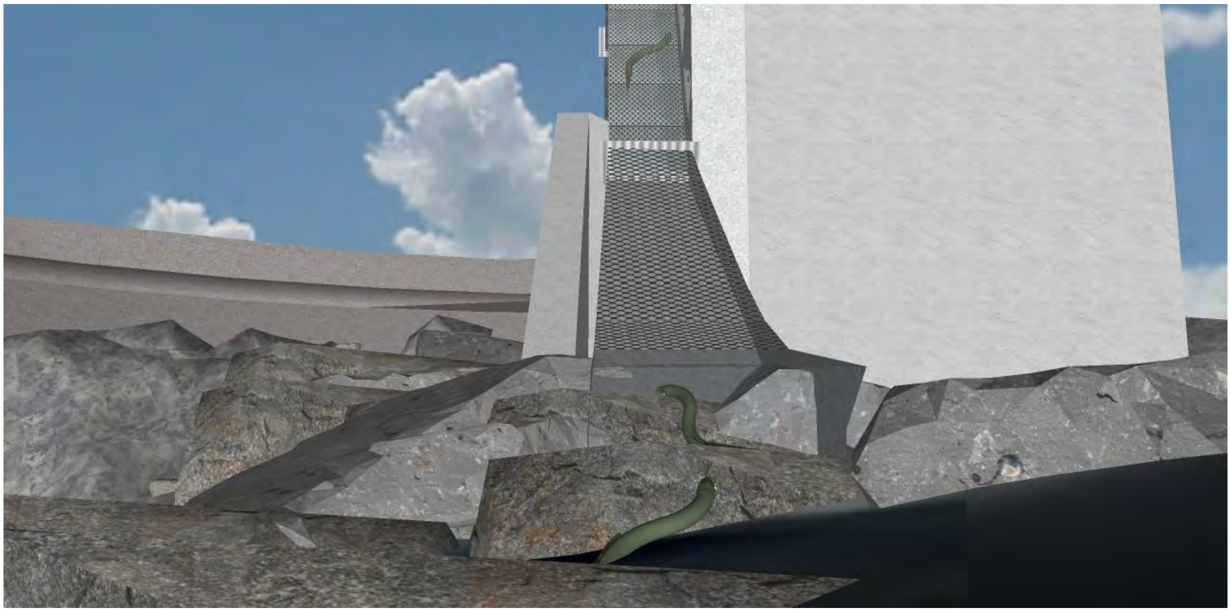

Figure 21. An alternative view of the entrance to the proposed LPS on the left bank at Prosser Dam.

Region:		What and Why	Where	How Big?	How much?	When		Who						
	Threats / Actions	**Description of Actions**	**Subbasin / Watershed**	**Geographic Scale**	**Benefits**	**Feasibility**	**Potential Funding Source**	**Implementing Entity**	**Comments**	**Current Funding and Future Estimated Need**	**Timing**	**Literature**	**Status**	**Lamprey focus action**
Threat #1	**Adult Migration**													
Action 1.1	**Monitoring of Adult Passage & Migration**	Adult movement studies: A) Continue radio telemetry study to determine passage success at irrigation diversion dams, expand to upper Yakima and Naches. B) Evaluate passage success after any passage improvements at the diversion dams using telemetry, or other appropriate methods.	Lower Yakima (lower 4 dams); Upper Yakima (Roza Dam, Town Canal Dam); Naches (Cowiche, Wapatox)	Point	High	High	BOR / BPA / USACE / USFWS/Wasco	Yakama Nation / USFWS	Next steps are to expand studies to Naches, and upper Yakima. Future need to monitor improved passage at structures, using radio telemetry would make comparable to recent studies. Could use PIT tags as well.	Current Funding No funding available. Future Needs: See Action 1.1.	2 release groups [summer (September) and spring (March)] to monitor movement year round	"Passage of Radio-Tagged Adult Pacific Lamprey at Yakima River Diversion Dams Annual Report" (USFWS 2011 and 2012), "Rapid Assessment of Passage Structures for Passage of Adult Pacific Lamprey in the Yakima and Umatilla Rivers" (Yakama Nation / CTUIR / / BOR 2012), "Low-Elevation Dams are Impediments to Adult Pacific Lamprey Spawning Migration in the Umatilla River, OR" (Jackson et al. 2012), YN Fisheries BPA & BOR 2012-2013 Reports (including "2012 Trapping Adult Pacific Lamprey in the Yakima river")	Initial study 2011-2015, in 3rd yr of 4 yr	yes
Action 1.2	**Adult Passage Improvement**	Improve passage at Diversion Dams: Prioritize improvements on the four lower diversion dams (2013-2015); then focus on assessments and improvements of upstream projects. Culvert passage evaluation in tributaries: 1) look at salmonid survey to identify impassable structures; 2) evaluate salmonid passage criteria for lamprey; 3) prioritize structures and culverts for improvements	Lower Yakima (lower 4 dams); Upper Yakima (Roza Dam, Town Canal Dam); Naches (Cowiche, Wapatox); and other small impediment structures	Point	High	High	BOR / USACE / BPA / USFWS	Yakama Nation / BOR / USFWS / WDFW	High priority. Focus on lower river first. Consider translocation areas. SRB in GIS is adding info about lamprey passage in structure/barrier layer. Develop measure of success. Also, managers are considering managing lower river structures to prevent predaceous warmwater fish from moving up.	Current Funding ~$30 k (USFWS for 2014), Future Needs: Approximately $20,000-50,000 per site.	Beginning in 2014, continue to plan and get funding.	Passage of Radio-Tagged Adult Pacific Lamprey at Yakima River Diversion Dams Annual Report (USFWS 2011 and 2012), "Low-Elevation Dams are Impediments to Adult Pacific Lamprey Spawning Migration in the Umatilla River, OR" (Jackson et al. 2012), "Guidelines for Salmonid Passage at Stream Crossings" (NMFS 2000)	1 yr	yes
Action 1.3	**Prevention of Adult Access to Roza Power wasteway #2**	Eliminate/reduce adult access to Roza Power wasteway. Long-term plans are to restructure this area, including wasteway, bridge and, dikes. Plans should include design to make it a barrier to adult lamprey. Short-term options - trap adults in wasteway and move out; explore options to reduce false attraction into wasteway.	Upper Yakima - Gap to Gap reach of mainstem Yakima	Point	High	Medium	BOR	Yakama Nation / BOR	Lamprey getting into the Roza Power wasteway #2. Radio tagged lamprey have entered (8 of 16 tagged, 50% moved in) and some were not able to get out. Short term unsure how to fix easily. Current picket configuration cannot handle ice. May be attracted in by pheromones or attracted by flow patterns.	Current Funding No funding available.	*future project - need to block adult access during spawning migration (March - October)	"Passage of Radio-Tagged Adult Pacific Lamprey at Yakima River Diversion Dams" (USFWS 2011 and 2012)		yes
Action 1.4	**Assess Adult Access to Drains, Wasteway and Outfalls**	1) Evaluate irrigation delivery system to find out where there are problems with adults entering drains, wasteways, and outfalls. Evaluate causes of false attraction (flows and pheromones from rearing ammocoetes). 2) Eliminate/reduce adult access to drains, wasteways, and outfalls (both inlets & outlets).	Sulphur, Zillah, N S Satus, Marion Drain, WIP - bypass -fallback entrained,	Point	Study / Medium	High			Need to assess where adult lamprey accessing then eliminate access.	Current Funding No funding available. Future Needs: Approximately $10,000 per site.				yes
Action 1.5	**Compile Information and Track Changes in Adult Status and Distribution**	1) Compile historical lamprey information on distribution and status, interview elders, assess historical distribution by looking at areas used by spring Chinook salmon, evaluate historical barriers. 2) Evaluate current distribution: use adult telemetry studies to evaluate their migration patterns and possible spawning areas. Larval larval distribution can also be used to determine current distribution.	Lower Yakima, Upper Yakima, Naches	Watershed	Study / Medium	High	BOR / BPA/USFWS	Yakama Nation / USFWS/WDFW		Current Funding Yakama Nation funding from 2008 Fish Accords. Future Needs: No additional funding required.	year round	"Passage of Radio-Tagged Adult Pacific Lamprey at Yakima River Diversion Dams" (USFWS 2011 and 2012), YN Fisheries BPA & BOR 2010-2013 Reports/Data		yes
Threat #2	**Juvenile Rearing (Fine Sediment & Food Source)**													
Action 2.1	**Determine Juvenile Distribution, Status, and Trend**	Continue larval/juvenile surveys in the Yakima River, Naches River, Ahtanum Creek, Toppenish Creek, Satus Creek and other key tributaries. Establish Index Sites to identify important juvenile rearing areas and long-term status and trend. Use these surveys to aid evaluation of adult passage and effectiveness monitoring from supplementation activities. Support development of the use of eDNA, use in the future to help with monitoring.	Region-wide	Watershed	Study / High	High	BPA/USWFWS	Yakama Nation / USFWS	Presence easier to determine, can also evaluate age classes present. Abundance and trends harder to determine, working to establish survey protocols.	Current Funding: Yakama Nation funding from 2008 Fish Accords. Future Needs: No additional funding required.	summer (June - October)	YN Fisheries BPA & BOR 2010-2013 Reports/Data		yes
Threat #3	**Downstream Passage - Entrainment**													
Action 3.1	**Determining New Screen Criteria for Larval/Juvenile Lamprey**	Support USGS in defining new lamprey screening criteria from laboratory research.	Region-wide	Region	Study / High	Medium	BOR/Wasco/USFWS	USGS / BOR	Should determine screening size etc. within 2 yrs, but may take longer for state to adapt. Want to upgrade screens where lamprey present. Might need more than a screen be of larval size. Big benefit, technically challenging, expect to be very expensive.	Current Funding: BOR, FWS funding (to USGS). Future Needs: Approximately $30,000.	year round (lab study)	"Effectiveness of Common Fish Screen Materials to Protect Lamprey Ammocoetes" (Rose and Mesa 2012), "Pacific Lamprey Passage Improvements Implementation Plan" (ACOE 2009), YN Fisheries BPA & BOR 2010-2013 Reports/Data		yes
Action 3.2	**Monitoring and Evaluation of Entrainment Impacts**	Continue working with BOR and other Irrigation Districts to survey irrigation systems to document entrainment and implement new monitoring that document precisely how lamprey are being entrained ("when", "how", "where", etc.). Evaluate solutions to prevent entrainment and passage into the canals.	Lower Yakima (lower 4 dams); Upper Yakima (Roza Dam, etc.); and diversions in supplementation sites (Ahtanum, Naches, Toppenish)	Point	Study / High	High	BPA / BOR	Yakama Nation / BOR / USFWS / PNNL		Current Funding: Approximately $25,000 per year from BOR - Yakama Nation Agreement. Additional support from BOR. Future Needs: Approximately $35,000 per year for 3 years.	winter (October - March)	"Pacific Lamprey 2011 Annual Report and 2012 Plan" (BOR 2012), YN Fisheries BPA & BOR 2010-2013 Reports/Data		yes

Region:		What and Why	Where	How Big?	How much?	When		Who						
	Threats / Actions	**Description of Actions**	**Subbasin / Watershed**	**Geographic Scale**	**Benefits**	**Feasibility**	**Potential Funding Source**	**Implementing Entity**	**Comments**	**Current Funding and Future Estimated Need**	**Timing**	**Literature**	**Status**	**Lamprey focus action**
Action 3.3	**Modify Diversion Facilities (Headgate, Fish Screens, etc.) to Reduce Lamprey Entrainment**	Upgrade screens where lamprey are present. Investigate other technological solutions to keep larvae out of diversions (such as the head gate). Their small size makes this a technically challenging problem.	Basinwide	Point	High	Low	BPA / BOR	BOR/WDFW/CD/Project sponsor	This might be a big benefit to lamprey because if in diversions they cannot survive. The feasibility is low because of time frame and technology challenges. Expect this will be very expensive.					yes
Action 3.4	**Reduction of Dewatering Mortality within Diversions**	Reduce mortality within diversions (between forebay and fish screens) by desiccation and predation during dewatering periods. When reducing flows, manage ramping rates to get the lamprey back to the by pass channel and eventually into the river. Creating perennial flow in these areas may also be an alternative approach.	Basin-wide	Point	High	High	BOR	Yakama Nation / BOR		Current Funding No funding available. Future Needs: Approximately $10,000 per year.	early winter (October - November)	"Pacific Lamprey 2011 Annual Report and 2012 Plan" (BOR 2012), YN Fisheries BPA & BOR 2010-2013 Reports/Data		yes
Action 3.5	**Reduction of Dewatering Mortality in Roza Pool and Diversion Forebay**	Manage water flow in Roza pool to prevent desiccation and predation of juvenile lamprey.	Roza pool and diversion forebay	Point	High	High	BOR	Yakama Nation / BOR	Roza pool has 20-30 acres of fine sediment (from deposits from Wilson Cr), gets dried up every year, but ideal and large lamprey habitat. Prosser pool does not have the same issues.	Current Funding No funding available. Future Needs: Approximately $10,000 per year.	early winter (October - November)	"Pacific Lamprey 2011 Annual Report and 2012 Plan" (BOR 2012), YN Fisheries BPA & BOR 2010-2013 Reports/Data		yes
Action 3.6	**Salvage Juvenile Lamprey in Drains, Wasteways, and Canals**	Salvage removal of lamprey from drains, wasteways, and canals. If lamprey move downstream of screens they will likely die if not removed. Release in the nearby river in suitable habitat. Use lamprey electrofishing techniques or other trapping methods to capture.	Lower Yakima (Sunnyside, Sulphur, Zillah, N S Satus, Marion Drain, WIP); Naches (Wapatox); Upper Yakima (Roza)	Point	Low	High	YN/BOR/WDFW	YN/BOR/WDFW	Electrofishing can be used to salvage, and initially to evaluate how much entrainment is happening (Action 3.2).					yes
Action 3.7	**Characterize Juvenile Out-Migration**	Monitor outmigration of juveniles from the Yakima River. Use Chandler (Prosser) facility to help characterize juvenile migration. In some years, thousands of macrophthalmia (juvenile) lamprey have been documented passing through this facility during winter/spring months (January~June) and can effectively estimate outmigration numbers using PIT tagging and other methods.	Lower Yakima (Prosser Dam)	Watershed	Study / High	High	BPA, BOR, USFWS	Yakama Nation		Current Funding Yakama Nation funding from 2008 Fish Accords. Future Needs: Approximately $1,000 per year.	late winter (January - March)	"Evaluation of Juvenile Salmonid Outmigration and Survival in the Lower Umatilla River Basin" (BPA 1996), "Results of 2012 Lamprey Monitoring" (Fish Passage Center 2012), YN Fisheries BPA & BOR 2010-2013 Reports/Data		yes
Threat #4	**In-Channel Degradation**													
Action 4.1	**Manage deposition of Fine Sediment and Organic Matter at diversions**	Manage and reduce fine sediment and organic matter deposition in front of and within diversions. Maintain sediment deposition in flood plain and side channel habitat and enhance processes for floodplain restoration and development/connection with perennial side-channels.	Basin wide (needs increase as one goes downstream	Point	High	Low	BOR / BPA / WDFW	WDFW / BOR / Irrigation Dist. / BIA	At meeting discussion about sediment supply and transport. Not a problem with sediment supply, low head dams are not interrupting in a way that reduces what needed. Need processes for floodplain restoration and perennial side channels.	Current Funding No funding available. Future Needs: Approximately $15,000 per year.	*future project - pilot project in 2013	YN Fisheries BPA & BOR 2010-2013 Reports/Data Gap to Gap floodplain restoration and enhancement plan (Anchor QEA LLC, 2014)		
Threat #5	**Riparian - Floodplain Degradation**													
Action 5.1	**Riparian/Floodplain Restoration**	Complete projects to restore natural, functioning riparian, floodplain, and side channels including removal of levees/dikes. The Gap to Gap floodplain restoration and enhancement plan should provide benefits to lamprey. Continue to work with the Yakima Fish and Wildlife Recovery Board and other funding agencies to link lamprey habitat restoration to ongoing salmonid restoration actions.	Gap to Gap, Wapato, Lower Naches, Lower Ahtanum, upper Yakima, lower Wenas, Satus, Toppenish	Watershed	High	High	BPA / SRFB / BOR /USFWS/ COR /DOE	Yakama Nation, counties, BOR, project sponsors	Gap to Gap, lower Naches	Current Funding No funding available. Future Needs: RME & assessment needed first.	*future project - pilot project in 2013	"Wapato Reach Assessment Report" (Yakama Nation 2012), "Pacific Lamprey Instream and Riparian Habitat Restoration Guide" (Crandall 2013) Gap to Gap floodplain restoration and enhancement plan (Anchor QEA LLC, 2014)		no
Action 5.2	**Inclusion into "Target Species" for Other Restoration Activities**	Update BMPs (Best Management Practices) for restoration projects that include measures to ensure the least harm and most benefit for lamprey. Address lamprey needs when planning restoration. Continue to work with the Yakima Fish and Wildlife Recovery Board, SRFB, and other various restoration funding agencies to link lamprey habitat restoration to ongoing salmonid restoration actions so that existing activities could further enhance lamprey habitat needs.	Region-wide	Region	High	High	BPA / SRFB	Yakama Nation / USFWS / YFWRB		Current Funding Yakama Nation funding from 2008 Fish Accords. Future Needs: No additional funding required.	*future project - start in 2013	"Pacific Lamprey Protection Guidelines for Natural Resources Conservation Service Instream Riparian Activities" (USDA 2010)		no
Threat #6	**Water Quality - Temperature**													
Action 6.1	**Monitoring Effects of Temperature Conditions on Lamprey Biology**	Continue to evaluate influence of seasonal water temperatures on lamprey biological characteristics, such as distribution, survival, growth, movement and egg hatch timing. High temperature is a known problem in lower Yakima, but remedy is difficult to find.	Lower Yakima (mainstem, lower Toppenish, lower Ahtanum, etc.), Upper Yakima (lower Wenas)	Watershed	Medium	High	BPA / CRITFC / Global Climate Change Grants	Yakama Nation / USFWS / USGS / PNNL		Current Funding No funding available. Future Needs: Approximately $10,000 per year.	year around, but especially summer (June - August)	"Effects of Temperature on Survival and Development of Early Life Stage Pacific and Western Brook Lampreys" (Meeuwig et al. 2005), "Modeling Water Temperature in the Yakima River, Washington, from Roza Diversion Dam to Prosser Dam, 2005-06" (Voss et al. 2008)		yes
Action 6.2	**Yakima Delta Restoration**	Improve water temperature, flows, juvenile rearing and adult attraction in the lower Yakima River near the mouth by allowing mixing of Columbia River water (in 60's$^{\circ}$F [15-20°C]) with lower Yakima water (in 80's$^{\circ}$ [25-30°C]). Breaching the causeway would allow cooler Columbia River water to spread into the entire Yakima delta area which also has a lot of fine sediment.	Lower Yakima River	Point	High	Low	COE /Mid-Col RFEG /SRFB	COE /DNR/ MCRFEG	Need design, evaluation of potential effects, and other steps yet so a few years out. Good support.					no

Region:		*What and Why*	*Where*	*How Big?*	*How much?*	*When*		*Who*						
	Threats / Actions	**Description of Actions**	**Subbasin / Watershed**	**Geographic Scale**	**Benefits**	**Feasibility**	**Potential Funding Source**	**Implementing Entity**	**Comments**	**Current Funding and Future Estimated Need**	**Timing**	**Literature**	**Status**	**Lamprey focus action**
Action 6.3	**Evaluation of Flow Management and resulting thermal regimes on lamprey**	Evaluate effects of Yakima river management for irrigation deliveries on the river thermal dynamics and those effects on lamprey (juvenile rearing, migration, and adults). Evaluate low winter/spring flows, high summer flows (upstream of Parker), low summer flows (downstream of Parker), and flip flop flows in the Tieton and Lower Naches.	Upper Yakima & Naches	Watershed	study	Medium	BOR	Yakama Nation/SOAC/USGS/BOR/	Action 6.3 and Action 9.1 both address how flow management affects lamprey due to temperature (action 6.3) and flows (action 9.1) and would be combined as one study to address two threats.	Current Funding No funding available. Future Needs: See Action 6.1	*future project - spring - summer (May - July)	"Evaluation of the Effects of 'Flip-Flop" Operations on Spring Chinook Production in the Yakima Basin" (Cramer Fish Sciences 2010), YN Fisheries BPA & BOR 2012-2013 Reports/Data,		yes
Threat #7	**Water Quality - Chemistry (DO, BOD, pH etc)**													
Action 7.1	**Monitoring of Water Chemistry Effects**	Evaluate lower Wapato and lower Yakima River for dissolved oxygen levels. Not sure whether DO is more limiting than water temperatures. Monitor water chemistry conditions in artificial propagation and translocation areas to document potential influence	Lower Yakima, lower Wapato reach, translocation sites	Watershed	Study / Medium	Medium	BOR / DOE / USGS /EPA	BOR / DOE / USGS /EPA /Yakima Nation		Current Funding No funding available. Future Needs: Approximately $5,000 per year.	summer (June - July)	See sea lamprey and other literature		yes
Threat #8	**Water Quality - Contaminants**													
Action 8.1	**Monitoring of Contaminants Effects**	Continue to collect tissue and stream sediment samples and evaluate for contaminants. Monitor areas that are more heavily contaminated (usually lower in the River) and document the effects on Pacific lamprey (at all life stages).	Lower Yakima (Prosser, Toppenish, Ahtanum, Naches, Satus); Upper Yakima (Lower Wenas)	Watershed	High	High	BOR / USACE / Wasco PUD / CRITFC / Strategic Environmental Research & Development Program (SERDP) / National Institute of Environmental Health Sciences (NIEHS)/ NRCS /	Yakama Nation / USGS /DOE/ EPA/ Pacific Northwest National Laboratory	Latest research by USGS/CRITFC shows that both larval and adult lamprey (as well as the fine sediment the larvae use) contain a high concentration of many legacy & currently used herbicides & pesticides	Current Funding Approximately $5,000 per year from BOR - YN Agreement. Future Needs: Approximately $10,000 per year for 3 years.	summer (June - July -> in 2012, it was collected in late October and early November to capture samples from canals)	"Pacific Lamprey Toxicity Study" (Portland Harbor 2011), "Emerging and Legacy Contaminants in Juvenile Pacific Lamprey in the Columbia River Basin - Draft Preliminary Report" (USGS & CRITFC 2013)		yes
Threat #9	**Water Quantity - Dewatering and Stream Flow Management**													
Action 9.1	**Evaluation of Flow Management on Lamprey Life History**	Evaluate effects of Yakima river management for irrigation deliveries on stream flows and dewatering and those effects on lamprey (juvenile rearing, migration, and adults). Evaluate low winter/spring flows, high summer flows (upstream of Parker), low summer flows (downstream of Parker), and flip flop flows in the Tieton and Lower Naches. River flow management, especially flip-flop, can affect watering and desiccation especially on the stream margins and other larval rearing areas. Evaluate the effects of changes in stream volume and velocity on adult spawning migration.	Upper Yakima & Naches	Watershed	Study / High	Medium	BOR	Yakama Nation/SOAC/USGS/BOR/	Action 6.3 and Action 9.1 both address how flow management affects lamprey due to temperature (action 6.3) and flows (action 9.1) and would be combined as one study to address two threats.	Current Funding No funding available. Future Needs: See Action 6.1	*future project - spring - summer (May - July)	"Evaluation of the Effects of 'Flip-Flop" Operations on Spring Chinook Production in the Yakima Basin" (Cramer Fish Sciences 2010), YN Fisheries BPA & BOR 2012-2013 Reports/Data,		yes
Action 9.2	**Minimize Flow Management Impacts**	Minimize effects of Yakima flow management on lamprey (juveniles, migrating, and adults). Implement changes in ramping rates and other elements of regulated flows to reduce impacts to lamprey. Consider that summer water diversions and ramping during summer months occurs during the same period as adult upstream migration, spawning, and early feeding of 0+ larvae, which is a very critical period for lamprey.	Upper Yakima, Naches	Watershed	High	Medium	BOR	Yakama Nation / USFWS / BOR	Flip-Flop (mid Aug-Sep) might affect incoming adults, emergence, early survival, larva rearing in sediments along stream margins that dry up.	Current Funding Yakama Nation funding from 2008 Fish Accords (Funding is insufficient to appropriately evaluation). Future Needs: Approximately $20,000 per year for 3 years.	summer (May - September)	"Evaluation of the Effects of 'Flip-Flop" Operations on Spring Chinook Production in the Yakima Basin" (Cramer Fish Sciences 2010), YN Fisheries BPA & BOR 2012-2013 Reports/Data		
Threat #10	**Predation**													
Action 10.1	**Juvenile Predation Reduction**	Support and initiate projects (such as salmon related ones) that reduce the abundance of predacious and/or invasive species that prey on juvenile, larval lamprey at a rate much higher than the historical background rates.	Lower Yakima (Wapato Reach), lower 4 dams	Point	High	Medium	BPA / BOR	Yakama Nation	There are a lot of predatory fish in the lower Yakima River, bass, pikeminnow.	Current Funding No funding available. Future Needs: RME & assessment needed first.	*future project - year round (as opportunity arise)	"Report on the Predation Index, Predator Control Fisheries, and Program Evaluation for the Columbia River Basin Experimental Northern Pikeminnow Management Program" (PSMFC 2011), YN Fisheries BPA & BOR 2010-2013 Reports/Data		no
Action 10.2	**Adult Predation Reduction (Providing Refuge in Areas of High Predation)**	Provide overwintering / refuge habitat for adults to reduce predation risks for adults	Lower Yakima (lower 4 dams), Wapato reach, Wanawish	Point	Medium (Unknown)	Low	BPA / BOR	Yakama Nation	High benefits - lots of predation. May be high predation of adult lamprey below Wanawish - adults found up on bank, unsure if otters. Feasibility is low, not enough lamprey to create concentration, not going to kill natural predators. Can improve refuge habitat for adults.	Current Funding No funding available. Future Needs: RME & assessment needed first.	*future project	YN Fisheries BPA & BOR Reports/Data (avian & mammalian predation of salmonids near dams)		yes
Threat #11	**Disease**													
Action 11.1	**Disease Monitoring**	Work with fish pathologists to integrate fish health monitoring and treatment during the process of artificial propagation and translocation activities.	Lamprey holding facilities (Prosser Hatchery, etc.)	Point	Medium	High	BPA / BOR / CRITFC / USFWS	Yakama Nation / USFWS		Current Funding No funding available. Future Needs: Approximately $5,000 per year.	year round (at the hatchery)	"Translocating Adult Pacific Lamprey within the Columbia River Basin: State of the Science" (CBFWA 2011), sea lamprey and other lamprey literature		yes
Threat #12	**Small Effective Population Size**													

Region:		*What and Why*	*Where*	*How Big?*	*How much?*	*When*		*Who*						
	Threats / Actions	**Description of Actions**	**Subbasin / Watershed**	**Geographic Scale**	**Benefits**	**Feasibility**	**Potential Funding Source**	**Implementing Entity**	**Comments**	**Current Funding and Future Estimated Need**	**Timing**	**Literature**	**Status**	**Lamprey focus action**
Action 12.1	**Supplementation Using Adult Translocation (Satus, Toppenish, Ahtanhum, Naches, mid Yakima,)**	Continue to translocate adults into the Yakima Basin to overcome the small effective population size with an emphasis on supplementing and monitoring Satus, Toppenish, Ahtanum creeks. Naches River and middle reaches of Yakima River are also potential future locations for translocation. Continue translocation initially for 10 years at stocking rate of approximately 300 fish per year.	Lower Yakima (Satus - rkm 13 [Plank Rd], rkm 31 [below Dry Cr confluence], Toppenish - rkm 37, rkm 57, Simcoe - rkm 2, Ahtanum - rkm 4 [La Salle High School], rkm 17 [Lower WIP], rkm 30 [Mission]); Naches: Naches (rkm 4 [below Cowiche confluence], rkm 22 [Naches City Bridge], rkm 40 [above Tieton confluence])	Watershed	High	High	BPA	Yakama Nation		Current Funding: Yakama Nation funding from 2008 Fish Accords. Future Needs: No additional funding required.	spring - summer (May - July)	"Tribal Pacific Lamprey Restoration Plan" (CRITFC 2011), "Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin" (in review 2013), "Translocating Adult Pacific Lamprey within the Columbia River Basin: State of the Science" (Ward et al. 2012), YN Fisheries BPA 2012-2013 Reports		yes
Action 12.2	**Supplementation Using Artificial Propagation (Holmes Acclimation Pond, Eschbach Park, Cle Elum Hatchery Side Channel); Holding and Rearing Facilities (Prosser Fish Hatchery, Marion Drain Hatchery, Cle Elum Fish Hatchery)**	Initiate juvenile supplementation research in selected stream reaches to obtain basic knowledge about survival and growth due to re-introductions. Continue development of laboratory techniques in propagation, rearing, handling for potential development of supplementation / research facility. Also, conduct effectiveness monitoring by evaluating survival, growth, density, dispersion and habitat density.	Upper Yakima (Yakima - rkm 261.0 [Holmes Acclimation Pond] & rkm 303.1 [Cle Elum Hatchery]), Naches (Naches - rkm 13.9 [Eschbach Park])	Watershed	High	High	BOR / BPA	Yakama Nation		Current Funding from BOR - Yakama Nation Agreement Future Needs: Approximately $50,000 per year for three years for facilities, staff and O&M.	*future project - fall (October - November)	"Tribal Pacific Lamprey Restoration Plan" (CRITFC 2011), "Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin" (in review 2013), "Translocating Adult Pacific Lamprey within the Columbia River Basin: State of the Science" (Ward et al. 2012), YN Fisheries BPA & BOR 2012-2013 Reports		yes
Action 12.3	**Supplementation Using Both Adult Translocation & Artificial Propagation (Ahtanum / Wenas / Taneum / Teanaway / Cle Elum)**	Reintroduce/supplement local populations by using both adult translocation and larval supplementation in Ahtanum, Wenas, Taneum, and/or Teanaway creeks and/or Cle Elum River. Also, conduct effectiveness monitoring by evaluating survival, growth, density, dispersion and habitat density	Upper Yakima (lower 11 km on Wenas, lower 5 km on Taneum, lower 20 km on Teanaway, lower 12 km on Cle Elum)	Watershed	High	Medium	BOR / BPA	Yakama Nation		Current Funding: Yakama Nation funding from 2008 Fish Accords. Future Needs: See Action 12.2.	*future project - fall (October - November)	"Tribal Pacific Lamprey Restoration Plan" (CRITFC 2011), "Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin" (in review 2013), "Translocating Adult Pacific Lamprey within the Columbia River Basin: State of the Science" (Ward et al. 2012)		yes
Action 12.4	**Monitoring Spawning Behavior (Prosser Fish Hatchery / Cle Elum Fish Hatchery / Holmes Acclimation Pond)**	Monitor adult spawning and recruitment of larval lamprey using the coho spawning channel located above the Holmes Coho Acclimation Pond, Prosser Fish Hatchery, and/or Cle Elum Fish Hatchery. This monitoring will help us understand spawning/recruitment relationships in Pacific lamprey.	Upper Yakima (Yakima - rkm 74.5 [Prosser Hatchery], rkm 261.1 [Holmes Acclimation Pond], rkm 303.1 [Cle Elum Hatchery])	Point	Medium	Medium	BPA / BOR	Yakama Nation		Current Funding No funding available. Future Needs: Approximately $10,000 per year.	*future project - spring - summer (May - July)	See sea lamprey and other lamprey literature		yes
Threat #13	**Lack of Awareness / Outreach and Education**													
Action 13.1	**Outreach and Education**	Outreach activities through student / community events.	Region-wide	Region	Medium	High	USFWS / BPA / BOR / CRITFC	Yakama Nation / USFWS / Local Schools and NPOs		Current Funding Yakama Nation funding from 2008 Fish Accords. Future Needs: No additional funding required.	year round	YN Fisheries BPA & BOR 2012-2013 Reports		yes
Action 13.2	**Community Involvement in Restoration**	Student / community involvement during restoration activities. As a result of translocation and artificial propagation supplementation projects, there will be many opportunities to involve local students in these activities (fish release, monitoring, etc.)	Region-wide and at schools (see 13.3)	Watershed	Medium	High	USFWS / BPA / BOR	Yakama Nation / Local Schools and NPOs		Current Funding Yakama Nation funding from 2008 Fish Accords. Future Needs: No additional funding required.	year round	YN Fisheries BPA & BOR 2013 Reports		yes
Action 13.3	**Larval Lamprey in Classrooms**	Lamprey (larval) in the classroom using aquarium tanks, etc. Providing more chances for students to have hands-on experiences with lamprey will greatly enhance awareness of lamprey, and potentially future decisions and interactions with lamprey.	Lower Yakima (Wapato k-12), Toppenish (White Swan / Harrah / Toppenish k- 12), Ahtanum (La Salles, West Valley, Ahtanum k-12), Naches (Naches k-12), Taneum (Thorp k-12), Cle Elum (Cle Elum k-12), Wenas (Selah k-12)	Watershed	Medium	High	USFWS / BPA / BOR / CRITFC	Yakama Nation / Local Schools		Current Funding Yakama Nation funding from 2008 Fish Accords. Future Needs: No additional funding required.	*future project - year round except summer months (September - June)	YN Fisheries BPA & BOR 2013 Reports		yes
Threat #14	**Climate Change**													
Action 14.1	**Assessing Climate Change Impacts on Species Distribution**	Assess climate change impacts (in terms of temperature and flow dynamics, etc.) within the Yakima Basin to further our understanding on how that may affect future lamprey distribution within the basin.	Lower Yakima (mainstem, lower Toppenish, lower Ahtanum, etc.), Upper Yakima (lower Wenas)	Region	Low	Low	BPA, CRITFC	Yakama Nation / USFWS / USGS		Current Funding No funding available. Future Needs: RME & assessment needed first.	*future project	"Changing Streamflow on Columbia Basin Tribal Lands - Climate Change and Salmon" (Dittmer 2013), "Modeling Water Temperature in the Yakima River, Washington, from Roza Diversion Dam to Prosser Dam, 2005-06" (Voss et al. 2008), "Best Management Practices to Minimize Adverse Effects to Pacific Lamprey" (USFWS 2010)		yes
Threat #15	**Other - Harvest**													
Action 15.1	**Harvest Monitoring**	Assess harvest of larvae, adults. Currently, no harvest, or very limited harvest, for adults is taking place within the Yakima Basin, but larvae harvest (for use as a fish bait) may be taking place in some places	Region-wide	Watershed	Low	Low	BPA / WDFW	Yakama Nation / WDFW		Current Funding No funding available. Future Needs: RME & assessment needed first.	*future project - year round	YN Fisheries BPA & BOR 2009-2013 Reports/Data		yes

Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin

95% Draft

Columbia River Inter-Tribal Fish Commission

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1 Introduction

1.1 Framework Context

This document is a Framework for Pacific lamprey (*Entosphenus tridentatus*) supplementation research, monitoring, and evaluation (RME), and not for supplementation itself; therefore, not all questions regarding supplementation risks, benefits, protocols, etc., are fully addressed. This Framework also does not address important RME topics not related to supplementation, such as evaluation of habitat restoration or natural recolonization of areas not supplemented. Many such questions are important and should be addressed in a supplementation Framework, in specific supplementation plans, or in an overarching RME plan. Questions/topics that should be fully addressed in supplementation plans include (1) the effect that lack of homing to natal streams may have on supplementation efforts, (2) considerations involved when taking lamprey from one watershed to another, (3) hatchery vs. wild considerations often associated with salmonid supplementation, (4) criteria for stopping production/supplementation, and (5) ensuring co-manager support of supplementation actions.

Current information suggests that Pacific lamprey do not home to their natal spawning grounds as do anadromous salmonids; rather, they will mix with the largely panmictic population of the Pacific Northwest. Therefore, it is possible that only a small proportion of any increase of adults resulting from supplementation efforts would be realized in the interior CRB. This potential lack of "efficiency" of artificial production regarding adult returns to specific subbasins or areas should be fully recognized and expected.

Moving lamprey between drainages raises the potential to alter future adult escapement in both donor and recipient areas. Though the latter may be a desired objective, shifting spawners from high to low productivity areas may serve to diminish overall productivity. Lamprey translocation programs should therefore not cause a substantial decrease in abundance in any currently occupied subbasin or area.

Risks associated with artificial production of salmonids include captive-bred adults producing offspring with reduced fitness (Araki et al. 2007; 2008), genetic adaptation occurring in a single generation in captivity (Christie et al. 2011), and the reduction of reproductive fitness of wild-spawning fish when they spawn with a captive-bred adults (Araki et al. 2009). Although Pacific lamprey differ from salmonids in many ways, these potential risks should be addressed prior to the implementation of a lamprey supplementation plan. If these risks apply to captive-bred lampreys, their adverse effects might be magnified by the fact that adult lampreys do not home to natal spawning grounds so their likelihood of straying and mixing with wild populations is greater than it is with salmonids.

In addition to developing criteria for implementing and monitoring supplementation efforts, specific supplementation plans should consider metrics and criteria for ceasing efforts. Triggers could include indicators that efforts have (1) been unsuccessful, (2) resulted in unacceptable risk to lamprey, or (3) have been successful in restoring lamprey to sustainable, harvestable levels.

Most subbasins within the CRB are co-managed by Tribes and state managers, with additional guidance for Pacific lamprey management provided by the U.S. Fish and Wildlife Service (USFWS). Threats to lamprey and proposed restoration and supplementation actions may vary among subbasins (see Appendices A through D). Although Tribes have generally been in the forefront of lamprey restoration actions, it is imperative to have agreement among co-managers regarding supplementation.

The Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, and Idaho Department of Fish and Game reviewed a previous draft of this Framework and provided technical comments (Appendix B). Various drafts were also reviewed by Columbia River Basin (CRB) tribes and the U.S. Fish and Wildlife Service. The Framework is meant to be living document and provide a basis for discussion regarding the research, development, and improvement of existing and proposed lamprey supplementation strategies within the CRB and beyond.

1.2 Background

Pacific lamprey is an anadromous fish species that has occupied freshwater rivers of western North American for the last 350 million years. These ancient fish are distinct from other fish within their range – lampreys are jawless, have no scales, and lack paired fins. Since pre-historic times, Native Americans have utilized lamprey for important subsistence, ceremonial, and medicinal purposes. Pacific lamprey are also important ecologically because they provide marine-derived nutrients to the freshwater riverine environment and the aquatic and terrestrial food web (Beamish 1980; Brown et al. 2009) and provide a high-calorie prey source for various marine and freshwater species.

Today, Pacific lamprey return to the Columbia River Basin (CRB) at a fraction of their historical numbers; daytime counts of adult Pacific lamprey at Bonneville Dam have declined from an estimated 400,000 in the 1960's and 1970's to lows of approximately 20,000 in 2009 and 2010 (Figure 1-1; CRITFC 2011a). At Willamette Falls, a traditional harvest location on the Willamette River, estimates of harvest declined from about 400,000 in the 1940's to about 4,000 in 2001 (Figure 1-1; Ward 2001).

Recent studies on this alarming trend of Pacific lamprey decline in the CRB cite the construction of hydroelectric and flood control dams, irrigation and municipal water diversions, habitat degradation and loss, poor water quality, excessive predation, contaminants, ocean cycles, prey-species availability, and chemical eradication as major contributors (Close et al. 1995; CRITFC 2011a; Luzier et al. 2011; Murauskas et al. 2012). Despite recent implementation of passage improvements at mainstem and tributary dams, habitat improvements, and adult lamprey translocation efforts (CRITFC 2011a; Luzier et al. 2011; Ward et al. 2012), adult returns remain relatively low and spatial distribution is increasingly limited to the lower portions of the CRB. Pacific lamprey have been extirpated from many subbasins in the interior CRB (Close et al. 1995; USFWS 2007; Luzier et al. 2011).

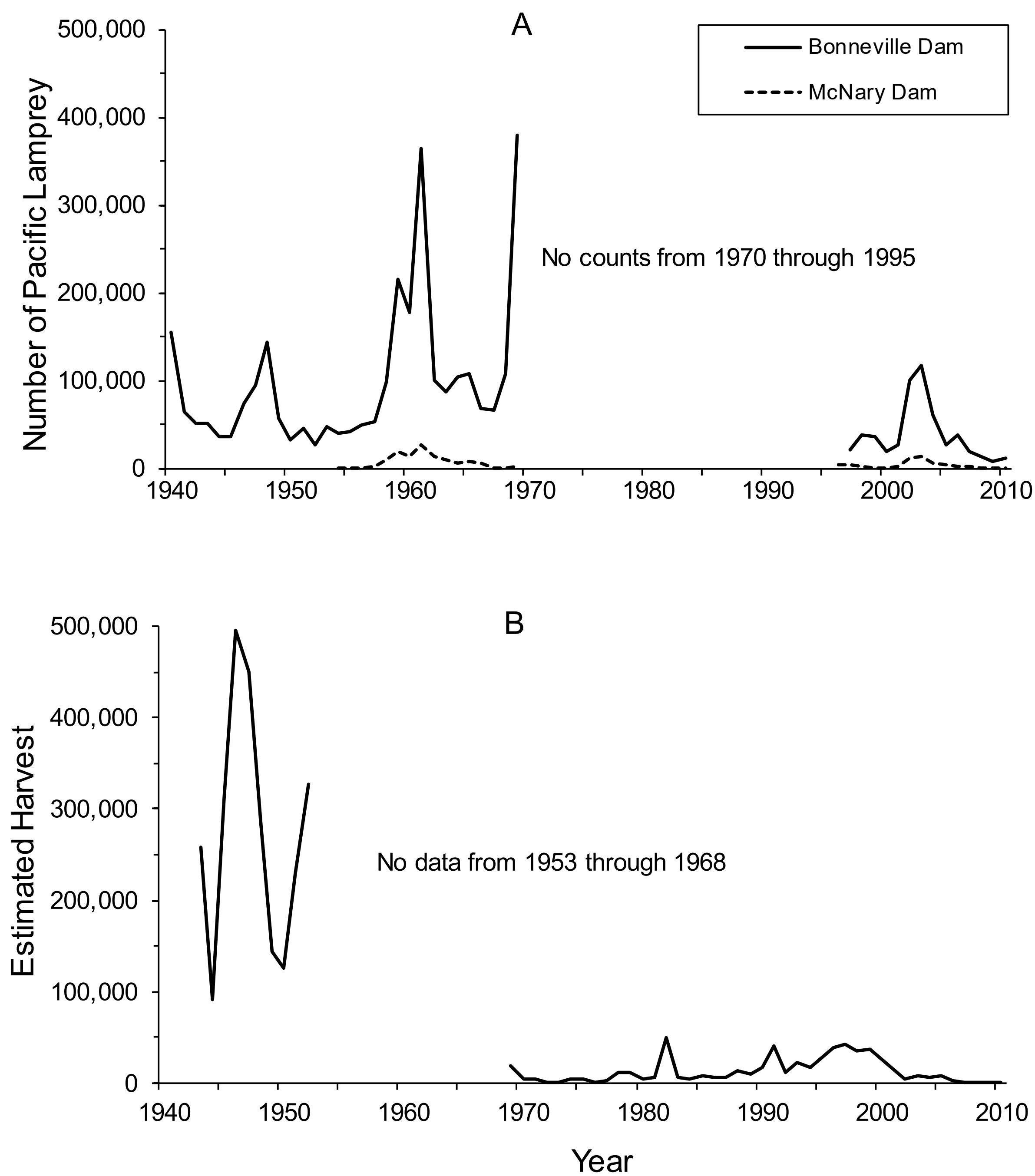

Figure 1-1. Counts of adult Pacific lamprey reported for Bonneville and McNary dams (A); Estimated number of Pacific lamprey harvested at Willamette Falls (B).

In addition to declines in the CRB, observational trends suggest that abundances of Pacific lamprey are declining from historical numbers in Pacific coast streams from Washington to southern California (Luzier et al. 2011). Pacific lamprey have been extirpated from many streams.

Considering the low numbers of Pacific lamprey, their value to the ecological health of the CRB, and their cultural significance, the time to address and recover lamprey stocks is now. Potential ecological impacts include decreased connectivity of marine with freshwater ecosystems, and decline in delivery of marine-derived nutrients into upper reaches of the Columbia River Basin. Low lamprey abundance may also decrease the potential prey base available to native fish, avian, and mammalian predators.

Cultural impacts include (1) loss of tribal heritage, (2) loss of fishing opportunities in traditional areas, and (3) necessity to travel great distances to the lower CRB for ever-decreasing lamprey harvest opportunities. As a consequence of reduced or eliminated harvest in the interior CRB, young tribal members are losing historically important legends associated with lamprey because they have not learned harvest and preparation methods.

Because of the long, complex, and poorly understood life history of Pacific lamprey, existing environmental conditions in the CRB, and scarcity of data, it remains unclear how quickly lamprey will recolonize extirpated streams, especially in the upper reaches of the CRB. Passage for adult lamprey is low (adult passage at mainstem dams hovers around 50%; Keefer et al. 2012), so natural recolonization of upper reaches may require extensive time, perhaps decades, considering that lamprey life history spans approximately 10 years. Efforts to utilize management strategies such as supplementation to aggressively maintain and reestablish Pacific lamprey in specific locations have recently increased.

Supplementation of Pacific lamprey has potential benefits and risks. Taking no action also has risks. Potential risks of lamprey supplementation are not all known, but some are briefly described in Section 1.1. Risks of taking no action include maintaining and increasing areas of extirpation, enhancing potential for "Founders Effects" in watersheds with low return rates, continued loss of ecological role served by lamprey, and continued loss of cultural heritage.

1.3 Supplementation Approaches

Pacific lamprey supplementation is defined here as an interim production facilitation strategy that supports region-wide efforts to reduce known threats to self-sustaining (natural) productivity. Facilitation actions include either the translocation of surplus adults from one watershed to a watershed with poor adult recruitment, or artificial propagation of larvae (ammocoetes) or juveniles (macrophthalmia) in a hatchery for release into a watershed that is under seeded. Section 5 of this Supplementation Research Framework describes guidance on how supplementation can be incorporated into subbasin-specific plans for lamprey recovery. Initial trials and accompanying monitoring and evaluation activities will better inform fish managers on how to use supplementation as a restoration tool.

1.3.1 Adult Translocation

Translocation is defined as the collection of adult Pacific lamprey from one location and transport for release into another location where they are extirpated or scarce (Ward et al. 2012). Translocation has been successfully implemented by several treaty tribes in the Mid-to Upper Columbia River and Snake River basins, though well-designed post-reintroduction monitoring programs are imperative to documenting success (Close et al. 2009; Ward et al. 2012). In the short term, these efforts are designed to increase larval abundance and maintain a larval connection, through pheromone signals, to returning spawning adults, while also facilitating adult passage beyond difficult up-stream obstacles. Translocation is not designed to be a long-term restoration strategy but rather a short-term, stop-gap measure to maintain lamprey presence while known limiting factors and critical uncertainties are addressed. Although monitoring and evaluation of these efforts has yielded substantial information about effectiveness and has contributed to critical life history information for lamprey, it remains unclear whether efforts will result in increased adult returns in the future.

1.3.2 Larval Outplanting

A second supplementation approach is to outplant larval Pacific lamprey into targeted areas. This requires successful collection, holding, spawning, incubation, and rearing of Pacific lamprey in a hatchery environment. It also requires the identification of suitable locations for the release of larval lamprey. Research on propagation of lamprey in hatchery settings began in the 1980s in Finland to address declines of an important commercial fishery. Over time, the success of lamprey propagation progressed to a level in Finland where fisheries managers were able to produce 17 million larvae per year for release into the Perhonjoki River between 1997 and 2009 (CRITFC 2011b). Unfortunately, very little post-release monitoring has been conducted in Finland or other countries.

1.3.3 Juvenile Outplanting

The third supplementation approach is to outplant older larval and juvenile Pacific lamprey into targeted areas. Protocols for rearing larvae for extended periods of time (years) to produce juvenile are lacking. In addition, the benefits of rearing fish to the juvenile stage may be difficult to assess because fish ready to immediately transform and migrate may not release the pheromones thought to attract returning adults.

1.4 Research and Monitoring Needs

Because of the low returns of lamprey and the assumption that successful natural recolonization to upstream tributaries may require many years, CRB Tribes and regional agencies have increasing interest in beginning research on the use of hatchery-reared larval and juvenile lamprey in short-term (0-5 years) and long-term supplementation (>10 years) efforts (CRITFC 2011a; USFWS 2012). In the short term, hatchery-reared larvae and juveniles would be used as a research tool to help evaluate critical uncertainties and limiting factors of the species as well as their potential use in supplementing locally extirpated populations. Many important questions regarding the biology of Pacific lamprey remain unanswered to date, such as the age classes of all three life stages (ammocoetes, macrophthalmia, and adults), the natural annual growth and survival rates of larvae, and the general migration behavior of larvae before transforming to macrophthalmia. Addressing all of these questions is essential to identifying factors limiting restoration of Pacific lamprey and to development of a life stage survival model for Pacific lamprey that will be a tool for evaluating conservation strategies. The use of artificial production and genetics analysis tools provide the opportunity to make incredible advancements in these unanswered biological questions. Use of supplementation may help minimize the number of larval and juvenile fish taken from the wild for evaluations.

Besides laboratory use, some larval lamprey will be established in extirpated streams to evaluate important questions related to the viability of the local population (i.e. limiting factors, passage barriers, pheromones). If larvae and juveniles are absent or functionally absent in these extirpated or near extirpated regions, there is virtually no way to identify and resolve major limiting factors. For instance, if irrigation diversions are a potential serious threat to migrating larval and juvenile lamprey, without the presence of larval lamprey either in the system or alternatively in lab settings, nothing can be effectively tested and evaluated to seek mitigation or resolution of the problem.

Hatchery-reared lamprey may also be used to supplement CRB lamprey by dramatically increasing larval/juvenile numbers, albeit in the short-term, with the goal of effectively compensating for the natural declines in adult returns. Doing this will not only allow the species to perform its natural ecological purposes in these extirpated streams and rivers, but it will also provide an opportunity to evaluate important overarching biological questions, such as stream selection criteria for returning spawning adults. For example, an evaluation of whether these larvae can attract upstream migrating spawning lamprey and contribute to increased recruitment can occur, which is a vital management.

Finally, if Pacific lamprey numbers continue to decline in the near future despite passage improvements, habitat restoration, and translocation, there will be a need for substantial research efforts to determine if a conservation hatchery is a feasible tool to protect the viability of the species and its remaining genetic diversity. The techniques and methods required for a successful conservation hatchery do not develop in a short time span, especially for an exceptionally cryptic and surreptitious species such as Pacific lamprey. It is important that learning and advancing conservation hatchery techniques and methods begin as soon as possible, so that they are available when needed. This will also help advance the knowledge on many of the important existing knowledge gaps in biology.

Before supplementation of Pacific lamprey with hatchery-reared fish can be used, it is important to develop and assess this type of strategy to the extent possible. Preliminary work includes (1) the development of basic propagation and rearing techniques for lamprey, (2) an assessment of the cost/benefits of releasing hatchery reared fish into the environment, and (3) the development of consistent and standard protocols for monitoring and evaluating artificial propagation releases. In short, before supplementation with hatchery reared lamprey can be utilized, basic research needs to occur to (1) refine existing supplementation methods (translocation), (2) develop new methods (artificial propagation), (3) assess feasibility of artificial propagation, (4) identify existing facilities and prospective new facility locations within the CRB to support development and implementation of artificial propagation, (5) identify natural riverine features within the CRB that provide spawning sites for adults and rearing habitat for hatchery reared juvenile Pacific lamprey, and (6) develop and refine research, monitoring, and evaluation (RME) methods for long-term supplementation strategies. It is important to understand the inherent risks (generally associated with genetics) of supplementation, and be mindful of two important concepts: "do no harm" and "risk management" for both the donor and recipient areas.

For these reasons, a significant planning effort, led by the CRITFC tribes, has been undertaken by regional fishery managers to guide the use of Pacific lamprey supplementation as a short-term research and long-term restoration tool in the CRB. Three distinct, yet inter-related products will be developed over time (also see Section 4):

1. Regional Framework for Pacific Lamprey Research, Monitoring, Evaluation and Reporting in the Columbia River Basin (RME Framework) which will encompass a broad scope of ongoing and needed research, monitoring and restoration activities;

2. Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin (Supplementation Research Framework) that will focus specifically on coordination and continuity in research and reporting of information associated with emerging and active lamprey restoration strategies such as propagation, reintroduction, translocation, and augmentation; and

3. Pacific Lamprey Restoration and Supplementation Research Subbasin Plans (Subbasin Supplementation Research Plans) which will summarize ongoing and proposed lamprey restoration activities in CRB subbasins within the context of the RME Framework and the Supplementation Research Framework described above such that consistency and continuity of important methods, analysis and reporting formats can be achieved.

This document focuses on the Supplementation Research Framework and a template for Subbasin Supplementation Research Plans (Items 2 and 3), which will be integral components of the larger RME Framework (Item 1). Collectively, these documents are anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan (CRITFC 2011a), (2) USFWS Conservation Agreement for Pacific Lamprey (Lamprey Conservation Agreement; USFWS 2012) and (3) Northwest Power and Conservation Council (NPCC) Fish and Wildlife Program (NPCC 2009). In total, each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be developed in years 2016-2017.

2 Purpose, Need and Scope for Supplementation Research Framework

2.1 Purpose

A framework is an organized foundation or structure that supports an intended area of research or the development of strategies that focus on the achievement of specific objectives. The framework typically consists of concepts, existing data and information, and various theories related to a particular research topic that, when assembled, form the basis of understanding. Relative to fisheries research and management, this foundation determines how information is interpreted, what problems are identified, and a range of appropriate solutions (Independent Scientific Group 1996) to achieve the ecological conditions necessary to meet specific goals and objectives. Lichatowich (1998) compares a conceptual foundation (i.e., framework) to the process of assembling a puzzle, where the foundation is the cover of the puzzle box, displaying what the fully assembled puzzle should look like.

As applied to Pacific lamprey supplementation research and ultimately the recovery of Pacific lamprey in the CRB, the USFWS and various state and tribal entities have developed visions for fully recovered Pacific lamprey. In the recent Lamprey Conservation Agreement, the ultimate future vision for lamprey is the "long-term persistence of Pacific lamprey… throughout their historic range in the United States". This vision is consistent with that of the Tribal Pacific Lamprey Restoration Plan, which states that lamprey should be restored to sustainable, harvestable levels throughout their range by 2050. To this end, the development of this Supplementation Research Framework requires input from various stakeholders to ensure consistency in purpose, approach, analysis and reporting.

The purpose of this Supplementation Research Framework is to initiate the development of a regionally coordinated and long-term RME and reporting plan (Section 1.4) directed towards the implementation of supplementation and recovery actions for Pacific lamprey within the CRB. Additionally, this Supplementation Research Framework intends to "standardize" key elements of supplementation RME and reporting so that findings associated with status and trends and other important objectives can be reported in a common and consistent format. Finally, the Supplementation Research Framework provides specific guidance for the development of Subbasin Supplementation Research Plans.

The development of this regional Supplementation Research Framework is needed to coordinate supplementation RME on both a regional and local level. The Supplementation Research Framework will provide consistency and serve as a communication and management tool for stakeholders to remain focused on the overall goals of the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement.

This Supplementation Research Framework will be updated over time as new, pertinent information becomes available. Importantly, this Supplementation Research Framework is intended to serve as a foundation and template for consistency in the development of more specific Subbasin Supplementation Research Plans. Findings associated with local planning and activities informed by this Supplementation Research Framework will provide sufficient information to update the Tribal Pacific Lamprey Restoration Plan. This can ensure the consistency among stakeholders in providing a more cohesive foundation for lamprey recovery in the CRB over the next five years, leading to the development of the Columbia River Basin Pacific Lamprey Management Plan. This management plan, envisioned to be developed in 2016–2017, will (1) update the Tribal Pacific Lamprey Restoration Plan (2) provide guidance for activities undertaken through the Lamprey Conservation Agreement and (3) direct future funding through the NPCC Fish and Wildlife Program. Contributors to this Supplementation Research Framework clearly recognize that because of our lack of knowledge and resources, this is a "work- in progress" and will be revisited and updated periodically to incorporate new findings and reflect management direction.

2.2 Need

2.2.1 Pacific lamprey are in low abundance or extirpated in many mid to upper watersheds, especially above McNary Dam

Abundance of Pacific lamprey has declined throughout the CRB, and counts decline rapidly from downstream to upstream areas (Table 2-1). Although counts at dams are incomplete, they serve as the only long-term index of Pacific lamprey abundance in the CRB. Annual cumulative daytime counts at Bonneville Dam prior to 1970 were regularly at least 50,000, with occasional peaks approaching 400,000 (Kostow 2002). Counts prior to 1970 at McNary Dam were generally in the few tens of thousands, but have decreased to less than 1,000.

In the Umatilla River, anecdotal information indicates that Pacific lamprey were historically abundant, with harvest occurring throughout the subbasin (Ward et al. 2012). Observations by tribal members and state and federal fisheries agency personnel (Jackson and Kissner 1997) indicate that lamprey were so abundant as to be a nuisance in the Umatilla River Subbasin. Abundance decreased precipitously in the late 1960s and early 1970s following broadscale chemical eradication (Close et al. 1995), and very few lamprey were observed in the subbasin during surveys conducted in the 1990s (Ward et al. 2012).

Few counts of Pacific lamprey at Snake River dams are available prior to the 1990's; however, counts ranged from approximately 5,000 to 7,000 at Ice Harbor dam from 1967 through 1969 (Fish Passage Center 2013). Recent counts have been under 1,000 fish at Ice Harbor Dam and under 100 fish at Lower Granite Dam (Table 2-1).

Although long-term information from dam counts in the Snake River is not available, information summarized by Cochnauer and Claire (2009) from the Clearwater Subbasin indicates a precipitous decline in Pacific lamprey abundance and distribution. The number of kilometers occupied by Pacific lamprey declined by an estimated 66% between 1960 and 2006. Counts at Lewiston Dam, near the mouth of the Clearwater River, decreased from over 5,000 in 1950 to zero by 1972, after which the dam was removed and lamprey once again had access to the upper drainage. Pacific lamprey ammocoetes and macrophthalmia were collected in Lolo Creek from 1994 through 2003; however, continued sampling failed to capture any lamprey from 2004 through 2006.

Anecdotal accounts indicate lamprey were historically plentiful in the Yakama Nation Ceded Lands, specifically in the Yakima River where adult lamprey were harvested locally at least till the 1960s and early 70s (Yakama Nation and GeoEngineers, Inc. 2012). Current adult lamprey occurrence data for the Yakima River Subbasin is based primarily upon observations at fishways at Prosser and Roza dams. At Prosser Dam, the number of adult lamprey counted at the fishway was low from 2000 to 2013, ranging from zero in 2000 to a high of 87 in 2003. In most years less than 20 adults pass Prosser Dam. No adults have been observed at Roza Dam since the counting program began (Yakama Nation and GeoEngineers, Inc. 2012). Recent abundance data indicates very low, numbers of larvae and juveniles throughout the subbasin as well. From 2000 to 2012, outmigrating larval and juvenile lamprey counts (unconfirmed species) from Chandler Canal Fish Collection Facility in lower Yakima River ranged between 18 and 1,450 (43% subsampling) with a mean annual count of 317.

In the upper Columbia River, numbers of Pacific lamprey passing Wells Dam (furthest upstream facility on the mainstem Columbia River with passage) each year have been declining, with some recent adult counts below ten per year (Table 2-1). Counts were over 1,400 fish as recently as 2004.

Table 2-1. Counts of adult Pacific lamprey at Columbia and Snake River dams, 2002-12. Counts are during the day only at most dams. Priest Rapids and Wells dams have 24-hour counts. Counts at Lower Granite dam have been conducted 24 hours a day since 2009.

Year	Lower Columbia River		Snake River		Mid-Columbia River	
	Bonneville Dam	McNary Dam	Ice Harbor Dam	Lower Granite Dam	Priest Rapids Dam	Wells Dam
2002	100,476	11,282	1,127	128	4,007	338
2003	117,029	13,325	1,702	282	4,339	261
2004	61,780	5,888	805	117	2,647	1,408
2005	26,664	4,158	461	40	2,598	291
2006	38,938	2,456	277	35	4,381	212
2007	19,313	3,454	290	34	6,593	21
2008	14,562	1,530	264	61	5,083	7
2009	8,622	676	57	12	2,714	9
2010	11,183	825	114	15	1,114	2
2011	18,305	868	269	48	3,868	1
2012	29,224	970	484	48	4, 025[a]	3

[a] Lamprey must pass the fish ladder counting window at Priest Rapids Dam, whereas lamprey are diverted through a navigation lock at McNary Dam, making counting there more problematic.

2.2.2 Pacific lamprey in upstream subbasins may need to be supplemented so that recovery can occur in a timeframe consistent with existing restoration plans

Given the precipitous decline in Pacific lamprey abundance, particularly in the upper reaches of the CRB, it is unlikely that large-scale restoration and passage improvement activities, though necessary for long-term sustainability, will result in increased abundance or distribution at a rate sufficient to offset continuing declines and preclude further extirpations. The development of Pacific lamprey supplementation tools has therefore been identified as a recovery action that should occur concurrently with improvements in fish passage, water quality, and habitat (CRITFC 2011a; Luzier et al. 2011; USFWS 2012; Ward et al. 2012; Yakama Nation and GeoEngineers 2012).

Potential supplementation tools include translocation of adults and reintroduction of larvae or juveniles using artificial propagation. Translocation can be used to bypass corridors where migration is impeded or blocked, increase number of spawning adults, increase larval abundance and distribution, and provide pheromones for potential attraction of additional adults. Hatchery rearing may be needed in some areas to increase larval abundance and provide pheromones. Both supplementation techniques are intended to be used while simultaneously improving known factors that limit productivity of lamprey in these specific watersheds. The goal is that self-sustaining natural productivity will provide meaningful ecological contributions and traditional tribal harvest. Research is needed to determine the feasibility of these approaches and to monitor and evaluate results.

One rationale for supplementation is the assumption that natural recolonization in the upper CRB will take too long. The assumption is based on attraction of adults to larval pheromones; if no larvae are rearing in a particular watershed, adults will not be attracted. However, other factors such as discharge, temperature, presence of Western brook lamprey rearing, and presence of other maturing Pacific lamprey adults may also help attract adults (Keefer et al. 2013).

One example of natural recolonization in the Hood River happened relatively rapidly. Hess et al. (in prep) sampled the upper Hood River shortly (<3 years) after the removal of Powerdale Dam, which was considered a lamprey barrier, and found only age-0 Pacific lamprey. The lack of other age classes (and other species) suggests this was a recent, rapid recolonization of an area that did not have rearing larvae as an attractant. Of note is that Pacific lamprey need migrate past one mainstem dam only to reach the Hood River. It is unknown if such rapid recolonization could occur upstream of multiple dams.

Although current passage rates at mainstem dams indicate that probability of successful passage past multiple dams is low (Keefer et al. 2013), work to improve passage at mainstem dams is ongoing. This exemplifies why dam passage improvement should be paired with supplementation and other restoration actions to improve conditions, without waiting for natural recolonization in all areas.

Supplementation is intended to be a short term action to boost Pacific lamprey numbers and make other restoration actions more meaningful. Research needs related to supplementation identified by the USFWS (Luzier et al. 2011) include evaluating the risks and benefits of translocation, evaluating techniques for artificial propagation, and evaluating if artificial propagation can be used to "jump start" ammocoete production in appropriate watersheds.

Supplementation would increase larval or juvenile abundance in seeded watersheds or stream reaches. Not only would these actions re-establish juveniles back into the local ecology, they may improve pheromone attraction of returning adults. Emerging evidence strongly suggests an association between juvenile lamprey pheromones and adult returns (Sorensen et al. 2005; Lin et al. 2008; Close et al. 2009; Spice et al. 2012). Adult Pacific lamprey, like sea lamprey (*Petromyzon marinus*), may be attracted to spawning sites by pheromones released by ammocoetes (Lin et al. 2008).

2.2.3 Supplementation research and use as a recovery and management tool will provide valuable insights into lamprey biology and ecology

In consideration of low numbers of adult lamprey, alternative management strategies must be employed as stop-gap measures to slow extirpation and re-establish genetic variability within local areas throughout the CRB. Supplementation areas will be identified, prioritized, and defined by local area managers and tribal groups in order to ensure research is conducted to maximize effectiveness. During this time, supplementation research should be implemented and important attributes, such as local genetic diversity must be monitored so that if/when supplementation is determined to move forward at a larger scale, the working knowledge will have increased to better plan and implement future management actions. As supplementation research is implemented in specific areas, monitoring and evaluation to determine action effectiveness of adult translocation, artificial propagation method development, and larval and juvenile reintroduction, will provide valuable insights into lamprey biology and ecology as well as provide the opportunity to research known and potential limiting factors and critical uncertainties.

Translocation efforts to date have resulted directly in successful transportation and holding techniques for adult Pacific lamprey. Successful holding and releases of adults have resulted in increased larval abundance (Ward et al. 2012), which has in turn increased knowledge of larval distribution and migration timing. In addition, by radio-tagging translocated adults, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Yakama Nation / USFWS have been able to collect information on adult passage at low-elevation diversion dams, providing insights on placement of lamprey passage structures such as the structure completed at Threemile Dam in the Umatilla River in 2009, and passage improvements currently being planned at Prosser Dam in the Yakima River. Ongoing translocation and future propagation research will have broad application in addressing other factors potentially limiting lamprey in the tributary environment including the effects of irrigation entrainment, flow management (ramping rates), emerging and legacy contaminants, and habitat availability.

Knowledge to be gained from evaluating lamprey artificial propagation includes information related to rearing techniques and with post-release monitoring. Development and evaluation of artificial propagation techniques will increase knowledge of laboratory protocols, growth and survival, food preferences, habitat needs, and possibly changes in morphology associated with metamorphosis. Monitoring of larval or juvenile releases will provide information on growth and survival in the wild, distribution including downstream movement, and outmigration timing.

Monitoring of supplementation activities may also provide opportunities to increase understanding of known limiting factors and critical uncertainties. These may include larval and juvenile passage at specific facilities, contaminant accumulation and effects, and predation. If larval pheromones guide adults to spawning sites, supplementation would encourage natural production in suitable spawning and rearing areas. Research is currently being conducted to isolate these pheromones and investigate how they may be used to improve adult returns (Yakama Nation and GeoEngineers, Inc. 2012). Investigations such as these are important to initiate at this time so that, if need be, this management strategy can be confidently implemented when necessary.

2.2.4 A regional Supplementation Research Framework will provide for a more comprehensive and systematic research and monitoring strategy and will contribute to greater consistency in data analysis and reporting

A successful, economical and rapid recovery of Pacific lamprey will require regionally coordinated efforts from tribes, federal and state fishery agencies, and others involved in conducting or funding lamprey restoration efforts. An important component of this coordination is consistency in protocols, data collection and reporting metrics. The need for this coordination was clearly identified in both the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement. Both documents clearly established a context for coordinated action among stakeholders across the CRB towards conservation actions, funding and RME.

2.3 Scope

The scope of this Supplementation Research Framework is intentionally narrow due primarily to the conservative nature of this initial effort and budgeting constraints. Actions guided by this Supplementation Research Framework are expected initially to focus on addressing important management questions, limiting factors, and critical uncertainties identified in both the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement. With regard to supplementation research, the Supplementation Research Framework will provide guidance to address Objective 3 of Tribal Pacific Lamprey Restoration Plan, Supplementation/Augmentation, and Objective 7 of the Lamprey Conservation Agreement, Restore Pacific Lamprey of the RMUs. The Supplementation Research Framework and associated Subbasin Supplementation Research Plans are integral components of the larger RME Framework.

The Supplementation Research Framework is further expected to guide consistent analysis methods and reporting formats for research and monitoring tools in the context of Objectives 5 and 6 of the Lamprey Conservation Agreement (Identify and characterize Pacific lamprey for the RMUs and Identify, secure and enhance watershed conditions contained in the RMUs) and Objective 6 of the Tribal Pacific Lamprey Restoration Plan (Research, Monitoring, and Evaluation).

Through adaptive management this Supplementation Research Framework will expand, with the intention of maintaining its relative simplicity. As more information becomes available through research efforts, the management actions guided by the Framework will be refined and additional individual subbasin strategies may be developed. Many critical uncertainties about Pacific lamprey remain and fishery managers expect that continued RME activities will likely modify the overall objectives and methods. For this reason, managers choose to maintain relative simplicity in the approach. Considering budgets, existing capacity, and the state of knowledge, it is not practical at this time to construct a Supplementation Research Framework overly burdened with details built upon speculation and uncertainty. Simply based on a 10-year life history of Pacific lamprey, managers recognize many important objectives may require a decade and longer to achieve.

3 Pacific Lamprey Genetic Structure

Influence on genetic integrity is a primary concern for all supplementation efforts, but the field of regional genetic study of Pacific lamprey is still in its infancy. Although much more work is needed to better understand lamprey genetics, compared to salmonids, lamprey appear to exhibit low genetic differentiation among regional stocks, and its population structure reflects a single broadly distributed population across much of its range in the Pacific Northwest (e.g., Goodman et al. 2008, Spice et al. 2012). The need for genetic diversity in artificial salmonid propagation and rearing programs has been well documented. With salmon, collecting broodstock across the entire run is advised to maintain the genetic diversity of supplemented populations (Cuenco et al. 1993; Bilby et al. 2003). Genetic heterogeneity among a population's individuals is a basic driving principle for sustainability to reduce the potential for deleterious population effects, including inbreeding depression. This genetic principle is applicable to all species, including Pacific lamprey, and provides organisms the ability to exhibit a selective response to environmental variability.

Another well-established premise for artificial propagation in salmonids is the use of locally-adapted broodstock. Such local stock may be comprised of individuals that are adapted to specific conditions in a basin, and subsequently exhibit higher fitness. However, in comparison to salmonids, Pacific lamprey do not appear to exhibit strict natal homing (Goodman et al. 2008; Hess et al. 2013; Spice et al. 2012). For this reason, unlike salmonids, the spatial scale that contains locally-adapted broodstock may be much broader for Pacific lamprey, and thus the specific watershed- or subbasin-of-origin of this broodstock may not be critical to the success of artificial propagation programs for Pacific lamprey.

Hess et al. (2013) concluded that although neutral genetic variation (i.e., gene variants detected have no direct effect on fitness) in Pacific lamprey is influenced by geography and adult phenotypes, there is high gene flow among individuals collected from the Columbia River, Oregon and California. However, Hess et al. (2013) and Lin et al. (2008) documented significant genetic differences among fish from different large-scale geographic regions but Lin et al. 2008 found no obvious geographical pattern of gene flow or differentiation in samples from the Pacific Northwest (i.e., Washington, Oregon and California). The choice of genetic marker may have some bearing on the results of the genetic studies that have been conducted on Pacific lamprey. For example, the findings of Lin et al. (2008) and Hess et al. (2013) were obtained using relatively large numbers of amplified fragment length polymorphism and single nucleotide polymorphism markers, respectively. These types of markers have high potential to represent adaptive variation from genomic regions under selection, which was one of the primary goals of the study by Hess et al. (2013). In contrast with patterns from neutral variation, adaptive variation was shown to drive relatively large genetic divergence between regions, even within the Columbia River between the lower river and interior tributaries (Hess et al. 2013).

Other genetic studies using putatively neutral markers (based on microsatellites and mitochondrial DNA) have provided evidence of high rates of gene flow across much of the range of Pacific lamprey with low geographic association among samples (Goodman et al. 2008; Spice et al. 2012). Results from Spice et al. (2012) suggest that most Pacific lamprey in the Pacific

Northwest could be managed as a single unit. In contrast, Lin et al. (2008) stated that the scale over which genetically significant management units are categorized (e.g., stocks, populations, distinct population segments) requires additional clarification through more study. Recently, however, the USFWS (Luzier et al. 2011) divided Pacific lamprey into ten Regional Management Units (RMUs). The division of lamprey stocks into regional units was not based on genetic information, but is intended to allow for a more refined level of life history and data collection from each RMU. At this time, the USFWS (2012) believes that "dividing management units into finer geographic scales would provide a risk-averse approach for conserving Pacific lamprey".

Despite some conflicting results, genetic studies generally corroborate the pattern that rates of gene flow are high among Pacific lamprey, particularly in the Pacific Northwest. The pool of potential donor-stock for artificial propagation or translocation programs may therefore be larger for lamprey than, for example, salmon. Similar genetic composition could be viewed as an advantage because healthy donor-stocks could be obtained from any RMU and translocated, or seeded, into suitable watersheds throughout the Pacific Northwest.

Still, from the viewpoint of conservation management vs. supplementation, Hess et al. (2013) emphasize that, although lamprey are capable of high levels of gene flow across most of their range, it is important to maintain "local" diversity (a suitable geographic area has not yet been described), primarily those adaptive genetic variants that respond to localized conditions. This would indicate that broodstock management and collection protocols must be cognizant of the need to maintain the diversity of donor-stock when faced with the potential for artificial propagation (i.e., hatchery programs). Similarly, the "mining" of donor-stock associated with lamprey translocation programs should not cause a substantial decrease in abundance in any currently occupied subbasin (Ward et al. 2012).

3.1 Genetic Monitoring and Analysis

The potential risks of supplementation tools have been recognized, and measures to minimize risks are outlined in the lamprey translocation guidelines agreed to by the Columbia River Inter-Tribal Fish Commission (CRITFC 2011a; Ward et al. 2012). Although consideration should be given to potential disruption of stock structure and associated genetic adaptations from sources, the risk of adverse effects associated with the continued downward trend in abundance may outweigh the potential loss of some adaptive genetic variants in isolated areas (Ward et al. 2012). This is particularly true in areas where numbers are decreasing rapidly. In these areas, it is possible that so few adults find their way into the watersheds that they may have trouble finding mates and the potential for genetic founder effects is increased. Given general support among genetics findings that a single homogenous population of Pacific lamprey exists throughout the Columbia River and Pacific Northwest region, there is likely less risk in temporary supplementation to increase abundance and genetic diversity.

Part of the planned monitoring that is described in this framework includes a genetic analysis component that will provide a means for tracking genetic diversity and the fitness consequences (if any) that are associated with genetic variation of lamprey used for translocation/outplanting. Genetic analysis will allow us to directly measure reproductive success of translocated lamprey adults and/or outplanted larvae (e.g. via parental based tagging), as well as provide a way to assess the genetic background of each individual adult and test whether this background affects reproductive success in a particular environment. The other advantage of this genetic analysis is that the age of the larvae can be quantified accurately based on parentage assignment, allowing us to further our understanding of the age structure of Pacific lamprey at various life stages.

4 Supplementation Research Framework

This section describes the Supplementation Research Framework that will be an integral component of the larger Pacific lamprey RME Framework (Item 1 described in Section1.4; Figure 4-1.). Collective development of these documents is anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan, (2) Lamprey Conservation Agreement, and (3) Northwest Power and Conservation Council Fish and Wildlife Program. Each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be drafted in years 2016-2017. Translocation and propagation continue to be tools necessary for learning, both in laboratory and the natural environment. Supplementation may be used as one method to address limiting factors and ultimately to help shape the management plan.

Because of the low returns of Pacific lamprey, including extirpation in some subbasins, and the assumption that natural recolonization will require a long time, the use and monitoring of adult translocation and hatchery reared larval and juvenile lamprey in short and long-term supplementation efforts will be necessary. In the short term, translocation and propagation efforts would be used to reestablish lamprey in extirpated streams and maintain lamprey presence to attract upstream migrating spawning lamprey. In the long term, artificially produced lamprey could be used to supplement CRB lamprey by dramatically increasing larval/juvenile numbers with the goal of effectively reversing declines.

Within key research areas, multiple threats recognized, both within and outside of subbasins, include degraded habitat, passage barriers, degraded water quality, dewatering, and predation (CRITFC 2011a; Luzier et al. 2011). To varying degrees these threats are being addressed, although it will take considerable time before their impacts are fully understood and corrected; therefore, appropriate supplementation is necessary during this time.

Fishery managers recognize the importance for both restoration and research to be complimentary efforts in addressing threats. It is especially important to recognize the use of supplementation in areas where lamprey numbers are too low to actually determine the nature or extent of potential limiting factors. Examples include juvenile entrainment and passage through irrigation screens or adult passage over irrigation facilities. Hatchery reared fish may also be used to address basic questions about growth and survival in natural riverine environments. Managers have concluded that without use of translocation and propagation research as a tool, it is essentially impossible to understand potential environmental threats in many subbasins. Short term focus should be on critical areas of research and longer-term application of supplementation in key areas.

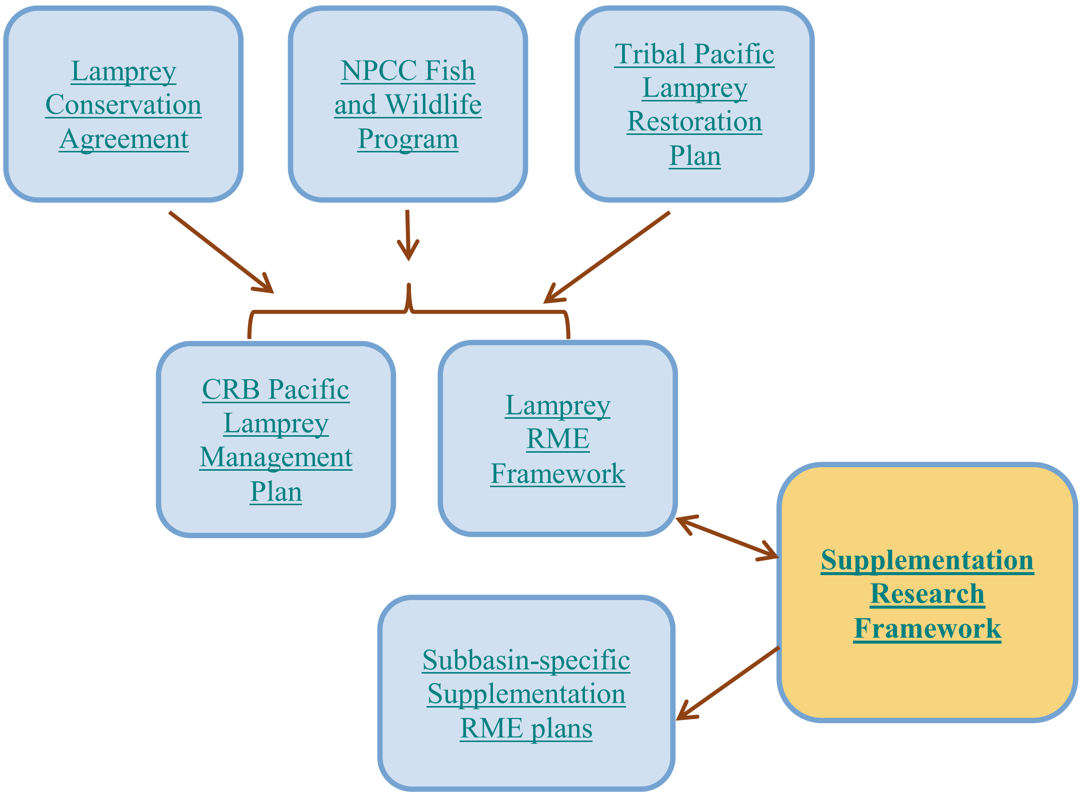

Figure 4-1. Context of the Reintroduction and Augmentation Research Framework relative to other existing and planned documents

4.1 Regional RME Framework

The larger scale Regional Framework for Pacific Lamprey Research Monitoring, Evaluation, and Reporting in the Columbia River Basin (RME Framework – Item 1 described in Section 1.4) will be guided by principles and concepts put forth by Luzier et al. (2011). The RME Framework will also be informed by biologists with experience in lamprey biology. At this time, some of the elements of a comprehensive RME Framework cannot be implemented because of a lack of scientific tools needed to collect data (e.g., juvenile tags). Nevertheless, the framework will identify appropriate RME questions and objectives, and the need to develop the tools necessary to address the questions and objectives.

4.1.1 Types of RME Efforts

Several types of monitoring are needed to allow managers to make sound decisions:

- **Status and Trend Monitoring.** Status monitoring describes the current state or condition and limiting factors at any given time. Trend monitoring tracks these conditions to provide a measure of the increasing, decreasing, or steady state of a status measure through time. Status and trend monitoring includes the collection of standardized information used to describe broad-scale trends over time. This information is the basis for evaluating the cumulative effects of actions on lamprey and their habitats.

- **Action Effectiveness Monitoring.** Action effectiveness monitoring is designed to determine whether a given action or suite of actions (e.g., propagation and translocation) achieved the desired effect or goal. This type of monitoring is research oriented and therefore requires elements of experimental design (e.g., controls or reference conditions) that are not critical to other types of monitoring. Consequently, action effectiveness monitoring is usually designed on a case-by-case basis. Action effectiveness monitoring provides funding entities with information on benefit/cost ratios and resource managers with information on what actions or types of actions improved environmental and biological conditions.

- **Implementation and Compliance Monitoring**. Implementation and compliance monitoring determines if actions were carried out as planned and meet established benchmarks. This is generally carried out as an administrative review and does not require any parameter measurements. Information recorded under this type of monitoring includes the types of actions implemented, how many were implemented, where they were implemented, and how much area or stream length was affected by the action. Success is determined by comparing field notes with what was specified in the plans or proposals. Implementation monitoring sets the stage for action effectiveness monitoring by demonstrating that the actions were implemented correctly and followed the proposed design.

- **Uncertainties Research**. Uncertainties research includes scientific investigations of critical assumptions and unknowns that constrain effective propagation and translocation. Uncertainties include unavailable pieces of information required for informed decision making as well as studies to establish or verify cause-and-effect and identification and analysis of limiting factors.

4.2 Supplementation Research Strategies

This supplementation research Framework covers the translocation and hatchery rearing of Pacific lamprey within the Columbia River Basin. It describes the RME recommended for assessing the status and trends of Pacific lamprey within subbasins and for evaluating the effectiveness of translocation and other actions implemented to restore Pacific lamprey within those subbasins. In addition, this Framework identifies current efforts and additional RME needs. Although logistical and monetary limitations exist, this plan will focus on the common goal of assessing success in Pacific lamprey translocation and propagation.

4.2.1 Adult Translocation

4.2.1.1 Background

Close et al. (1995) conceptualized the goal of lamprey translocation to “begin establishment or supplementation of lamprey in selected tributaries above Bonneville Dam where populations have been extirpated or are at extremely low levels." The overall goal of translocation is to restore natural production to self-sustaining levels.

Translocation programs in the CRB have been well documented by Close (1999), Close et al. (2009), and Ward et al. (2012). The approach for translocation efforts to date has been to collect adult Pacific lamprey at Bonneville, The Dalles, and John Day dams. Adults are then transported and held at facilities near release areas. Adults are tagged and treated at the holding facilities and released the following spring.

4.2.1.2 Rationale and Assumptions

Although the best long-term sustainable option for increasing Pacific lamprey abundance and distribution may be improving the passage environment for adults and juveniles, translocation of adults may be the best immediate option to begin the process of rebuilding populations in depressed subbasins. Translocation efforts are likely to increase production of larval lamprey in recipient subbasins, "seeding" underutilized rearing habitat and increasing pheromone cues to attract adults. Translocation and other restoration programs could therefore have a synergistic effect in breaking the downward cycle of Pacific lamprey abundance and recruitment.

Another potential benefit of translocation is expanded spatial distribution of Pacific lamprey, via occupation of subbasins where they have been severely depressed or extirpated. Until passage is better understood and improved at mainstem dams, translocation from lower dams may also produce an escapement benefit for lamprey. These benefits may help decrease the risk of lamprey local extirpation by decreasing the overall impact of catastrophic events within a subbasin, or even within a larger portion of the Columbia River Basin.

Lamprey translocation may also produce ecosystem benefits. Because ammocoetes are filter feeders and detritivores, increased production is expected to facilitate nutrient cycling in rivers where adult lamprey have been reintroduced. Other potential benefits include increased connectivity of marine with freshwater ecosystems, and delivery of marine-derived nutrients into upper reaches of the Columbia River Basin. Lamprey restoration will also increase the prey base available to native fish, avian, and mammalian predators.

4.2.1.3 Critical Uncertainties

Critical uncertainties regarding translocation of adult Pacific lamprey that have been identified through monitoring of existing programs include:

- Survival of translocated adults
- Spawning success
- Viability and survival of eggs, larvae, and juveniles

Potential risks (albeit unknown) from lamprey translocation often raised include:

- Disruption of population structure and associated genetic adaptations
- Exposure to survival risks such as pathogens and disease
- Decreased abundance in donor areas.

These potential risks have been recognized (Ward et al. 2011), and steps have been taken to avoid or reduce them by adherence to lamprey translocation guidelines agreed to by the Columbia River Inter-Tribal Fish Commission (CRITFC 2011a).

A remaining uncertainty may be the appropriate number of adults to release within a target location. The apparent lack of homing of Pacific lamprey to natal watersheds confounds attempts to address this uncertainty. Long-term efforts are needed to document the effect of increased larval abundance on returns of adults.

4.2.1.4 Research and Monitoring Objectives

The four Columbia River treaty tribes have proposed creating a regional lamprey supplementation plan that includes adult translocation with the following general objectives (CRITFC 2011a):

- Continue translocation in accordance with tribal guidelines.
- Develop and implement lamprey translocation as a component of a regional supplementation plan.

Tribal translocation strategies will:

- Utilize historical and tribal records of lamprey distribution, abundance and habitat to help determine outplanting priorities.
- Use the best available knowledge to evaluate if translocation is necessary.
- Choose donor sources wisely and make efforts to minimize negative effects on donor groups.
- Monitor and improve collection, transport, and holding protocols and facilities.
- Evaluate and select target streams, release locations, and timing of releases using the best available knowledge.
- Closely monitor and evaluate translocations at a variety of spatial and temporal scales.
- Accurately record and sufficiently share translocation results with the region.

4.2.2 Larval and Juvenile Outplanting

4.2.2.1 Background

The biological features of lamprey (especially after hatching) require new innovative ideas and methods to improve culture success. Formative work on lamprey propagation in Finland, research on sea lamprey from the Great Lakes region, and research on Arctic lamprey from Japan provide important insights on how artificial propagation of Pacific lamprey could be used in the CRB. Some experimental work on the artificial propagation of Pacific lamprey has already been conducted within the CRB; however, the primary focus in the past has been on propagating small number of lamprey for research purposes and the processes and techniques applied were not scaled for aquacultural use.

In 2012, the Yakama Nation and Umatilla Tribe joined forces and collaborated on the artificial propagation of Pacific lamprey. Over a 10-week period between April and June, 2012, 41 adults were spawned successfully primarily at Marion Drain and Prosser hatcheries. Some of the individuals (both male and female) spawned repeatedly, resulting in a total of 55 propagation events. Over 40% of the adults, however, did not mature in 2012 and were overwintered for another year. Fertilization and hatching success varied widely (0-99%). The success of fertilization and hatching depended chiefly on four variables: 1) seasonality; 2) quality of gametes; 3) water quality; and 4) incubation methods.

Many tribal and federal agencies experimented with larval rearing in 2012 using hatchery reared age 0+ larvae. Different feeds and substrate types were tested, and the effects of temperature and feeding regime on growth and survival were evaluated. Most studies demonstrated that larvae can attain positive growth and relatively high rates of survival under active dry yeast feed. However, a certain combination of feeds in addition to active dry yeast (such as hatch fry feeds or marine larvae feed) appeared to be potentially effective in producing even better growth and warrants further research. Larvae appeared to show preference for natural fine substrates, such as clay, silt, sand, detritus and straw. However, considering the enormous difficulty in separating larvae from clay/silt, detritus, and straw, fine sand appears to be the most promising substrate to date.

Protocols for rearing larvae and juveniles for extended periods of time (years) are lacking. Growing lamprey to larger sizes will be particularly challenging partly due to 1) the length of time they spend as larvae (3-7 years) and 2) their cryptic nature (i.e. burrowing under fine sediment), which makes any type of monitoring both very time-consuming and difficult.

4.2.2.2 Rationale and Assumptions

Once developed, artificial propagation could be an important management action to aid in the restoration of Pacific lamprey, especially in areas of low abundance or extirpation. A primary role of larval propagation and outplanting besides increased larvae/juvenile production would be to maintain and increase pheromone cues to attract returning adults. Increased numbers of larvae are likely needed to occupy available habitat, release pheromones, and begin reversing declines in numbers of returning adults.

Hatchery reared larval lamprey may also be valuable as study organisms. Larval lamprey behavior is secretive and larvae are elusive (i.e. burrowed in sediments), making them difficult to study in their natural environments. Rearing and evaluating lamprey in a controlled laboratory environment and connecting this work with controlled research in the natural environment may be the most effective way to better understand various life stages efficiently, both in time and expense.

Juvenile (macrophthalmia) outplanting may not be the most effective strategy for supplementation because larvae are needed in the streams to produce pheromones that attract adults and the economic cost of growing larvae for 3-7 years would also be substantial. Raising lamprey to the juvenile stage may have some benefits, however. For example, if the facility is in a suitable location, pheromones released by larvae being reared over long periods may serve to attract returning adults. Continued holding of fish may facilitate refinement of rearing techniques. Finally, survival rates of outplanted juveniles are most likely going to be higher than that of larvae.

Hatchery-raised lamprey could also be used for other research programs other than re-stocking in streams. Very little is known about lamprey juvenile passage and migration, but the diminished abundance and distribution, and the unique size and shape of the lamprey make any kind of sizeable tagging studies extremely difficult, if not impossible, to implement. Therefore, artificial propagation of Pacific lamprey may be extremely valuable for research purposes to better understand their early life history and biology, and to meet the critical need of samples required for such studies. Hatchery lamprey could be raised to various life stages and used as test organisms for determining screen design, screening efficiencies, survival through hydroelectric projects, and other juvenile studies of critical importance.

Using hatchery reared fish in the natural environment provides several distinct research opportunities because lamprey could be placed in selected stream reaches or reservoir deltas at desired densities. For example, this type of lamprey placement allows for opportunities to test sampling protocols against a known sample. Larval lamprey placed in cages in certain streams could evaluate if their presence will attract adults via pheromones, or alternatively, their tolerance to certain levels of contaminant loads. In general, experiments using hatchery-raised lamprey will aid in the understanding of lamprey behavior and guide future restoration actions without the need to extract and harm existing lamprey from the natural environment.

4.2.2.3 Critical Uncertainties

Substantial obstacles must be overcome to achieve a scale necessary for hatchery production. Critical knowledge gaps at the hatchery production level include:

- Optimal temperature regime for holding adults
- Best management practice for successfully spawning and incubating lamprey
- Disease and fish health issues specific to lamprey
- Tolerance level of adults/eggs/larvae to disease/fungus controlling chemical treatments
- Influence of rearing density on larval growth; larval food quality, quantity, and feeding methods
- Methods to efficiently separate larvae from fine sediment for counting and monitoring

Although many knowledge gaps exist at the hatchery production level, these questions can be answered relatively easily by the use of targeted experiments. In fact, from the first year of propagation efforts by the CRB tribes and federal agencies, many of these knowledge gaps are beginning to get answered (such as spawning and incubation techniques, chemical treatment effects, effective types of feed and substrate media, etc.).

Growing lamprey to larger sizes will be particularly challenging partly due to 1) the length of time they spend as larvae (3-7 years) and 2) their cryptic nature (i.e. burrowing under fine sediment), which makes any type of monitoring both time-consuming, difficult, and stressful for the larvae. For example, in a salmon hatchery, large mortality events are obvious to the hatchery personnel because the fish are directly visible in the water tanks. In the case of larval lamprey, even if a significant larvae mortality event occurs, this event may go unnoticed for some time because they all live under the sediment and remain invisible most of the time. As larvae increase in size, their weight density will continue to increase, most likely requiring more and more space to rear them successfully.

Significant critical uncertainties related to post hatchery production remain. The release of hatchery reared larvae into the natural environment has taken place in Finland, Japan and other countries, but very little monitoring has been conducted to successfully validate its effectiveness in increasing and boosting natural reproduction levels. Critical knowledge gaps post hatchery production include:

- Optimal release sites
- Optimal larval release life stages (0+ ~ 7+ larvae)
- Optimal release density
- Changes in growth and survival of hatchery reared larvae after release
- Dispersal rates after release
- Interactions with naturally produced larvae and juveniles.

In addition to larval habitat in mainstem and side channels of rivers and streams, potential release sites include salmon acclimation ponds, hatchery pollution abatement ponds, and irrigation diversions and canals. To determine the optimal larval release life stage, a much better understanding on the life stage survival model for Pacific lamprey and the corresponding “bottleneck” life stage is needed. If the primary bottleneck is in the egg incubation and prolarvae stage, being able to rear them past this stage should increase the larvae production immensely (at least in quantity). On the other hand, if the primary bottleneck takes place in later life stages as larvae, it would become crucial to rear them past this stage. The optimal density levels of the larval release also require more information on the life stage survival model. At what density of larval outplanting (per watershed size) are increases in larvae production noticeable? Can larval lamprey adapt quickly to the natural environment after being reared in the hatchery settings for over a year? How many of the larvae would stay put within the release site vs. others that disperse to other habitat? How would the outplanting affect naturally- produced larvae? Salmon and trout hatcheries have learned from 100+ years of experience. All these questions will require intense monitoring that will span multiple years.

4.2.2.4 Research and Monitoring Objectives

The four Columbia River treaty tribes proposed creating this Framework with the following general objectives (CRITFC 2011a):

- Immediate evaluation of potential regional lamprey aquaculture facilities.
- Consolidation and synthesis of existing lamprey propagation information.
- Development and refinement of husbandry techniques for Pacific lamprey.
- Continued research on lamprey genetics, potential population substructure, and source locations.
- Assessment of appropriate release locations and strategies for hatchery reared lamprey within the region.
- Monitoring and evaluation of supplementation using hatchery reared lamprey.

These objectives are intended to answer basic questions on the feasibility of large scale lamprey propagation in the northwest. The next steps in research should focus on basic observations in nutrition, growth, rearing densities, survival, and habitat preferences. Preferably, efforts should build on previous propagation research on other lamprey species, especially related to collection of brood stock, fertilization techniques, incubation conditions, and release timing, for the efficient and cost-effective development of propagation programs in the CRB. The Yakama Nation and the CTUIR has begun initial efforts for propagation starting the spring of 2012 by hatching and rearing several thousand Pacific lamprey larvae at their facilities. In 2013, propagation and rearing experiments ensued by the Yakama Nation and CTUIR to assess critical questions, such as 1) how to improve fertilization and incubation rates, 2) how to maximize survival of newly hatched larvae during facility-to-facility transfer, 3) how to efficiently count eggs and hatched larvae, and 4) how to effectively feed and rear larvae in large tanks under high density (>50,000) conditions.

4.3 Monitoring and Evaluation Approaches

4.3.1 Adult Translocation

4.3.1.1 Adult Survival

Monitoring questions

- How many translocated adults moved out of the release areas?
- How far and in what direction did translocated adults move following release?
- How many translocated adults moved to spawning areas?
- How did release timing and location affect spawn timing?
- What environmental factors (e.g., flows, temperature, etc.) may have caused translocated adults to leave the target areas?

Performance metrics

- Number of adults released
- Direction of movement
- Rate of movement
- Distance moved
- Adult maturation rate
- Estimated percentage of released adults that successfully reached spawning areas

Performance may be influenced by variables including water temperature and stream flow.

Approach

A tagging study (e.g., radio telemetry) is needed to determine the movement and habitat use of translocated adult Pacific lamprey. If water conditions allow and no lamprey are in the area, visual observations without tagging studies can be used to determine if translocated adults use the target spawning areas. This, however, is a less robust approach than using tagging studies.

Analysis

If a tagging study is used, the analyses are straightforward for estimating direction of movement (fraction moving upstream and downstream), rates of movement (distance moved per week), numbers leaving the target area, and numbers of adults spawning within the target area. Correlations between environmental factors (flows and temperatures), time and location of release, and spawn timing can be evaluated.

4.3.1.2 Adult Spawning

Monitoring questions

- How many translocated adults constructed redds and engaged in reproduction within target areas?
- What was the distribution of spawners within target areas?
- What habitat conditions (e.g., flows, temperature, substrate, etc.) favored the construction of redds and reproductive success within target areas?
- How many adults successfully spawned and contributed offspring?
- What are the effects on spawning success of multi-year over-wintered adults?
- What are the effects of an individual's genetic background on spawning success?

Performance metrics

- Number and distribution of redds
- Number of adults engaged in reproduction
- Number of eggs per red
- Presence of live eggs and larvae within redds
- Number of live eggs and larvae within redds
- Number of offspring assigned back to translocated adults

Performance may be influenced by a number of variables including water temperature, stream flow, water velocity, water depth, cover, and substrate composition.

Approach

An important assumption of translocation is that the translocated Pacific lamprey are ready to spawn shortly after release. This means that the translocated adults will successfully find mates, select suitable spawning sites, construct redds, and reproduce. For indirect measures of reproduction, if water conditions do not allow for visual observations, a tagging study may be needed to determine the number and distribution of spawners within the target areas. If water conditions allow, visual observations can be used to determine the number, distribution, and reproductive activities of translocated adults within the target areas. Ideally, spawning surveys should occur weekly throughout the spawning period (i.e., from time of release to the end of spawning). Field observations can be used to document redd construction and reproductive behavior. The location and timing of redds can be mapped using GPS. The size (width, length, and depth) of each redd can also be recorded. Habitat conditions (temperature, depths, velocities, cover, and substrate composition) can be measured at the locations of redds within the target areas. Stream flows can be downloaded from nearby gauging stations. Note that lamprey spawning surveys can be coupled with steelhead spawning surveys.

A genetic tagging study can be used to evaluate reproductive success metrics. Hess et al. (in prep) have developed and evaluated a set of genetic markers for Pacific lamprey that can accurately assign offspring to their parents. Tissues from ALL translocated lamprey adults must be collected for this tagging approach to be possible to execute for efficient monitoring.

Analysis

Descriptive analyses can be used to describe the number, distribution, and spawning activities of translocated adult lamprey within the target areas. Correlation and regression techniques can be used to assess the relationships between habitat conditions and the abundance and distribution of redds in the target areas. These relationships can then be used by biologists to fine-tune their selection of appropriate release locations. Based on the distribution of redds, biologists can sample a random number of redds to determine the total number of eggs deposited per red; randomly sampling redds for the presence of viable eggs and larvae over a specified time interval (e.g., weekly). To the extent possible, biologists should count the total number of viable eggs and larvae within a redd to gain a better understanding of the natural survival mechanism during early life history (methods may need to be developed to measure viable eggs and larvae over time).

Because the sampling of redds can alter the survival of eggs and larvae over time, biologists will need to determine if sampling with or without replacement is appropriate. That is, should a given redd be sampled more than once over time? Ideally, the total number of redds sampled should be no more than 10% of the total redds within the target area. Habitat conditions (temperature, water depth, egg-pocket depth, redd size, velocities, and substrate composition) can be measured at the locations of redds within the target areas.

4.3.1.3 Larval Survival and Growth

Monitoring questions

- Did translocated adults produce viable larvae in target areas?
- What fraction of the eggs survived to emergent larvae?
- What habitat conditions (e.g., flows, temperature, substrate, etc.) were associated with larvae survival and production?
- What is the survival rates for various age classes of larvae (i.e. 0+, 1+, 2+, 3+,etc.)
- Is genetic makeup associated with larval growth and survival?

Performance metrics

- Egg-to-larvae survival rates
- Larval survival and growth rates at various age classes
- Size, age, and abundance of larval lamprey identified as offspring from translocated adults

Performance may be influenced by a number of variables including water temperature, stream flow, water velocity, water depth, and substrate composition.

Approach

If translocation is to be successful in increasing the status of Pacific lamprey within a subbasin, then translocated adults must produce viable offspring. Therefore, measuring successful hatching and surviving larvae is critical to the assessment of translocation. If hatching and larvae production is successful, biologists will be equipped to re-establish lamprey in areas currently void of Pacific lamprey. Larval and juvenile lamprey of particular age classes will be able to be assigned back to translocated adults using genetic analyses. Offspring will be able to be assigned to adults translocated in 2013 and onwards.

Analysis

Descriptive analyses can be used to describe the mean number of eggs per redd, mean number of viable eggs and larvae per redd, and egg-to-larvae survival rates, as well as number of viable offspring per spawner pair. Correlation and regression techniques can be used to assess the relationships between habitat conditions and survival rates.

An important assumption of propagation is that planted larvae will use intended rearing areas over time. Biologists will identify suitable release sites based on rearing conditions within those sites. If biologists are able to identify suitable rearing areas that are used successfully by hatchery reared larvae, it may improve the status of Pacific lamprey within the subbasin. It will also be possible to track hatchery reared larvae via parentage analysis at various stages of maturity as they continue their continuous migration downstream.

4.3.1.4 Larval Abundance and Distribution

Monitoring questions

- How many larvae were produced by translocated adults?
- What size distribution is represented by each cohort of lamprey?
- How many larvae remained within the target areas over time?
- Did the distribution of larvae expand into areas outside the target areas?
- How did release timing and location affect the density and distribution of larval or juvenile lamprey within the target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval distribution and abundance?

Performance metrics

- Density of larvae (CPUE or fish/m^2)
- Distribution and abundance of larvae
- Presence and proportion of various size classes of larvae

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

Approach

Annual larval sampling within treated and untreated areas before and after supplementation activities will determine the relative abundance and size classes of larvae within the target areas. Parentage analysis will identify which larvae originated from which translocated adults, thereby providing a way to verify larvae were derived from translocation efforts and to measure distance traveled from last known spawner release site.

Electrofishing techniques modified for sampling larval lamprey may be the most appropriate method for estimating relative abundance, size classes and distribution. However, recent research from Europe shows that a significant proportion of lamprey populations (especially anadromous lamprey) can be found in deep water habitat that are not normally targeted with the standard electrofishing methods for lamprey. Alternative methods may need to be evaluated further (such as deep water shocking, suction dredging, passive traps, and infra-red cameras) to target these other areas that larvae may use extensively. Locations of juveniles can be mapped using GPS. Lamprey biologists will need to identify a protocol for sampling habitat conditions.

Analysis

A time series of the densities (CPUE or fish/m^2) of larval lamprey and numbers of transformers can be constructed to show how densities and numbers changed before and after supplementation efforts. Distribution maps can be generated that show how the spatial extent of larvae expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and larval abundance and distribution.

4.3.1.5 Larval and Juvenile Outmigration

Monitoring questions

- How many larvae or juveniles transformed and migrated downstream?
- What ages are larvae or juveniles at particular maturation stages during their migration?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with outmigration?

Performance metrics

- Number of outmigrating larvae and transformers
- Rate of movement
- Distance moved
- Genetic diversity of larvae and macrophthalmia

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

Approach

Rotary screw traps or other traps can be used to estimate the number (or presence) of downstream migrating transformers. Field research suggests that transformers can be caught by electrofishing techniques as well, focusing on coarse sediment near Type I and Type II larval lamprey habitat in late summer / early fall season. Lamprey biologists will need to identify a modified protocol for electrofishing transformers and their associated habitat conditions. Locations of juveniles can be mapped using GPS. Juveniles will be assigned to particular brood years of translocated adults via parentage analysis, and thereby provide an accurate age for each fish.

Analysis

A time series of the numbers of transformers can be constructed to show how densities and numbers changed before and after supplementation. Distribution maps can be generated that show how the spatial extent of larvae and transformers expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and transformer abundance and distribution. Parentage-based ages can be related to juvenile size and life-stage to refine our knowledge of size-at-age relationships.

4.3.1.6 Adult Returns

Monitoring questions

- Are supplementation strategies influencing adult returns to specific streams and watersheds?
- What is the status and trend of returning adults in experimental and control streams and watersheds?
- What percentage of offspring derived from translocations return to the interior Columbia River as adults?

Performance metrics

- Number of returning adults
- Number of returning adults that were offspring of translocated lamprey
- Historical estimates of returning adults

Performance may be influenced by a number of variables including river conditions (e.g. water temperature, stream flow, water velocity) and basin-wide adult returns (e.g. adult counts at Bonneville Dam).

Approach

Addressing the adult life history stage will require a variety of monitoring techniques. Pacific lamprey do not appear to be philopatric (in the strict sense we use for salmonids), which makes associating changes in adult returns to specific supplementation strategies problematic. The simplest approach will be to actively and passively monitor adult returns, in specific streams and watersheds, through a combination of active adult trapping, video and visual monitoring, or spawning/redd surveys. Many of these approaches require “bottleneck” locations (e.g.

dams/diversions, waterfalls, manmade weirs) to facilitate passage/return estimates. Other approaches, such as spawning/redd surveys, may require significant manpower to complete.

Regardless of the approach used, any estimates of adult returns would need to be compared to historical estimates/counts to evaluate changes in adult returns in relation to specific supplementation strategies. Alternatively, if a long-term monitoring timeframe is utilized, in ~7+ years (around 2020) returning adults that were derived from these translocation efforts could conceivably be identified. These adults would be tissue sampled as they pass Bonneville Dam and identified as translocation offspring through parentage analysis, utilizing our translocation broodstock genetic dataset (brood years 2012-2015).

Analysis

Evaluating changes in adult returns will require a time series analysis of adult returns/estimates to specific streams and watersheds before, during, and after the implementation of supplementation strategies. Comparisons of adult returns/estimates before and after specific supplementation strategies would provide a qualitative assessment of adult returns. An assessment of adult returns in relation to supplementation strategies may be influenced by a number of variables including river conditions (e.g. water temperature, stream flow, water velocity) and basin-wide adult returns (e.g. adult counts at Bonneville Dam). These variables will need to be taken into account during analysis.

4.3.2 Larval and Juvenile Rearing

4.3.2.1 Broodstock Survival

Monitoring questions

- How many adults survived and sexually matured in the second spring/summer season after collection?
- What water temperature regimes, water source (river vs. well water), and holding conditions (density, tank type and size, substrate, flow rates, diel light conditions, etc.) are optimal for increasing survival and sexual maturation?
- Does pheromone from larvae and adults (opposite sex) stimulate sexual maturation?
- Can sexual maturation be stimulated and synchronized using insulin-like growth factor and other hormonal chemicals?
- Under natural conditions, what proportions of adults spend more than a year to sexually mature?

Performance metrics

- Transportation and holding survival rates
- Sexual maturation rates
- Timing of sexual maturation
- Spawning rates (ability to successfully utilize gametes before they lose viability)

Performance may be influenced by a number of variables including water temperature, flow rates, water velocity, water depth, and substrate composition.

Approach

The primary goals of broodstock holding is to increase transportation and holding survival rates, increase sexual maturation rates, and enhance spawning success.

Efforts to collect, transport, and hold adult Pacific lamprey from the lower Columbia River have been largely successful with few observed mortalities. However, there are still important questions regarding the potential effects of artificial holding on the sexual maturation of adult lamprey. Although adults overwintering for multiple years may be a natural phenomenon, it is likely that the artificial holding conditions may negatively impact the rates of sexual maturation. It will be important to test and experiment the effects of various holding conditions (temperature, water source, lighting, etc.) strategically and systematically at various holding facilities to investigate the best conditions for successful sexual maturation.

Availability of larval and adult pheromone scents in the water may have an impact on this as well. An individual's genetic makeup may also affect its successful use in propagation. Sexually mature adults are often times covered with fungus and are extremely fragile and vulnerable and as a result, adults have a relatively short timeframe for successful spawning and propagation. If the sexual maturation is not in synchrony between males and females, gametes can often remain unused and go to waste. Insulin-like growth factor and other hormonal chemicals can be tested for its efficacy on synchronizing sexual maturation. It is important to note that what is learned from these propagation experiments will also help improve the holding conditions for adult lamprey that are part of the translocation programs.

Analysis

Correlation and regression techniques can be used to assess the relationships between holding conditions, genetic makeup, and rates of survival and sexual maturation. It is important to compare the survival and sexual maturation rates among all the facilities that hold the adults and from that determine the key factors that drive success (namely high rates of survival and sexual maturation). Every year, certain tank conditions can be modified strategically within and among the various facilities to evaluate the effects.

4.3.2.2 Fertilization to Hatch Survival

Monitoring questions

- What spawning methods maximize the fertilization rates (methodology of gametes and water mixing, holding time, amount of water, chemical treatment, etc.)?
- What incubation methods maximize the hatching rates (McDonald jars, upwelling and downwelling jars, flow rates, chemical treatment, mesh size, etc.)?
- How long can gametes (eggs and milt) be preserved and remain viable using refrigeration, cryopreservation, etc.?
- How can eggs be quickly counted to evaluate production levels and survival rates?

Performance metrics

- Fertilization rates and successional egg development
- Hatching rates

- Genetic diversity and fitness
- Ability of incubation methods to separate gametes (so that fertilization and hatching rates can be assessed for each spawner group)

Approach

Maximizing the fertilization and hatching rates are fairly easy tasks, given that the propagation protocols that already exist for other lamprey species in other countries as well as salmon species in general can be emulated and fine tuned. The Yakima Nation and CTUIR have worked collaboratively since 2012 to investigate fertilization and hatching success and many improvements in protocols have been made since then (see section 4.2.2 for more information). A wide variety of incubation methods were compared and contrasted in 2012 to evaluate the success rates of various incubation methods. In 2013, more in-depth questions related to propagation were investigated to continue to refine and improve fertilization and hatching success.

Genetic diversity of Pacific lamprey is influenced by two main sources: 1) the pool of adults that were originally collected from lower Columbia river dams and 2) the degree to which mixing of adults occur in propagation (for instance, 3x3 or higher breeding matrices of males and females can enhance genetic diversity of offspring). Genetic fitness will need to be evaluated on a long-term basis as more information is collected on survival rates and eventually return rates in future years. Lamprey eggs and newly hatched prolarvae are extremely small, allowing them to slide through the smallest gaps in incubation trays and tank dividers. If fertilization and hatching success are to be evaluated accurately for each spawner group, it is important to use an incubation method or holding vessels that minimize the unanticipated movement of eggs and prolarvae between trays and tank sections.

Analysis

Correlation and regression techniques can be used to assess the relationships between propagation and incubation conditions, genetic makeup, and rates of fertilization and hatching. Every year, certain elements of the protocols can be modified strategically to evaluate the effects on propagation success. Increasing the genetic diversity of off spring can be achieved by increasing the breeding matrices as well as the diversity of the source adult population. Subsequent genetic diversity of hatched larvae in the hatchery can be compared to that of hatched larvae from wild and/or translocated adults in the rivers and streams. Because of the limited number of adults and larvae present in many of the supplemented areas, striving to attain higher levels of genetic diversity appears important, but other genetic traits may be important fitness traits for survival in the upper Columbia reaches (such as large body lengths and weights) as well.

4.3.2.3 Hatch to Outplant Survival

Monitoring questions

- What are the best conditions for maximizing prolarvae and larvae survival (density, water temperature, cover material, lighting conditions, etc.)?

- What type of holding tanks (circular, trough, inlet and outlet styles, etc.) provide the best conditions for prolarvae and rearing larvae?
- What substrate media (clay, silt, sand, artificial media, etc.) will be optimal for survival, growth, and monitoring of larvae?
- What type of feeds will be optimal for survival, growth, and the overall health of larvae?
- How can larvae be separated from substrate media in a timely manner with the least amount of stress incurred to them for monitoring and transfer/transportation?
- How can larvae be quickly counted to evaluate survival and growth rates?
- What is the best way to maximize genetic diversity of the offspring?

Performance metrics

- Survival rates of prolarvae
- Survival and growth rates of feeding larvae
- Genetic diversity

Approach

Although experimental rearing of larvae in laboratory settings have been conducted for many decades, cases where lamprey were reared from eggs to larger larvae are rare. Based on the fact that Pacific lamprey has very high fecundity (~100,000 eggs per female), the survival rates of Pacific lamprey from egg to larva may be relatively low in the natural environment. In laboratory settings, however, there may be ways to greatly enhance the survival rates at this critical life history stage from eggs to larvae.

The Yakima Nation, CTUIR, USGS, and USFWS have worked collaboratively since 2012 to investigate larval rearing as well as the survival between egg/prolarva and larva life stages. Life stages between egg and prolarva is fairly easy to monitor as they do not require fine substrate for survival and many of the conventional fish hatchery tanks and equipment can be used effectively with small minor modifications. However, once the larvae is ready to feed, it appears that the presence of fine sediment, a medium through which larvae burrow and feed, is vital for their survival. On the flip side, this means that larvae will remain invisible for the majority of time, and monitoring for survival and growth becomes considerably difficult.

Newly hatched prolarvae and young larvae are extremely small (6~10mm long) and refining ways to enumerate them quickly and efficiently is crucial in evaluating the hatching success and survival in general. In 2013, The Yakama Nation has begun testing and calibrating XperCount device (an automated enumerating device for small fish/organisms by XpertSea, Inc - see http://www.xpertsea.com/ for more information) to find effective ways of counting these small larvae with minimal stress on fish.

Many questions still remain about appropriate feed for larvae in terms of survival, growth, and general fish health. Although active dry yeast has proven to be effective in attaining relatively high survival and growth within a short (<1 year) time frame, a certain combination of feeds in addition to active dry yeast (such as hatchfry feeds or marine larvae feeds) may be potentially effective in producing healthier fish and warrants further research. Protocols for rearing and monitoring larvae for extended periods of time (months and years) will need to be developed with ideally minimum handling impacts on larvae.

Analysis

Correlation and regression techniques can be used to assess the best methods to hold and rear prolarvae and larvae in terms of survival, growth, and general fish health. The variables of interest are tank settings, density, media substrate, feed type, feed amount and delivery system. Coordination and collaboration on these unique arrays of experiments among various agencies and tribes will be key to maximize our progress in this field of research. The genetic makeup of the surviving larvae will also be investigated to evaluate whether any natural selection is at work within the lab settings. Furthermore, genetic diversity of larvae in the hatchery can be compared to that of larvae from wild and/or translocated adults in the rivers and streams.

Various larvae extraction methods should also be compared and evaluated from the perspective of fish stress and survival as well as time efficiency. Unlike most other hatchery fish, lamprey larvae will need to be separated from the sediment in order to monitor them, so refining the methodology for this task will be important. Use of automated enumeration tools (such as XperCount) may be needed to effectively count and sort the hundreds of thousands of progeny produced from each female.

4.3.3 Larval and Juvenile Outplanting

4.3.3.1 Larval Survival and Growth

Monitoring questions

- How do the survival rates of hatchery reared larval lamprey compare to naturally-produced lamprey?
- Did release timing and location negatively affect the growth and survival of larval lamprey within target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval growth and survival?
- Is genetic makeup associated with larval growth and survival?

Performance metrics

- Size, age, and abundance of larval lamprey
- Number of immigrants and emigrants
- Survival and growth rates

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

Approach

For propagation to be successful, released larvae need to grow and survive to the juvenile stage. Ideally, growth and survival rates would be compared to values for “wild” fish. If growth and survival are similar to or better than those measured for “wild” fish, propagation of larval lamprey would be considered a valid approach to improve the status of lamprey populations within subbasins. Growth and survival rates can be measured using parentage analysis. If all parents of hatchery reared larvae are genetically sampled, then routine sampling of the juveniles while they mature in the wild could be used to track the offspring of adults that were spawned for the propagation efforts. These offspring could then be compared to wild larvae in the same area though confirming the age classes of the wild larvae may be difficult.

Alternative techniques to assess growth and survival rates of larval lamprey are not currently available. Visible Implant Elastomer (VIE) markings have been tested for various size classes of juvenile and larval lamprey (down to 30mm size) and appears to be a promising technique for marking early life stage lamprey. VIE marks appear to last for a long term. Survival appears to be very high but effects on feeding and growth requires further investigation. Fin clips have also been used to mark larval and juvenile lamprey, but their impacts on both survival and growth have not been evaluated extensively to date. Genetic analysis may be the best available approach for monitoring movement of larvae in and out of sites, aging larvae, and assessing handling effects.

Annual larval sampling within treated and untreated areas before and after propagation will be needed to assess growth and survival rates. This work should be done within target areas and areas supporting natural production of Pacific lamprey. This will allow the comparison of growth and survival rates between the two areas, especially if mark and recapture studies can be incorporated into the sampling. Electrofishing techniques modified for sampling larval lamprey may be the most appropriate collection method for shallow water. Collected fish would be measured for length and weight, aged (method yet to be developed), and marked or tagged (standard method yet to be developed). A separate study would be needed to determine the effects of shocking, handling, and marking/tagging on larval lamprey growth and survival. This work would likely be conducted in a laboratory. Finally, lamprey biologists will need to identify a protocol for sampling habitat conditions.

Analysis

An appropriate model would be used to estimate growth and survival from mark-recapture data. These rates would then be compared between hatchery reared and naturally produced larvae. Alternatively, focus can be on sampling in areas where the hatchery reared and naturally produced larvae are well isolated from each other, if it is assumed that immigration and emigration rates are minimal between the sampling dates. Because data will be collected annually, a time series of annual growth and survival rates can be generated and compared between populations and laboratory studies. Correlation and regression techniques can be used to assess the relationships among habitat conditions, larval abundance, growth rates, and potentially survival rates.

Although techniques are not currently standardized for continuously measuring growth and survival rates, length, weight, and condition factors can be compared among areas or groups of fish. In addition, using correlation and regression techniques, these factors can be evaluated to see if they are associated with densities (density-dependent effects) and habitat conditions.

4.3.3.2 Larval Abundance and Distribution

Monitoring questions

- How many larvae remained within the target areas over time?
- Did the distribution of released larvae expand into areas outside the target areas?
- Did release timing and location negatively affect the density and distribution of larval or juvenile lamprey within the target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval distribution and abundance?

Performance metrics

- Density of larvae (CPUE or fish/m^2)
- Distribution and abundance of larvae
- Presence and proportion of various size classes of larvae

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

Approach

An important assumption of propagation is that planted larvae will use intended rearing areas over time. Biologists will identify suitable release sites based on rearing conditions within those sites. If habitat is not suitable for rearing, hatchery reared larvae may leave the area or die. Even if the habitat is suitable, larvae may naturally migrate downstream over time. If biologists are able to identify suitable rearing areas that are used successfully by hatchery reared larvae, it may improve the status of Pacific lamprey within the subbasin.

Annual larval sampling within treated and untreated areas before and after propagation will determine the relative abundance of larvae within the target areas. Electrofishing techniques modified for sampling larval lamprey may be the most appropriate method for estimating relative abundance and distribution in shallow water. Locations of juveniles can be mapped using GPS. Lamprey biologists will need to identify a protocol for sampling habitat conditions.

Analysis

A time series of the densities (CPUE or fish/m^2) of larval lamprey and numbers of transformers can be constructed to show how densities and numbers changed before and after the propagation and release of larvae. Direct assessment of the abundance and distribution of planted larvae can be implemented via parentage analysis to identify offspring of adults that were spawned in the hatchery. Distribution maps can be generated that show how the spatial extent of larvae expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and larval abundance and distribution.

4.3.3.3 Larval and Juvenile Outmigration

See Section 4.3.1.5 for information on monitoring questions, performance metrics, approach and analysis.

4.3.3.4 Adult Returns

See Section 4.3.1.6 for information on monitoring questions, performance metrics, approach and analysis.

4.3.4 Experimental Controls

For supplementation to be successful, larvae produced by translocated adults or released from hatcheries need to survive, grow, and eventually transform and migrate. Ideally, survival, growth, and transformation rates would be compared to values for areas not being supplemented. If survival, growth, and transformation rates are similar to or better than those measured for areas not being supplemented, then translocation or propagation would be considered a valid approach to improve the status of lamprey populations within subbasins. Feasible approaches may range from simple comparisons of adult returns among areas to actual comparisons of larval survival, growth and transformation among areas. Non-supplemented "control" areas might be distinct watersheds within a subbasin being supplemented elsewhere, or a nearby subbasin considered a suitable control. The use of experimental controls is implicit in most of the approaches described above.

4.3.5 Genetic Monitoring and Analysis

Recently, a set of 96 high-throughput genetic assays (single nucleotide polymorphisms, SNPs) have been developed for Pacific lamprey and have been demonstrated to perform the following three critical functions: 1) species identification, 2) parentage assignment, and 3) characterization of adaptive variation (Hess et al. in prep). These functions have important implications for the conservation of Pacific lamprey, and have already been applied successfully to specific management questions.

For example, 1) species identification via genetic analysis has been utilized to document a natural recolonization of Pacific lamprey in a tributary in which this species was thought to be extirpated (Hess et al. in prep). The putative Pacific lamprey larvae that were collected were all 0-year age class, which is a particularly challenging age class to morphologically distinguish Pacific lamprey from other species such as Western brook lamprey, however in this case all larvae were confirmed as Pacific lamprey.

2) Parentage assignment has been utilized to verify reproductive success of translocated adults that had been released in 2007 into Newsome Creek (Snake River Basin). A smolt trap was used in 2012 to collect over a hundred juvenile lamprey of which nearly 100% were successfully assigned back to their parents that had been translocated in 2007 (Hess et al. in prep). Therefore, types of information that parentage assignment can provide includes a direct measure of reproductive success of a group of adults (e.g. number of viable offspring per spawner pair) and an accurate method for aging offspring. This latter piece of information is particularly critical for refining our understanding of the relationship between larval size and age distributions, and the age-timing of juvenile lamprey life-stage transformations (i.e. ammocoete to macropthalmia).

3) Adaptive variation that was found to be associated with morphology, run-timing, and geography (Hess et al. 2013) can be characterized using the 96 high-throughput assays, and was demonstrated to reflect differences in body-size and run-timing among adults collected at Willamette Falls in the Lower Columbia River. Specific adaptive genetic markers will be characterized in the adults used for supplementation to assess how the genotypes of individuals may help predict their reproductive success at particular supplementation sites. Therefore, these three central functions of the 96 SNPs will provide critical pieces of information needed to implement effective monitoring of these Pacific lamprey conservation efforts.

5 Supplementation Research Plans for Individual Subbasins –General Outline

This section provides a template for Subbasin Supplementation Plans that will be integral components of the RME Framework. Development of these plans is anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan (CRITFC 2011a), (2) USFWS Conservation Agreement for Pacific Lamprey (Lamprey Conservation Agreement; USFWS 2012) and (3) Northwest Power and Conservation Council Fish and Wildlife Program (NPCC 2009). Plans provide information specific to a subbasin regarding lamprey status, limiting factors, ongoing and planed actions, and rationale for those actions. Plans describe supplementation actions and RME actions associated with supplementation, including metrics, parameters, etc. Although plans will vary in scope and content among subbasins, each plan should provide a minimum of information described here to facilitate consistency and continuity of important methods, analysis, and reporting formats. An example plan for the Yakama River Subbasin is provided for further guidance in Appendix D.

5.1 Introduction

5.1.1 Subbasin overview

Provide general information about the subbasin such as location, drainage size, annual and seasonal discharge, major topographic features, and important human population centers. Include information about major natural lakes and reservoirs, diversions, and other facilities potentially affecting passage or habitat quantity/quality. Briefly describe changes from the natural seasonal hydrograph, if any, and how changes in passage, habitat, and the hydrograph have affected Pacific lamprey.

5.1.2 Importance of Lamprey in the Ecosystem and as a Cultural Resource

Describe importance of Pacific lamprey to the ecosystem and tribal culture within the subbasin. Provide information on historic harvest sites, numbers, etc. if possible.

5.1.3 Brief Historic and Current Status and USFWS Findings for Subbasins

Briefly summarize subbasin-specific information from the 2011 USFWS Conservation Assessment. Include information on potential population groupings and historic and current status and trends. If available, include information on limiting factors and critical uncertainties. Summarize information in tables as appropriate.

5.1.4 Ultimate Goals and Vision: Natural Production and Harvest

State the overall goals or vision of the supplementation research plan. Demonstrate how these are consistent or complimentary with those of existing plans or programs. Examples may include the Tribal Restoration Plan, the Conservation Agreement, NPCC subbasin plans, or goals or plans of pertinent management entities.

5.2 Summary of Pacific Lamprey Status in the Subbasins

5.2.1 Adult Abundance, Run Timing, and Spawning Locations

Summarize as much historical and current information as possible to document information on adult Pacific lamprey abundance and distribution in the subbasin. Use tables as appropriate. Discuss the implications of continuing downward trends when relevant. Summarize information on run timing if available.

5.2.2 Juvenile Abundance and Run Timing

Summarize as much historical and current information as possible to document information on juvenile Pacific lamprey abundance and distribution in the subbasin. Use tables as appropriate. Discuss the implications of continuing downward trends when relevant. Summarize information on migration timing if available.

5.2.3 Ammocoete Abundance and Distribution

Summarize as much historical and current information as possible to document information on ammocoete abundance, distribution, and habitat use in the subbasin. Use tables as appropriate. Note if information is specific to Pacific lamprey or includes brook lamprey. Discuss the implications of continuing downward trends when relevant.

5.3 Analysis Units (Optional)

Provide justification for partitioning Pacific lamprey within the subbasin into analysis units if applicable. Preference would be to adopt USFWS groupings. Additional justification for groupings may include management areas, passage constraints, differences in habitat quality/quantity, or others. Provide a map of the subbasin highlighting the various analysis units.

5.3.1 Analysis Unit Descriptions

Use subsections to define and describe each analysis unit. These should be referenced from existing documents if possible to avoid the need to define new geographic units. Include geographic bounds (e.g., watersheds included), and general descriptions of Pacific lamprey abundance and distribution.

5.4 Summary of Pacific Lamprey Primary Limiting Factors

Describe known limiting factors and critical uncertainties for Pacific lamprey in the subbasin. Use a different subsection for each analysis unit if applicable. For each unit, describe factors for adults, juveniles, and ammocoetes when possible. Use tables to summarize information. Example of limiting factors may include passage at dams and diversions (including juvenile or ammocoete entrainment), water quality, habitat quantity/quality, and others.

5.5 Lamprey Supplementation Research Actions over the Next 5-10 Years

Describe both ongoing and anticipated supplementation RME actions. Provide sufficient detail to fully describe and justify actions. Ensure that critical uncertainties, key hypotheses, and general monitoring strategies have been described. Include a summary of potential comparisons to assist in evaluating effectiveness of supplementation actions (Table 5-1 and Table 5-2). Describe any cross-regional efforts that are addressed. Examples of potential actions for the Grande Ronde, Tucannon, Walla Walla, Umatilla, and John Day subbasins, including comparisons and timelines, are provided (Table 5-3).

Table 5-1. Numerical codes for monitoring and evaluating supplementation research strategies. Strategies are described in Section 4.3 of the Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin; codes reflect the section number in the Framework document.

Translocation		Hatchery		Outplanting	
4.3.1	Adult Translocation	**4.3.2**	Larval and Juvenile Rearing	**4.3.3**	Larval and Juvenile Outplanting
4.3.1.1	Adult Survival	**4.3.2.1**	Broodstock survival	**4.3.3.1**	Larval Survival and Growth
4.3.1.2	Adult Spawning	**4.3.2.2**	Fertilization to hatch survival	**4.3.3.2**	Larval Abundance and Distribution
4.3.1.3	Larval Survival and Growth	**4.3.2.3**	Hatch to outplant survival	**4.3.3.3**	Larval and Juvenile Outmigration
4.3.1.4	Larval Abundance and Distribution			**4.3.3.4**	Adult Returns
4.3.1.5	Larval and Juvenile Outmigration				
4.3.1.6	Adult Returns				

Table 5-2. Comparison chart displaying all potential comparison pairs of the different supplementation and research strategies. T = Translocation; larval/juvenile lamprey from translocated adults. H = Hatchery; larval/juvenile lamprey born and reared in a hatchery environment. O = Outplanting; larval/juvenile lamprey hatchery reared and released into the natural environment. C = Control; larval/juvenile lamprey born and rearing in the natural environment.

Comparison	Translocation	Hatchery	Outplanting	Control
Translocation	TxT	HxT	OxT	CxT
Hatchery	TxH	HxH	OxH	CxH
Outplanting	TxO	HxO	OxO	CxO
Control	TxC	HxC	OxC	CxC

Table 5-3. Lamprey supplementation research actions over the next 5-10 years within the Umatilla River Subbasin. See Table 5-1 and Table 5-2 for the monitoring and evaluation (M&E) and comparison codes.

Location	Supplementation Research Strategy								Start Timeline	End Timeline
	Adult Translocation (T)		Hatchery Rearing (H)		Larval and Juvenile Outplanting (O)		Control (C)			
	M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison		
Mainstem Umatilla River	4.3.1.1 – 4.3.1.5	TxC TxH TxT	--	--	--	--	--	--	Ongoing	1-3 years 5+ years 1-3 years
Upper Maxwell Diversion	--	--	--	--	4.3.3.1 - 4.3.3.2	OxH OxO	--	--	Ongoing	1-3 years 1-3 years

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Appendix A. INVENTORY OF ARTIFICIAL PROPAGATION FACILITIES AND RIVERINE NURSERY AREAS ABOVE MCNARY DAM

ADULT TRANSLOCATION SITES – GRANDE RONDE SUBBASIN

Subbasin	Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Grande Ronde River	Minam StateRecreation Area Campground	Wallowa River, Rkm 13.4, accessed via Minam State Park Road Lat: 45.636264° Long: -117.728667°	Oregon State Parks	Riffle, pool and glide habitats adjacent; easy access from public road/land	Currently extirpated above Troy, OR	Redd surveys planned upstream and downstream of site; utilize existing screw trap efforts (ODFW or NPT); establish long-term juvenile sediment sampling index sites in lower Wallowa River	CTUIR will focus adult translocation in the Grande Ronde River basin. Adults have been released at this site since 2011; plans are to continue releases and monitor spawning success and population trend through time.
Grande Ronde River	Starkey/Upper Grande Ronde River above La Grande, OR	Grande Ronde River, Rkm TBD, accessed via Grand Ronde River Road/NF-51 Lat: TBD Long: TBD	Private or USFS, depending on location chosen	Pool-riffle complexes; high in system; easy access from public road adjacent to river	Currently extirpated above Troy, OR	Redd surveys planned upstream and downstream of site; utilize existing screw trap efforts (above La Grande and in lower river near Troy), establish long-term juvenile sediment sampling index sites in Grande Ronde River below site	CTUIR will focus adult translocation in the Grande Ronde River basin. CTUIR will initiate adult releases and monitor spawning success and population trend through time.
Grande Ronde River	Catherine Creek near Union, OR	Catherine Creek, Rkm TBD, accessed via SR 203, SR 237 or Cove Highway Lat: TBD Long: TBD	Private - agricultural	Low gradient sinuous channels through agricultural matrix, with fine sediments.	Currently extirpated above Troy, OR	Sediment sampling could be used to document any existing population and potential for natural recolonization in tributary basin of Grande Ronde River.	Control site in basin without supplementation.
Grande Ronde River	Lookingglass Creek	Lookingglass Creek, Rkm TBD, accessed via Lookingglass Road Lat: TBD Long: TBD	ODFW	Confined riffle-run channel affected by road development and other adjacent structures, including the Lookingglass Creek Hatchery.	Currently extirpated above Troy, OR	Sediment sampling could be used to document existing population and potential for natural recolonization in tributary basin of Grande Ronde River.	Control site in basin without supplementation.

JUVENILE RELEASE/REARING SITES – WALLA WALLA AND TUCANNON SUBBASINS

Subbasin	Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Walla Walla River	Touchet River	Touchet River, Rkms TBD, access via Ice Harbor Drive/SR 124 and/or S Touchet Road Upper Touchet (above Dayton), approx.: Lat: 46.278088° Long: -117.953322° Lower Touchet (below Prescott), approx.: Lat: 46.294721° Long: -118.340461° Mouth at Walla Walla River: Lat: 46.034036° Long: -118.683803°	National Forest above Dayton, WA (Asotin County); private below, would need to obtain landowner permission in the lower river.	Upper Touchet River – above Dayton, WA (Asotin Co.): steelhead habitat that may be representative of typical lamprey spawning habitat; unconfined channel that meanders through a matrix of forest and lightly developed land. Lower Touchet River – below Prescott, WA: channel remains relatively unconfined and meanders through an agricultural and partially undeveloped landscape; anticipate finer sediments, need more baseline conditions assessment.	Currently extirpated	Fisheries biologists believe there is an existing screw trap somewhere in the area– additional details/research needed. Objective would be to monitor the upper and lower river simultaneously, and attempt to distinguish between the pro-larvae and larger larvae outplanting strategies.	CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Walla Walla system. For the Touchet River, two different approaches to juvenile supplementation are proposed with the goal of evaluating differences in cost-benefit. These two strategies are: (1) outplanting pro-larvae, with minimal artificial rearing investment, higher up in the system, and (2) outplanting larger larvae, reared in the artificial environment for 1-2 years, lower in the system.
Walla Walla River	Mill Creek	Mill Creek above Bennington Lake Diversion, Rkm TBD, access via Mill Creek Road Bennington Lake Diversion: Lat: 46.079697° Long: -118.254212°	Private up to National Forest boundary; would need to obtain landowner permission to access private portion of river.	Mill Creek is not channelized and includes meandering areas and backwater habitats above the Bennington Lake diversion.	Currently extirpated	Fisheries biologists believe there is an existing screw trap somewhere in the area– additional details/research needed. If used as a control site, monitoring would focus on the existing population and could be used to identify natural recolonization from adjacent streams as the population rebounds.	CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Walla Walla River system. For Mill Creek, the strategy will focus on outplanting pro-larvae with minimal artificial rearing investment above Bennington Lake diversion. An alternate strategy may be to use Mill Creek as a control system without outplanting. This may be a good strategy for Mill Creek because it is anticipated to be less productive than other streams in the Walla Walla River subbasin.
Walla Walla River	South Fork Walla Walla	South Fork Walla Walla River near existing acclimation pond, Rkm TBD, access via South Fork Walla Walla River Road Acclimation Pond: Lat: 45.859123° Long: -118.222371°	Likely private unless outplanting occurs on the CTUIR/BPA property (acclimation pond) or upstream in National Forest	River is somewhat confined in narrow valley, with existing road and low levels of land development.	Currently extirpated	There are three known existing traps in the mainstem Walla Walla River below the confluence between the North and South Forks that are operated by CTUIR and could be used to monitor fish outmigration from the South Fork Walla Walla River. One of these traps is located where Walla Walla River Road/US 603 crosses the river. Another is located where Old Milton Highway/CO 448 crosses the river. The third is located off US 12 approximately 9 km upstream from the mouth of the Walla Walla River.	CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Walla Walla River system. For South Fork Walla Walla River, the strategy will focus on outplanting pro-larvae with minimal artificial rearing investment above Milton-Freewater, OR, and up to the vicinity of the existing South Fork Walla Walla River Acclimation Pond.
Walla Walla River	Lower mainstem Walla Walla	Walla Walla River between confluence with Touchet River and mouth at Columbia River, Rkm TBD, access via US 12 Confluence with Touchet River: Lat: 46.034036° Long: -118.683803° Mouth at Columbia River: Lat: 46.060571° Long: -118.910810°	Private	Fine sediments and backwater conditions in lower river	Currently extirpated	An existing screw trap operated by CTUIR is located off US 12 approximately 9 km upstream from the mouth of the Walla Walla River.	CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Walla Walla River system. For the lower Walla Walla River, the strategy will focus on outplanting larger larvae, reared in the artificial environment for 1-2 years.

Subbasin	Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Tucannon River	Tucannon River	Tucannon River near Wooten State Fish Hatchery, Rkm TBD, access via Tucannon Road Wooten State Fish Hatchery: Lat: 46.320471° Long: -117.662954°	ODFW, private, or National Forest	Fine sediments are only present in the lowest reach of this river; in general, this basin has larger substrate.	Small remnant population, in decline and inadequate population replacement; limited captures in screw trap.	There is an existing screw trap in the lower river. Monitoring in the lower river may also include sediment sampling. Lower river monitoring could establish a baseline until outplanted juveniles higher in the system work their way down with time after outplanting.	CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Tucannon River subbasin. Only one outplanting strategy is proposed in this basin due to limited geography and habitat conditions (larger substrates). The strategy will focus on outplanting larger larvae, reared in the artificial environment for 1-2 years. A targeted survey will be performed to identify appropriate outplanting locations. Outplanting locations will be targeted to match steelhead habitat and/or existing lamprey spawning grounds, if they can be identified.

PROPAGATION FACILITIES – WALLA WALLA, TUCANNON, AND GRAND RONDE SUBBASINS

Subbasin	Site	Location	Owner	Current Use	Available Resources	Facility Features	Monitoring Opportunities	Other Benefits	Potential Concerns
Walla Walla River	South Fork Walla Walla Acclimation Pond	South Fork Walla Walla River Rkm 8.49 Lat: 45.860102° Long: -118.221686°	CTUIR/BPA	Adult holding and spawning of Spring Chinook; hold lamprey (May-Nov) for translocation and propagation programs before moving to Umatilla basin.	5 Holding ponds (one dedicated for lamprey currently); potential to expand for larval incubation and rearing with hatchery addition anticipated in 2014	Planned expansion as a hatchery in 2014 for incubation and rearing of Spring Chinook; excellent water quality/temp	Propagation and rearing studies, adult behavior experiments	Potential use for artificial propagation and outplanting, evaluating strategies for juvenile outplanting, and/or larval rearing. Will be expanded to become hatchery facility.	Space limitations – lamprey program may be expelled; two construction alternatives for hatchery expansion – one includes lamprey, one does not.
Walla Walla River	Water and Environmental Center (WEC) Laboratory at Walla Walla Community College (WWCC)	Near confluence of Titus Creek and Mill Creek Lat: 46.077803° Long: -118.274385°	WWCC	This new facility is oriented toward lamprey and mussels applied research, but is also available for a variety of other fishery research uses, including tagging of wild salmon.	A multi-lateral agreement (MLA) is in place between WWCC and CTUIR for office space and laboratory use.	Facility includes: circular ponds; raceways; aquatic laboratory facilities; and holding, spawning and early life history rearing facilities.	Laboratory resources are available for adult holding prior to spawning, incubation and early rearing. Juveniles reared at the lab can be outplanted into the upper and lower Walla Walla River, Mill Creek, and the Touchet River.	Abundant and diverse water sources (City water, Titus Creek runs through facility and may be tapped, Mill Creek runs adjacent to facility, existing plans to develop a new deep well).	N/A
Tucannon River	Tucannon Hatchery	Tucannon River Lat: 46.320471° Long: -117.662954°	WDFW	Spring Chinook, summer steelhead, rainbow trout	UNKNOWN	Potential use for adult holding, spawning and/or rearing	Potential to outplant in adjacent habitat reaches, and then monitor movement and/or return.	TBD	State-owned; no current agreement in place for lamprey use.
Grande Ronde River	Lookingglass Hatchery	Lookingglass Creek Lat: 45.731528° Long: -117.864519°	ODFW	Spring Chinook	Adult holding and circular ponds, rearing ponds	Potential use for adult holding, spawning and/or rearing	Potential to outplant in adjacent habitat reaches, and then monitor movement and/or return. Existing screw trap just downstream of the hatchery.	TBD	State-owned; no current agreement in place for lamprey use.

ADULT TRANSLOCATION SITES – YAKIMA SUBBASIN

Assessment Unit	Site	Location	Property Owner	Site Features	Population Status (2009-2012 Yakama Nation surveys)	Monitoring Opportunities	Supplementation/Research Goals
Upper Yakima	Wenas	Wenas Creek near S Wenas Rd, Rkm 5.8 Lat: 46.713113° Long: -120.541115°	Private (rural)	Potential research site – single-thread channel. Very low flows, Wenas Creek over-allocated and highly regulated at dam by water users	Currently extirpated	Need	Need
	Taneum	Taneum Creek off W Taneum Rd, Rkm 5.0 Elk Meadows Lat: 47.084974° Long: -120.757281°	Rocky Mtn. Elk Foundation Lands	Single thread, low gradient channel through cattle/elk pasture at canyon exit. Access off W. Taneum Rd via Thorp Cemetery Rd., exit off I-90 via S. Thorp Hwy	Currently extirpated	Instream flow needs. Flow-based geomorphic channel change analysis.	Downstream a short distance, KRD spillway flows into Taneum Cr. Potential flow-management/analysis site upstream vs. downstream. USBR/SOAC, KRD, and other irrigation district support/coordination would be required.
	Teanaway	Teanaway River off W Fork Teanaway Rd, Rkm 20.1 Lat: 47.256387° Long: -120.897924°	American Forest Land Company – Forest Service	Single thread, moderate gradient channel through ponderosa pine and doulas fir forest. Access via W. Fork Teanaway Rd. Stream in reasonable condition. Some impacts from prior timber land use. Some sediment loading from upstream slides.	Unknown	Need	Need
	Cle Elum	Cle Elum River downstream of Cle Elum Dam, Rkm 12.0 Lat: 47.244197° Long: -121.067785°	Need	Large single-thread river immediately downstream from spillway. Access via Cle Elum Dam.	Small population verified in 2012	Potential to collect adults at Cle Elum spillway. Potential to configure macropthalmia collection system at, above or below spillway if lamprey are restored to upper Cle Elum (above lake).	Cle Elum River core monitoring station
Middle Yakima	Lower Ahtanum	Ahtanum Creek off Goodman Rd, Rkm 4.0, Union Gap area & La Salle Lat: 46.547672° Long: -120.495850°	Mixed: private, school	Single thread, accessible via Goodman Rd, S. 42nd Ave and S. 62nd Ave.	Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek	Some electrofishing completed at site to verify population. Additional sampling possible	Population supplementation and document canal entrainment
	Mid Ahtanum	Ahtanum Creek off S 79th Ave, Rkm 16.5 Lat: 46.541407° Long: -120.610602°	Mostly private	Single thread, accessible via Lynch Ln., Carson Rd., Ahtanum Rd., Marks Rd., Stanton Rd., Wiley Rd., S. 90th Ave., and S. 74th Ave.	Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek	Need	Population supplementation and document canal entrainment
	Upper Ahtanum	Ahtanum Creek off Lynch Lane, Rkm 29.9 Tampico - At forks of N. Fk. And S. Fk Ahtanum Lat: 46.528279° Long: -120.747768°	Mixed private – forest land	Braided channel through partially wooded floodplain. Access primarily from S. Fork Ahtanum Rd., south from Tampico.	Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek	Need	Population supplementation and document canal entrainment
Lower Yakima	Simcoe Creek	Simcoe Creek off Barks Rd, Rkm 2.0, White Swan Lat: 46.386613° Long: -120.628231°	Mixed: Tribal, private	Single thread, intermittent. Accessible mostly at bridges: e.g. White Swan Rd., Wesley Rd.	Currently extirpated	Need	Population supplementation
Naches-Tieton	Lower Naches	Naches River near Cowiche Diversion, Rkm 3.8 Mapped as 40th Ave Exit Lat: 46.626020° Long: -120.560948°	Private (rural)	Side Channel floodplain habitat and ponds on south (R) bank of Naches River.	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Population supplementation, document canal entrainment, and address flow management impacts

Assessment Unit	Site	Location	Property Owner	Site Features	Population Status (2009-2012 Yakama Nation surveys)	Monitoring Opportunities	Supplementation/Research Goals
	Mid Naches	Naches River at S Naches Rd bridge, Rkm 21.7 Naches, Wa, S. Naches Rd. Lat: 46.724084° Long: -120.699823°	Private-rural and quasi-municipal (Naches)	Channel downstream from S. Naches Rd. bridge is single thread with multiple side channels. Accessible off S. Naches Rd., Lewis Rd. immediately south of US -12	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Population supplementation, document canal entrainment, and address flow management impacts
	Upper Naches	Naches River off SR 410, Rkm 38.9 Lat: 46.789604° Long: -120.871210°	Mixed private – national forest	Higher gradient, coarser substrate, cold water – may be less suitable to Pacific lamprey.	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Population supplementation, document canal entrainment, and address flow management impacts
Satus-Toppenish	Lower Satus	Satus Creek at Plank Road, Rkm 12.8 Lat: 46.290402° Long: -120.221004°	Mixed, Yakama Nation and private	Lower Satus Creek is a low-gradient single-thread channel located within the historic Yakima River floodplain, bisecting irrigated land, shrub-steppe uplands, and wetlands located in the Satus Wildlife Area. Accessible through wildlife area and public roads.	Small population verified in lower Satus Creek	Ease of access to Yakama Nation lands at Satus Cr. – Yakima R. confluence makes for opportune juvenile, macropthalmia and adult monitoring location.	Population supplementation & translocation evaluation site. Potential juvenile release sites in Satus Wildlife Area and adjacent WDFW lands.
	Upper Satus	Satus Creek at Rd 148, Rkm 31.0 Lat: 46.255659° Long: -120.394332°	Yakama Nation Forest Lands	Single thread, intermittent. Accessible off US-97	Currently extirpated	Need	Population supplementation
	Lower Toppenish	Toppenish Creek near Lateral A Rd, Rkm 37.3 Lat: 46.325093° Long: -120.481040°	Mixed: Private, Federal (e.g. USFWS)	Lower Toppenish Creek is a low-gradient single-thread channel located within the historic Yakima River floodplain, bisecting irrigated land, shrub-steppe uplands, and wetlands.	Currently extirpated	Existing trapping for salmonids in lower Toppenish. Could augment with lamprey traps.	Population supplementation and document canal entrainment
	Upper Toppenish	Toppenish Creek at Fort Rd, Rkm 56.8 Lat: 46.375283° Long: -120.641224°	Mixed: Tribal, private, forested	Substantial areas of restoration, access to these sites and potentially others. Mostly open space shrub-steppe or agriculture	Currently extirpated	Need	Population supplementation and document canal entrainment

JUVENILE RELEASE/REARING SITES – YAKIMA SUBBASIN

Assessment Unit	Site	Location	Property Owner	Site Features	Population Status (2009-2012 Yakama Nation surveys)	Monitoring Opportunities	Supplementation/Research Goals
Upper Yakima	Wenas Creek	Wenas Creek near S Wenas Rd, Rkm 5.8 Lat: 46.713113° Long: -120.541115°	Need	Research site?	Currently extirpated	Need	Supplement local population, evaluate survival, growth, density, dispersion and habitat use
	Lower Wilson	Wilson Creek off Thrall Rd, Rkm 2.0 Lat: 46.930942° Long: -120.503684°	Need	Need	Currently extirpated	Need	Need
	Lower Reecer	Reecer Creek off W Dolarway Rd, Rkm 0.25 – 1.6 Lat: 46.999895° Long: -120.575643°	Need	Need	Unknown	Need	Need
	Holmes Rearing Ponds	Yakima River off Oneil Rd, Rkm 260.7 Lat: 47.041405° Long: -120.628567°	Need	Good habitat for juvenile rearing, proximal to spawning habitat, coho spawning channel located above the rearing ponds	Currently extirpated	Need	Supplement local population, evaluate survival, growth, density, dispersion and habitat use
	Gladmar Park Side Channels	Yakima River off Gladmar Park Rd, Rkm 262.7 Lat: 47.050235° Long: -120.644894°	Need	Need	Small population verified in one location near Cle Elum in 2012	Need	Need
	Teanum Creek	Taneum Creek off W Taneum Rd, Rkm 10.1 Lat: 47.090062° Long: -120.813649°	Need	Need	Small population verified in one location near Cle Elum in 2012	Need	Supplement local population, evaluate survival, growth, density, dispersion and habitat use
	Church Property	Yakima River off SR 10/Airport Rd, Rkm 291.5 Lat: 47.172134° Long: -120.857112°	Need	Need	Small population verified in one location near Cle Elum in 2012	Need	Need
	Easton Side Channels	Yakima River off Shady Glen Dr, Rkm 322.0 Lat: 47.222670° Long: -121.128635°	Need	Need	Small population verified in one location near Cle Elum in 2012	Need	Need
	Cle Elum Side Channels	Yakima River off Iron Horse Trail, Rkm 306.6 Lat: 47.174812° Long: -121.009934°	Need	Need	Small population verified in one location near Cle Elum in 2012	Need	Supplement local population, evaluate survival, growth, density, dispersion and habitat use
Middle Yakima	Upper Ahtanum – Forks	Ahtanum Creek off Ahtanum Rd, Rkm 39.4 Lat: 46.523441° Long: -120.853438°	Need	Need	Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek	Need	Need
	Lower Ahtanum	Ahtanum Creek off McCullough Rd, Rkm 13.2 Lat: 46.551420° Long: -120.579333°	Need	Need	Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek	Need	Need
	Lower Ahtanum – La Salle	Ahtanum Creek off Goodman Rd, Rkm 4.3 Lat: 46.547440° Long: -120.498270°	Need	Need	Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek	Need	Need
Lower Yakima	Wapato Dam	Yakima River downstream of Wapato Dam, Rkm 175.0 Lat: 46.519073° Long: -120.471495°	Need	Need	Presence verified	Need	Need
Naches-Tieton	Stills Pond by Gleed	Naches River off McCormick Rd, Rkm 9.4 Lat: 46.650052° Long: -120.611270°	Need	Need	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Need
	Naches Trout Hatchery Side Channel	Naches River off Young Grade Rd, Rkm 10.5 Lat: 46.654728° Long: -120.627931°	Need	Need	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Need
	Eschbach Park	Naches River off S Naches Rd, Rkm 13.2 Lat: 46.672399° Long: -120.646605°	Yakima County	Good habitat for juvenile rearing, good access from S Naches Rd	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Supplement local population, evaluate survival, growth, density, dispersion and habitat use
	Cowichie Creek Mouth	Cowiche Creek off Clover Ln, Rkm 0.4 Lat: 46.628131° Long: -120.573250°	Need	Need	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Need

Assessment Unit	Site	Location	Property Owner	Site Features	Population Status (2009-2012 Yakama Nation surveys)	Monitoring Opportunities	Supplementation/Research Goals
	40th Ave Exit Side Channel	Naches River near 40th Street, Rkm 3.0 Lat: 46.624622° Long: -120.550643°	Need	Need	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Need
	Naches River Side Channel	Naches River off Lewis Rd, Rkm 20.8 Lat: 46.719707° Long: -120.692676°	Need	Need	Small population verified in Naches River and in Yakima River near mouth of Naches River	Need	Need

PROPAGATION FACILITIES – YAKIMA SUBBASIN

Assessment Unit	Site	Location	Owner	Current Use	Available Resources	Facility Features	Monitoring Opportunities	Other Benefits	Potential Concerns
Upper Yakima	Cle Elum Hatchery	Yakima River Rkm 303.0	Yakama Nation	Spring Chinook rearing	Existing raceways not being utilized, spawning channel, natural side channel for potential rearing	Water temperature modulation, high water quality	Propagation; rearing and feeding of larvae; Tests on adult and juvenile fish behavior	Located high in the watershed, good rearing habitat available in adjacent side channel, potential source of pheromone attraction into prime spawning reach	Potential interactions between spring Chinook and lamprey.
	Holmes Acclimation Ponds	Yakima River Rkm 260.7	Yakama Nation	Floodplain mitigation – pasture, residence	Currently being developed for coho program and has both spawning channels and rearing ponds	50 ac land area. Potential 12.6 ac available for facility development, approx. 4 ac wetland/floodplain meander scroll	Test rearing potential of salmon acclimation ponds; spawning recruitment relationship	Water rights on property acquired. Grant applications suggested water is to go to instream flow. Convert some to fish production?	Can coho and lamprey program goals both be achieved at this location?
Lower Yakima	Marion Drain	Yakima River Rkm 134.4	Yakama Nation	None	Current design includes construction of buildings and ponds for lamprey propagation program	Existing well water on site, infiltration gallery proposed	Collection of macropthalmia and returning adults	Potential for rearing in adjacent riverine wetland areas; proximal to Yakama Nation office	Potential attraction of adults towards Marion Drain; requires investment and development of infrastructure.
	Prosser Hatchery	Yakima River Rkm 74.4	Yakama Nation	Kelt re-conditioning, Spring/ Summer/ Fall Chinook, Coho	Adequate space to implement proposed upgrades for lamprey propagation; existing spawning channel; sediment pond available for rearing; experienced staff on site	Surface and well water	Propagation; rearing and feeding of larvae; Tests on adult and juvenile fish behavior; effects of contaminants	High water quality; efficiency - potential to re-use sturgeon water; adjacent stream potentially available for modification as rearing habitat	Low in watershed; lack of good spawning and rearing habitat in immediate vicinity
	Yakima Groundwater Recharge Channel	Yakima River Rkm 182.4	City of Yakima	None	City of Yakima is studying feasibility of running treated water from a treatment facility into a constructed channel for groundwater recharge	Surface water (through inlet)	Test rearing potential of restored side channels	Great pilot site to assess survival/movement over multiple years	Can lamprey survive year round in the restored side channel?

Appendix B. Comments on Previous Framework Draft by ODFW, WDFW, and IDFG

1 Introduction

1.1 Background

Pacific lamprey (*Entosphenus tridentatus*) is an anadromous fish species that has occupied freshwater rivers of western North American for the last 350 million years. These ancient fish are distinct from other fish within their range – lampreys are jawless, have no scales, and lack paired fins. Since pre-historic times, Native Americans have utilized lamprey for important subsistence, ceremonial, and medicinal purposes. Pacific lamprey are also important ecologically because they provide marine-derived nutrients to the freshwater riverine environment and the aquatic and terrestrial food web (Beamish 1980; Brown et al. 2009) and provide a high-calorie prey source for various marine and freshwater species.

Today, Pacific lamprey return to the Columbia River Basin (CRB) at a fraction of their historical numbers; daytime counts of adult Pacific lamprey at Bonneville Dam have declined from an estimated 400,000 in the 1960's and 1970's to lows of approximately 20,000 in 2009 and 2010 (CRITFC 2011a). At Willamette Falls, a traditional harvest location on the Willamette River, estimates of harvest declined from about 400,000 in the 1940's to about 4,000 in 2001 (Ward 2001).

Recent studies on this alarming trend of Pacific lamprey decline in the CRB cite the construction of hydroelectric and flood control dams, irrigation and municipal water diversions, habitat degradation and loss, poor water quality, excessive predation, contaminants, ocean cycles, prey-species availability, and targeted chemical eradication as major contributors (Close et al. 1995; CRITFC 2011a; Luzier et al. 2011; Murauskas et al. 2012). Despite recent implementation of passage improvements at mainstem and tributary dams, habitat improvements, and adult lamprey translocation efforts, (CRITFC 2011a; Luzier et al. 2011; Ward et al. 2012), adult returns remain relatively low and spatial distribution is increasingly limited to the lower portions of the CRB. Pacific lamprey have been extirpated from many subbasins in the interior CRB (Close et al. 1995; USFWS 2007; Luzier et al. 2011). Considering their low numbers and their apparent value to the ecological health of the CRB, the time to address and recover lamprey stocks is now. Ecological effects include reductions in marine derived nutrients and the potential prey base.

The absence of lamprey in the interior CRB also represents a significant cultural loss (Close et al. 1995). . The decline of lamprey has a number of cultural impacts, including: (1) loss of tribal heritage, (2) loss of fishing opportunities in traditional areas, and (3) necessity to travel great distances to the lower CRB for ever-decreasing lamprey harvest opportunities. As a consequence of reduced or eliminated harvest in the interior CRB, young tribal members are losing historically important legends associated with lamprey because they have not learned harvest and preparation methods.

Because of the long, complex, and poorly understood life history of Pacific lamprey, existing environmental conditions in the CRB, and scarcity of data, it remains unclear how quickly lamprey will recolonize extirpated streams, especially in the upper reaches of the CRB. Passage for adult lamprey is low (adult passage at mainstem dams hovers around 50%; Keefer et al. 2012), so natural recolonization of upper reaches may require extensive time, perhaps decades, considering that lamprey life history spans approximately 10 years. Efforts to utilize alternative management strategies such as supplementation to aggressively maintain and reestablish Pacific lamprey in specific locations have recently increased.

-unsure about upstream recolonization rates, passage is bad (and there are other issues), effort is occurring to improve, many upstream locations have no lamprey, difficult to assess passage issues for upstream/downstream movement, this may require short-term actions to accurately assess issues—which will require fish, also in the long-term recolonization/seeding of streams will require fish—

supplementation—both of these actions will require fish,--(1) propagation of fish, (2) translocation of fish, (3) monitoring and evaluation strategies
This document is a "framework" for monitoring and evaluating potential short and long-term supplementation approaches
Goal of the framework—develop a RME framework for implementing short and long-term supplementation approaches to (1) improve status in certain subbasins, maintain presences, bypass difficult migration corridors, assess upstream movements = **Translocation**, (2) maintain presence, assess passage/habitat issues, develop release strategies, = **release of art. prop. fish**, (3) improve status, significantly increase larval/juvenile output, recolonize extirpated streams, = **release of art. prop./full scale hatchery fish**

1.2 Supplementation Approaches

Pacific lamprey supplementation is defined here as an interim production facilitation strategy that supports region-wide efforts to reduce known threats to self-sustaining (natural) productivity. Facilitation actions include either the translocation of surplus adults from one watershed to a watershed with poor adult recruitment, or artificial propagation of larvae (ammocoetes) and juveniles (macrophthalmia) in a hatcheryfor release into a watershed that is underseeded. . . Section 5 of this Supplementation Research Framework describes guidance on how supplementation can be incorporated into subbasin-specific plans for lamprey recovery. Initial trials and accompanying monitoring and evaluation activities will better inform fish managers on how to use supplementation as a restoration tool.

1.2.1 Adult Translocation

Translocation is defined as the collection of adult Pacific lamprey from one location and transport for release into another location where they are extirpated or scarce (Ward et al. 2012). Translocation has been successfully implemented by several treaty tribes in the Mid-to Upper Columbia River and Snake River basins, though well-designed post-reintroduction monitoring programs are imperative to documenting success (Close et al. 2009; Ward et al. 2012). In the short term, these efforts are designed to increase larval abundance and maintain a larval connection, through pheromone signals, to returning spawning adults. Translocation is not designed to be a long-term restoration strategy but rather a short-term, stop-gap measure to maintain lamprey presence while known limiting factors and critical uncertainties are addressed. Although monitoring and evaluation of these efforts has yielded substantial information about effectiveness and has contributed to critical life history information for lamprey, it remains unclear whether efforts will result in increased adult returns in the future.

1.2.2 Larval Outplanting

A second strategy to improve the status of Pacific lamprey within a subbasin is to outplant larval Pacific lamprey into targeted areas. This requires successful collection, holding, spawning, incubation, and rearing of Pacific lamprey in a hatchery environment. It also requires the identification of suitable locations for the release of larval lamprey. Research on propagation of lamprey in hatchery settings began in the 1980s in Finland to address declines of an important commercial fishery. Over time, the success of lamprey propagation progressed to a level in Finland where fisheries managers were able to produce 17 million larvae per year for release into the Perhonjoki River between 1997 and 2009 (CRITFC 2011b). Unfortunately, very little post-release monitoring has been conducted in Finland or other countries.

1.2.3 Juvenile Outplanting

The third strategy to improve the status of Pacific lamprey within a subbasin is to outplant older larval and juvenile Pacific lamprey into targeted areas. Protocols for rearing larvae for extended periods of time (years) to produce juvenile are lacking. In addition, the benefits of rearing fish to the juvenile stage may be difficult to assess because fish ready to immediately transform and migrate may not release the pheromones thought to attract returning adults

1.3 Research and Monitoring Needs

Because of the low returns of lamprey and the assumption that successful natural recolonization will require a long-term strategy, CRB Tribes and regional agencies have increasing interest in beginning research on the use of artificially propagated larval and juvenile lamprey in short and long-term supplementation efforts (CRITFC 2011a; USFWS 2012). In the short term, artificially produced larvae and juveniles would be used as a research tool to evaluate critical uncertainties and limiting factors of the species as well as its potential use in supplementing the locally extirpated populations. Many important questions regarding the biology of Pacific lamprey remain unanswered to date, such as the age classes of all three life stages (ammocoetes, macrophthalmia, adults), the natural annual growth and survival rates of larvae, and the general migration behavior of larvae before transforming to macrophthalmia. All these questions are absolutely essential in developing a life stage survival model for Pacific lamprey which will lead to better conservation and management of the species. Through the use of artificial production and genetics analysis tools, we have the opportunity to make incredible advancements in these unanswered biological questions.

Besides laboratory use, some larval lamprey will be established in extirpated streams to evaluate important questions related to the viability of the local population (i.e. limiting factors, passage barriers, pheromones). If larvae and juveniles are absent or functionally absent in these extirpated or near extirpated regions, there is virtually no way to identify and resolve the region-specific threats for the species. For instance, if irrigation diversions are a potential serious threat to migrating larval and juvenile lamprey, without the presence of larval lamprey either in the system or alternatively in lab settings, nothing can be effectively tested and evaluated to seek mitigation or resolution of the problem.

Artificially produced lamprey may also be used to supplement CRB lamprey by dramatically increasing larval/juvenile numbers, albeit in the short-term, with the goal of effectively compensating for the natural declines in adult returns. By doing this, we will not only allow the species to function its natural ecological purposes in these extirpated streams and rivers, but it will also provide an opportunity to evaluate important overarching biological questions, such as stream selection criteria for returning spawning adults. For example, we can effectually evaluate whether these larvae can attract upstream migrating spawning lamprey and contribute to increased recruitment, which is a vital management question.

Finally, if Pacific lamprey numbers continue to decline in the near future, there may be a need for conservation hatchery to protect the viability of the species and its remaining genetic diversity. The techniques and methods required for a successful conservation hatchery do not develop in a short time span, especially for an exceptionally cryptic and surreptitious species such as lamprey. It is important that we begin learning and advancing conservation hatchery techniques and methods as soon as possible, so that they are available when needed. This will also help us advance our knowledge on many of the important existing knowledge gaps in biology.

Supplementation of Pacific lamprey has potential benefits and risks. Taking no action also has risks. Potential risks of lamprey supplementation are not all known, but may include disruption of any connection between stock structure and particular subbasins (genetic risk), moving fish to areas with substantial limiting factors, introduction of pathogens and disease, and decreases in abundance from donor areas. Risks of taking no action include maintaining and increasing areas of extirpation, enhancing potential for "Founders Effects" in watersheds with low return rates, continued loss of ecological role served by lamprey, and continued loss of cultural heritage.

Before supplementation of Pacific lamprey with artificially propagated fish can be used, it is important to develop and assess this type of strategy to the extent possible. Preliminary work includes (1) the development of basic propagation and rearing techniques for lamprey, (2) an assessment of the cost/benefits of releasing artificially propagated fish into the environment, and (3) the development of consistent and standard protocols for monitoring and evaluating artificial propagation releases. In short, before supplementation with artificially propagated lamprey can be utilized, basic research needs to occur to (1) refine existing supplementation methods (translocation), (2) develop new methods (artificial propagation), (3) assess feasibility of artificial propagation, (4) identify existing facilities and prospective new facility locations within the CRB to support development and implementation of artificial propagation, (5) identify natural riverine features within the CRB to provide spawning and rearing sites for artificially propagated pre-adult Pacific lamprey, and (6) develop and refine research, monitoring, and evaluation (RME) methods for long-term supplementation strategies. It is important to understand the inherent risks (generally associated with genetics) of supplementation, and be mindful of two important concepts: "do no harm" and "risk management" for both the donor and recipient areas.

For these reasons, a significant planning effort, led by the CRITFC tribes, has been undertaken by regional fishery managers to guide the use of Pacific lamprey supplementation as a short-term research and long-term restoration tool in the CRB. Three distinct, yet inter-related products will be developed over time:

1. Regional Framework for Pacific Lamprey Research, Monitoring, Evaluation and Reporting in the Columbia River Basin (RME Framework) which will encompass a broad scope of ongoing and needed research, monitoring and restoration activities;

2. Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin (Supplementation Research Framework) which will focus specifically on coordination and continuity in research and reporting of information associated with emerging and active lamprey restoration strategies such as propagation, reintroduction, translocation, and augmentation; and

3. Pacific Lamprey Restoration and Supplementation Research Subbasin Plans (Subbasin Supplementation Research Plans) which will summarize ongoing and proposed lamprey restoration activities in CRB subbasins within the context of the RME Framework and the Supplementation Research Framework described above such that consistency and continuity of important methods, analysis and reporting formats can be achieved.

This document focuses on the Supplementation Research Framework and a template for Subbasin Supplementation Research Plans (Items 2 and 3), which will be integral components of the larger RME Framework (Item 1). Collectively, these documents are anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan (CRITFC 2011a), (2) USFWS Conservation Agreement for Pacific Lamprey (Lamprey Conservation Agreement; USFWS 2012) and (3) Northwest Power and Conservation Council (NPCC) Fish and Wildlife Program (NPCC 2009). In total, each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be developed in years 2016-2017.

2 Pacific Lamprey Genetic Structure

Influence on genetic integrity is a primary concern for all supplementation efforts, but the field of regional genetic study of Pacific lamprey is still in its infancy. Although much more work is needed to better understand lamprey genetics, compared to salmonids, lamprey appear to exhibit low genetic differentiation among regional stocks, and its population structure reflects a single broadly distributed population across much of its range in the Pacific Northwest (e.g., Goodman et al. 2008, Spice et al. 2012). The need for genetic diversity in artificial salmonid propagation and rearing programs has been well documented. With salmon, collecting broodstock across the entire run is advised to maintain the genetic diversity of supplemented populations (Cuenco et al. 1993; Bilby et al. 2003). Genetic heterogeneity among a population's individuals is a basic driving principle for sustainability to reduce the potential for deleterious population effects, including inbreeding depression. This genetic principle is applicable to all species, including Pacific lamprey, and provides organisms the ability to exhibit a selective response to environmental variability.

Another well-established premise for artificial propagation in salmonids is the use of locally-adapted broodstock. Such local stock may be comprised of individuals that are adapted to specific conditions in a basin, and subsequently exhibit higher fitness. However, in comparison to salmonids, Pacific lamprey do not appear to exhibit strict natal homing (Goodman et al. 2008; Hess et al. 2013; Spice et al. 2012). For this reason, unlike salmonids, the spatial scale that contains locally-adapted broodstock may be much broader for Pacific lamprey, and thus the specific watershed- or subbasin-of-origin of this broodstock may not be critical to the success of artificial propagation programs for Pacific lamprey.

Hess et al. (2013) concluded that although neutral genetic variation (i.e., gene variants detected have no direct effect on fitness) in Pacific lamprey is influenced by geography and adult phenotypes, there is high gene flow among individuals collected from the Columbia River, Oregon and California. However, Hess et al. (2013) and Lin et al. (2008) documented significant genetic differences among fish from different large-scale geographic regions but Lin et al. 2008 found no obvious geographical pattern of gene flow or differentiation in samples from the Pacific Northwest (i.e., Washington, Oregon and California). The choice of genetic marker may have some bearing on the results of the genetic studies that have been conducted on Pacific lamprey. For example, the findings of Lin et al. (2008) and Hess et al. (2013) were obtained using relatively large numbers of amplified fragment length polymorphism and single nucleotide polymorphism markers, respectively. These types of markers have high potential to represent adaptive variation from genomic regions under selection, which was one of the primary goals of the study by Hess et al. (2013). In contrast with patterns from neutral variation, adaptive variation was shown to drive relatively large genetic divergence between regions, even within the Columbia River between the lower river and interior tributaries (Hess et al. 2013).

Other genetic studies using putatively neutral markers (based on microsatellites and mitochondrial DNA) have provided evidence of high rates of gene flow across much of the range of Pacific lamprey with low geographic association among samples (Goodman et al. 2008; Spice et al. 2012). Results from Spice et al. (2012) suggest that most Pacific lamprey in the Pacific Northwest could be managed as a single unit. In contrast, Lin et al. (2008) stated that the scale over which genetically significant management units are categorized (e.g., stocks, populations, distinct population segments) requires additional clarification through more study. Recently, however, the USFWS (Luzier et al. 2011) divided Pacific lamprey into ten Regional Management Units (RMUs). The division of lamprey stocks into regional units was not based on genetic information, but is intended to allow for a more refined level of life history and data collection from each RMU. At this time, the USFWS (2012) believes that "dividing management units into finer geographic scales would provide a risk-averse approach for conserving Pacific lamprey".

Despite some conflicting results, genetic studies generally corroborate the pattern that rates of gene flow are high among Pacific lamprey, particularly in the Pacific Northwest. The pool of potential donor-stock for artificial propagation or translocation programs may therefore be larger for lamprey than, for example, salmon. Similar genetic composition could be viewed as an advantage because healthy donor-stocks could be obtained from any RMU and translocated, or seeded, into suitable watersheds throughout the Pacific Northwest.

Still, from the viewpoint of conservation management vs. supplementation, Hess et al. (2013) emphasize that, although lamprey are capable of high levels of gene flow across most of their range, it is important to maintain "local" diversity (a suitable geographic area has not yet been described), primarily those adaptive genetic variants that respond to localized conditions. This would indicate that broodstock management and collection protocols must be cognizant of the need to maintain the diversity of donor-stock when faced with the potential for artificial propagation (i.e., hatchery programs). Similarly, the "mining" of donor-stock associated with lamprey translocation programs should not cause a substantial decrease in abundance in any currently occupied subbasin (Ward et al. 2012).

2.1 Genetic monitoring and analysis

The potential risks of supplementation tools have been recognized, and measures to minimize risks are outlined in the lamprey translocation guidelines agreed to by the Columbia River Inter-Tribal Fish Commission (CRITFC 2011a; Ward et al. 2012). Although consideration should be given to potential disruption of stock structure and associated genetic adaptations from sources, the risk of adverse effects associated with the continued downward trend in abundance may outweigh the potential loss of some adaptive genetic variants in isolated areas (Ward et al. 2012) This is particularly true in areas where numbers are decreasing rapidly. In these areas, it is possible that so few adults find their way into the watersheds that they may have trouble finding mates and the potential for genetic founder effects is increased. Given general support among genetics findings that a single homogenous population of Pacific lamprey exists throughout the Columbia River and Pacific Northwest region, there is likely less risk in temporary supplementation to increase abundance and genetic diversity.

Part of the planned monitoring that is described in this framework includes a genetic analysis component that will provide a means for tracking genetic diversity and the fitness consequences (if any) that are associated with genetic variation of lamprey used for translocation/outplanting. Genetic analysis will allow us to directly measure reproductive success of translocated lamprey adults and/or outplanted larvae (e.g. via parentage assignment of putative offspring), as well as provide a way to assess the genetic background of each individual adult and test whether this background affects reproductive success in a particular environment. The other advantage of this genetic analysis is that the age of the larvae can be quantified accurately based on parentage assignment, allowing us to further our understanding of the age structure of Pacific lamprey at various life stages.

3 Purpose, Need and Scope for Supplementation Research Framework

3.1 Purpose

A framework is an organized foundation or structure that supports an intended area of research or the development of strategies that focus on the achievement of specific objectives. The framework typically consists of concepts, existing data and information, and various theories related to a particular research topic that, when assembled, form the basis of understanding. Relative to fisheries research and management, this foundation determines how information is interpreted, what problems are identified, and a range of appropriate solutions (Independent Scientific Group 1996) to achieve the ecological conditions necessary to meet specific goals and objectives. Lichatowich (1998) compares a conceptual foundation (i.e., framework) to the process of assembling a puzzle, where the foundation is the cover of the puzzle box, displaying what the fully assembled puzzle should look like.

As applied to Pacific lamprey supplementation research and ultimately the recovery of Pacific lamprey in the CRB, the USFWS and various state and tribal entities have developed visions for fully recovered Pacific lamprey. In the recent Lamprey Conservation Agreement, the ultimate future vision for lamprey is the "long-term persistence of Pacific lamprey… throughout their historic range in the United States". This vision is consistent with that of the Tribal Pacific Lamprey Restoration Plan, which states that lamprey should be restored to sustainable, harvestable levels throughout their range by 2050. To this end, the development of this Supplementation Research Framework requires input from various stakeholders to ensure consistency in purpose, approach, analysis and reporting.

The purpose of this Supplementation Research Framework is to initiate the development of a regionally coordinated and long-term RME and reporting plan directed towards the implementation of supplementation and recovery actions for Pacific lamprey within the CRB. Additionally, this Supplementation Research Framework intends to "standardize" key elements of supplementation RME and reporting so that findings associated with status and trends and other important objectives can be reported in a common and consistent format. Finally, the Supplementation Research Framework provides specific guidance for the development of Subbasin Supplementation Research Plans.

The development of this regional Supplementation Research Framework is needed to coordinate supplementation RME on both a regional and local level. The Supplementation Research Framework will provide consistency and serve as a communication and management tool for stakeholders to remain focused on the overall goals of the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement.

This Supplementation Research Framework will be updated over time as new, pertinent information becomes available. Importantly, this Supplementation Research Framework is intended to serve as a foundation and template for consistency in the development of more specific Subbasin Supplementation Research Plans. Findings associated with local planning and activities informed by this Supplementation Research Framework will provide sufficient information to update the Tribal Pacific Lamprey Restoration Plan. This can ensure the consistency among stakeholders in providing a more cohesive foundation for lamprey recovery in the CRB over the next five years, leading to the development of the Columbia River Basin Pacific Lamprey Management Plan. This management plan, envisioned to be developed in 2016–

2017, will (1) update the Tribal Pacific Lamprey Restoration Plan (2) provide guidance for activities undertaken through the Lamprey Conservation Agreement and (3) direct future funding through the NPCC Fish and Wildlife Program. Contributors to this Supplementation Research Framework clearly recognize that because of our lack of knowledge and resources, this is a "work- in progress" and will be revisited and updated periodically to incorporate new findings and reflect management direction.

3.2 Need

3.2.1 Pacific lamprey are in low abundance or extirpated in many mid to upper watersheds, especially above McNary Dam.

Abundance of Pacific lamprey has declined throughout the CRB, and counts decline rapidly from downstream to upstream areas (Table 1). Although counts at dams are incomplete, they serve as the only long-term index of Pacific lamprey abundance in the CRB. Annual cumulative daytime counts at Bonneville Dam prior to 1970 were regularly at least 50,000, with occasional peaks approaching 400,000 (Kostow 2002). Counts prior to 1970 at McNary Dam were generally in the few tens of thousands, but have decreased to less than 1,000.

In the Umatilla River, anecdotal information indicates that Pacific lamprey were historically abundant, with harvest occurring throughout the subbasin (Ward et al. 2012). Observations by tribal members and state and federal fisheries agency personnel (Jackson and Kissner 1997) indicate that lamprey were so abundant as to be a nuisance in the Umatilla River Subbasin. Abundance decreased precipitously in the late 1960s and early 1970s following treatments, and very few lamprey were observed in the subbasin during surveys conducted in the 1990s (Ward et al. 2012).

Few counts of Pacific lamprey at Snake River dams are available prior to the 1990's; however, counts ranged from approximately 5,000 to 7,000 at Ice Harbor dam from 1967 through 1969 (Fish Passage Center 2013). Recent counts have been under 1,000 fish at Ice Harbor Dam and under 100 fish at Lower Granite Dam (Table 1).

Although long-term information from dam counts in the Snake River is not available, information summarized by Cochnauer and Claire (2009) from the Clearwater Subbasin indicates a precipitous decline in Pacific lamprey abundance and distribution. The number of kilometers occupied by Pacific lamprey declined by an estimated 66% between 1960 and 2006. Counts at Lewiston Dam, near the mouth of the Clearwater River, decreased from over 5,000 in 1950 to zero by 1972, after which the dam was removed and lamprey once again had access to the upper drainage. Pacific lamprey ammocoetes and macrophthalmia were collected in Lolo Creek from 1994 through 2003; however, continued sampling failed to capture any lamprey from 2004 through 2006.

Anecdotal accounts indicate lamprey were historically plentiful in the Yakama Nation Ceded Lands, specifically in the Yakima River where adult lamprey were harvested locally at least till the 1960s and early 70s (Yakama Nation and GeoEngineers, Inc. 2012). Current adult lamprey occurrence data for the Yakima River Subbasin is based primarily upon observations at fishways at Prosser and Roza dams. At Prosser Dam, the number of adult lamprey counted at the fishway was low from 2000 to 2013, ranging from zero in 2000 to a high of 87 in 2003. In most years less than 20 adults pass Prosser Dam. No adults have been observed at Roza Dam since the counting program began (Yakama Nation and GeoEngineers, Inc. 2012). Recent abundance data indicates very low, numbers of larvae and juveniles throughout the subbasin as well. From 2000 to 2012, outmigrating larval and juvenile lamprey counts (unconfirmed species) from Chandler Canal Fish Collection Facility in lower Yakima River ranged between 18 and 1,450 (43% subsampling) with a mean annual count of 317.

In the upper Columbia River, numbers of Pacific lamprey passing Wells Dam (furthest upstream facility on the mainstem Columbia River with passage) each year have been declining, with some recent adult counts below ten per year (Table 1). Counts were over 1,400 fish as recently as 2004.

3.2.2 Pacific lamprey in some subbasins may need to be supplemented so that recovery can occur in a timeframe consistent with aggressive restoration plans.

Brian, ODFW technical staff offers the comments below on natural colonization, and passage at dams but not sure best place for you to address them:

- **One of the fundamental rationale's for supplementation is the assumption that natural recolonization will take too long. This assumption is not backed by any data and is indeed contradicted by the one case study cited. The assumption is likely based on the fact that adults are attracted to larval pheromones; the assumption being that if there are no larvae rearing in a particular watershed, there is nothing to attract adults to that watershed. However, there are other factors besides larval pheromones likely attracting adults to spawn such as discharge, temperature, presence of Western brook lamprey rearing, presence of other maturing Pacific lamprey adults, and so on (Keefer et al. 2013).**

- **Moreover, the one example of actual natural recolonization mentioned in this document happened relatively rapidly and the authors disingenuously refer to it as a "natural reintroduction." The case study comes from Hess et al. (in prep), and looks to be a really interesting paper for more than this reason. Hess et al. sampled the upper Hood River shortly (<3 years) after the removal of Powerdale Dam, which was considered a lamprey barrier, and found only age-0 Pacific lamprey. The lack of other age classes (and no Western brook larvae) suggests this was a recent, rapid recolonization of an area that did not have rearing larvae as an attractant.**

- **Given that very little is known about natural recolonization rates of Pacific lamprey, one might expect that this topic would be a high priority in their research framework. However, this framework does not propose to evaluate natural recolonization rates and the factors affecting them even though there are plenty of rivers in this region where dams have been removed in the last 15 years that could serve as study watersheds. Here is a partial list (from American Rivers) of Washington and Oregon watersheds where occupancy estimation studies could improve our understanding of Pacific lamprey recolonization rates: Sandy River (Marmot Dam, 2007), Hood River (Powerdale Dam, 2010), White Salmon River (Condit Dam, 2012), Trout Creek (Wind River, Emerald Dam, 2010), Elwha River (Elwha and Glines Canyon Dams, 2013), Clackamas River, Cowlitz River, Lewis River, Rogue River (Gold Ray Dam, 2010; Savage Rapids Dam, 2009), South Fork Necanicum River (Diversion Dam, 2012), South Fork Siletz River (Valsetz Dam,**

2012), Birch Creek (Taylor Dam, 2012), Elk Creek (Elk Creek Dam, 2009), Calapooia River (Brownsville Dam, 2007), South Fork Klaskanine River (SF Klaskanine Dam, 2007), Dinner Creek (Dinner Creek Dam, 2003), Little Applegate River (Buck & Jones Diversion Dam, 2003), Wagner Creek (2003), Beaver Creek (Byrne Diversioin Dam, 2002), Evans Creek (Maple Gulch Diversion Dam, 2002; Alphonso Dam, 1999), Ashland Creek (2000).

- Another rationale for supplementation is that improving passage at mainstem dams will take too much time to meet the ambitious restoration goals set by tribal and regional conservation plans. And once passage is improved and a greater proportion of adults make it to the interior CRB, rearing populations need to be in place to attract these adults. In their effort to establish a supplementation program, the authors might be losing sight of how bad passage is at the dams. Here is a table that shows how pitiful it is, based on PIT and radiotelemetry data from and collected by Keefer et al. (2013):
-

	Probability of upstream passage success at individual lower CRB dams				
	Bonneville	Dalles	John Day	McNary	Total
Mean	0.40	0.56	0.40	0.65	0.06
Low	0.37	0.50	0.27	0.50	0.02
High	0.43	0.72	0.55	0.80	0.14

-
- Based on these data, during a mean year, the probability that adults trying to access the interior CRB will successfully pass these four mainstem dams is 6%. Year after year, almost 95% of the migratory adult population headed for the interior CRB is blocked by these dams. This does not account for the upper CRB and lower Snake River dams. Until passage at dams is dramatically improved, supplementation may have little effect on the status of Pacific lamprey in the interior CRB.

Given the precipitous decline in Pacific lamprey abundance, particularly in the upper reaches of the CRB, it is unlikely that large-scale restoration and passage improvement activities, though necessary for long-term sustainability, will result in increased abundance or distribution at a rate sufficient to offset continuing declines and preclude further extirpations. Pacific lamprey supplementation has therefore been identified as a recovery action that should occur concurrently with improvements in fish passage, water quality, and habitat (CRITFC 2011a; Luzier et al. 2011; USFWS 2012; Ward et al. 2012; Yakama Nation and GeoEngineers 2012).

Potential supplementation tools include translocation of adults and reintroduction of larvae or juveniles using artificial propagation. Translocation can be used to bypass corridors where migration is impeded or blocked, increase number of spawning adults, increase larval abundance and distribution, and provide pheromones for potential attraction of additional adults. Artificial propagation may be needed in some areas to increase larval abundance and provide pheromones. Both supplementation techniques are intended to be used while simultaneously improving known factors that limit productivity of lamprey in these specific watersheds. The goal is that self-sustaining natural productivity will provide meaningful ecological contributions and traditional tribal harvest. Research is needed to determine the feasibility of these approaches and to monitor and evaluate results.

Table 1. Counts of adult Pacific lamprey at Columbia and Snake River dams, 2002-12. Counts are during the day only at most dams. Priest Rapids and Wells dams have 24-hour counts. Counts at Lower Granite dam have been conducted 24 hours a day since 2009.

Year	Lower Columbia River		Snake River		Mid-Columbia River	
	Bonneville Dam	McNary Dam	Ice Harbor Dam	Lower Granite Dam	Priest Rapids Dam	Wells Dam
2002	100,476	11,282	1,127	128	4,007	338
2003	117,029	13,325	1,702	282	4,339	261
2004	61,780	5,888	805	117	2,647	1,408
2005	26,664	4,158	461	40	2,598	291
2006	38,938	2,456	277	35	4,381	212
2007	19,313	3,454	290	34	6,593	21
2008	14,562	1,530	264	61	5,083	7
2009	8,622	676	57	12	2,714	9
2010	11,183	825	114	15	1,114	2
2011	18,305	868	269	48	3,868	1
2012	29,224	970	484	48	4, 025	3

Supplementation is intended to be a short term action to boost Pacific lamprey numbers and make other restoration actions more meaningful. Research needs related to supplementation identified by the USFWS (Luzier et al. 2011) include evaluating the risks and benefits of translocation, evaluating techniques for artificial propagation, and evaluating if artificial propagation can be used to "jump start" ammocoete production in appropriate watersheds.

Supplementation would increase larval or juvenile abundance in seeded watersheds or stream reaches. Not only would these actions re-establish juveniles back into the local ecology, they may improve pheromone attraction of returning adults. Emerging evidence strongly suggests an association between juvenile lamprey pheromones and adult returns (Sorensen et al. 2005; Lin et al. 2008; Close et al. 2009; Spice et al. 2012). Adult Pacific lamprey, like sea lamprey (*Petromyzon marinus*), may be attracted to spawning sites by pheromones released by ammocoetes (Lin et al. 2008).

3.2.3 Supplementation research and use as a recovery and management tool will provide valuable insights into lamprey biology and ecology.

In consideration of low numbers of adult lamprey, alternative management strategies must be employed as stop-gap measures to slow extirpation and re-establish genetic variability within local areas throughout the CRB. During this time, supplementation research should be implemented and important attributes, such as local genetic diversity must be monitored so that if/when supplementation is determined to move forward at a larger scale, the working knowledge will have increased to better plan and implement future management actions. As supplementation research is implemented in specific areas, monitoring and evaluation to determine action effectiveness of adult translocation, artificial propagation method development, and larval and juvenile reintroduction, will provide valuable insights into lamprey biology and ecology as well as provide the opportunity to research known and potential limiting factors and critical uncertainties.

Translocation efforts to date have resulted directly in successful transportation and holding techniques for adult Pacific lamprey. Successful holding and releases of adults have resulted in increased larval abundance (Ward et al. 2012), which has in turn increased knowledge of larval distribution and migration timing. In addition, by radio-tagging translocated adults, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Yakama Nation / USFWS have been able to collect information on adult passage at low-elevation diversion dams, providing insights on placement of lamprey passage structures such as the structure completed at Threemile Dam in the Umatilla River in 2009, and passage improvements currently being planned at Prosser Dam in the Yakima River. Ongoing translocation and future propagation research will have broad application in addressing other factors potentially limiting lamprey in the tributary environment including the effects of irrigation entrainment, flow management (ramping rates), emerging and legacy contaminants, and habitat availability.

Knowledge to be gained from evaluating lamprey artificial propagation includes information related to rearing techniques and with post-release monitoring. Development and evaluation of artificial propagation techniques will increase knowledge of laboratory protocols, growth and survival, food preferences, habitat needs, and possibly changes in morphology associated with metamorphosis. Monitoring of larval or juvenile releases will provide information on growth and survival in the wild, distribution including downstream movement, and outmigration timing.

Monitoring of supplementation activities may also provide opportunities to increase understanding of known limiting factors and critical uncertainties. These may include larval and juvenile passage at specific facilities, contaminant accumulation and effects, and predation. If larval pheromones guide adults to spawning sites, supplementation would encourage natural production in suitable spawning and rearing areas. Research is currently being conducted to isolate these pheromones and investigate how they may be used to improve adult returns (Yakama Nation and GeoEngineers, Inc. 2012). Investigations such as these are important to initiate at this time so that, if need be, this management strategy can be confidently implemented when necessary.

3.2.4 A regional Supplementation Research Framework will provide for a more comprehensive and systematic research and monitoring strategy and will contribute to greater consistency in data analysis and reporting.

A successful, economical and rapid recovery of Pacific lamprey will require regionally coordinated efforts from tribes, federal and state fishery agencies, and others involved in conducting or funding lamprey restoration efforts. An important component of this coordination is consistency in protocols, data collection and reporting metrics. The need for this coordination was clearly identified in both the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement. Both documents clearly established a context for coordinated action among stakeholders across the CRB towards conservation actions, funding and RME.

3.3 Scope

The scope of this Supplementation Research Framework is intentionally narrow in both time (5 years) and space (only a few key CRB subbasins) due primarily to the conservative nature of this initial effort and budgeting constraints. Actions guided by this Supplementation Research Framework are expected initially to focus on addressing important management questions, limiting factors, and critical uncertainties identified in both the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement. With regard to supplementation research, the Supplementation Research Framework will provide guidance to address Objective 3 of Tribal Pacific Lamprey Restoration Plan, *Supplementation/Augmentation*, and Objective 7 of the Lamprey Conservation Agreement, *Restore Pacific Lamprey of the RMUs*. The Supplementation Research Framework and associated Subbasin Supplementation Research Plans are integral components of the larger RME Framework.

The Supplementation Research Framework is further expected to guide consistent analysis methods and reporting formats for research and monitoring tools in the context of Objectives 5 and 6 of the Lamprey Conservation Agreement (*Identify and characterize Pacific lamprey for the RMUs* and *Identify, secure and enhance watershed conditions contained in the RMUs*) and Objective 6 of the Tribal Pacific Lamprey Restoration Plan (Research, Monitoring, and Evaluation).

Through adaptive management this Supplementation Research Framework will expand, with the intention of maintaining its relative simplicity. Many critical uncertainties about Pacific lamprey remain and fishery managers expect that continued RME activities will likely modify the overall objectives and methods. For this reason, managers choose to maintain relative simplicity in the approach. Considering budgets, existing capacity, and the state of knowledge, it is not practical at this time to construct a Supplementation Research Framework overly burdened with details built upon speculation and uncertainty. Simply based on a 10-year life history of Pacific lamprey, managers recognize many important objectives may require a decade and longer to achieve.

4 Supplementation RME Framework

This section describes the Supplementation Research Framework that will be an integral component of the larger Pacific lamprey RME Framework (Item 1 described in Section 1.4). Collective development of these documents is anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan, (2) Lamprey Conservation Agreement, and (3) Northwest Power and Conservation Council Fish and Wildlife Program. Each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be drafted in years 2016-2017.
Translocation and propagation continue to be tools necessary for learning, both in laboratory and the natural environment. Supplementation may be used as one method to address limiting factors and ultimately to help shape the management plan.

Because of the low returns of Pacific lamprey, including extirpation in some subbasins, and the assumption that natural recolonization will require a long time, the use and monitoring of adult translocation and artificially propagated larval and juvenile lamprey in short and long-term supplementation efforts will be necessary. In the short term, translocation and propagation efforts would be used to reestablish lamprey in extirpated streams and maintain lamprey presence to attract upstream migrating spawning lamprey. In the long term, artificially produced lamprey could be used to supplement CRB lamprey by dramatically increasing larval/juvenile numbers with the goal of effectively reversing declines.

Within key research areas, multiple threats recognized, both within and outside of subbasins, include degraded habitat, passage barriers, degraded water quality, dewatering, and predation (CRITFC 2011a; Luzier et al. 2011). To varying degrees these threats are being addressed, although it will take considerable time before their impacts are fully understood and corrected; therefore, appropriate supplementation is necessary during this time.

Fishery managers recognize the importance for both restoration and research to be complimentary efforts in addressing threats. It is especially important to recognize the use of supplementation in areas where lamprey numbers are too low to actually determine the nature or extent of potential limiting factors. Examples include juvenile entrainment and passage through irrigation screens or adult passage over irrigation facilities. Propagated fish may also be used to address basic questions about growth and survival in natural riverine environments. Managers have concluded that without use of translocation and propagation research as a tool, it is essentially impossible to understand potential environmental threats in many subbasins. Short term focus should be on critical areas of research and longer-term application of supplementation in key areas.

4.1 Regional RME Framework

The larger scale Regional Framework for Pacific Lamprey Research Monitoring, Evaluation, and Reporting in the Columbia River Basin (RME Framework – Item 1 described in Section 1.4) will be guided by principles and concepts put forth by Luzier et al. (2011). The RME Framework will also be informed by biologists with experience in lamprey biology. At this time, some of the elements of a comprehensive RME Framework cannot be implemented because of a lack of scientific tools needed to collect data (e.g., juvenile tags). Nevertheless, the framework will identify appropriate RME questions and objectives, and the need to develop the tools necessary to address the questions and objectives.

4.1.1 Types of RME Efforts

Several types of monitoring are needed to allow managers to make sound decisions:

- **Status and Trend Monitoring.** Status monitoring describes the current state or condition and limiting factors at any given time. Trend monitoring tracks these conditions to provide a measure of the increasing, decreasing, or steady state of a status measure through time. Status and trend monitoring includes the collection of standardized information used to describe broad-scale trends over time. This information is the basis for evaluating the cumulative effects of actions on lamprey and their habitats.

- **Action Effectiveness Monitoring.** Action effectiveness monitoring is designed to determine whether a given action or suite of actions (e.g., propagation and translocation) achieved the desired effect or goal. This type of monitoring is research oriented and therefore requires elements of experimental design (e.g., controls or reference conditions) that are not critical to other types of monitoring. Consequently, action effectiveness monitoring is usually designed on a case-by-case basis. Action effectiveness monitoring provides funding entities with information on benefit/cost ratios and resource managers with information on what actions or types of actions improved environmental and biological conditions.

- **Implementation and Compliance Monitoring**. Implementation and compliance monitoring determines if actions were carried out as planned and meet established benchmarks. This is generally carried out as an administrative review and does not require any parameter measurements. Information recorded under this type of monitoring includes the types of actions implemented, how many were implemented, where they were implemented, and how much area or stream length was affected by the action. Success is determined by comparing field notes with what was specified in the plans or proposals. Implementation monitoring sets the stage for action effectiveness monitoring by demonstrating that the actions were implemented correctly and followed the proposed design.

- **Uncertainties Research**. Uncertainties research includes scientific investigations of critical assumptions and unknowns that constrain effective propagation and translocation. Uncertainties include unavailable pieces of information required for informed decision making as well as studies to establish or verify cause-and-effect and identification and analysis of limiting factors.

4.2 Supplementation Research Strategies

This supplementation research Framework covers the translocation and artificial propagation of Pacific lamprey within the Columbia River basin. It describes the RME recommended for assessing the status and trends of Pacific lamprey within subbasins and for evaluating the effectiveness of translocation and other actions implemented to restore Pacific lamprey within those subbasins. In addition, this plan identifies current efforts and additional RME needs. Although logistical and monetary limitations exist, this plan will focus on the common goal of assessing success in Pacific lamprey translocation and propagation.

4.2.1 Adult Translocation

4.2.1.1 Background

Close et al. (1995) conceptualized the goal of lamprey translocation to “begin establishment or supplementation of lamprey in selected tributaries above Bonneville Dam where populations have been extirpated or are at extremely low levels.” The overall goal of translocation is to restore natural production to self-sustaining levels.

Translocation programs in the CRB have been well documented by Close (1999), Close et al. (2009), and Ward et al. (2012). The approach for translocation efforts to date has been to collect adult Pacific lamprey at Bonneville, The Dalles, and John Day dams. Adults are then transported and held at facilities near release areas. Adults are tagged and treated at the holding facilities and released the following spring.

4.2.1.2 Rationale and Assumptions

Although the best long-term sustainable option for increasing Pacific lamprey abundance and distribution may be improving the passage environment for adults and juveniles, translocation of adults may be the best immediate option to begin the process of rebuilding populations in depressed subbasins. Translocation efforts are likely to increase production of larval lamprey in recipient subbasins, “seeding” underutilized rearing habitat and increasing pheromone cues to attract adults. Translocation and other restoration programs could therefore have a synergistic effect in breaking the downward cycle of Pacific lamprey abundance and recruitment.

Another potential benefit of translocation is expanded spatial distribution of Pacific lamprey, via occupation of subbasins where they have been severely depressed or extirpated. Until passage is better understood and improved at mainstem dams, translocation from lower dams may also produce an escapement benefit for lamprey. These benefits may help decrease the risk of lamprey local extirpation by decreasing the overall impact of catastrophic events within a subbasin, or even within a larger portion of the Columbia River Basin.

Lamprey translocation may also produce ecosystem benefits. Because ammocoetes are filter feeders and detritivores, increased production is expected to facilitate nutrient cycling in rivers where adult lamprey have been reintroduced. Other potential benefits include increased connectivity of marine with freshwater ecosystems, and delivery of marine-derived nutrients into upper reaches of the Columbia River Basin. Lamprey restoration will also increase the prey base available to native fish, avian, and mammalian predators.

4.2.1.3 Critical Uncertainties

Critical uncertainties regarding translocation of adult Pacific lamprey that have been identified through monitoring of existing programs include:

- Survival of translocated adults
- Spawning success
- Viability and survival of eggs, larvae, and juveniles

Potential risks (albeit unknown) from lamprey translocation often raised include:

- Disruption of population structure and associated genetic adaptations
- Exposure to survival risks such as pathogens and disease
- Decreased abundance in donor areas.

These potential risks have been recognized (Ward et al. 2011), and steps have been taken to avoid or reduce them by adherence to lamprey translocation guidelines agreed to by the Columbia River Inter-Tribal Fish Commission (CRITFC 2011a)).

A remaining uncertainty may be the appropriate number of adults to release within a target location. The apparent lack of homing of Pacific lamprey to natal watersheds confounds attempts to address this uncertainty. Long-term efforts are needed to document the effect of increased larval abundance on returns of adults.

4.2.1.4 Research and Monitoring Objectives

The four Columbia River treaty tribes have proposed creating a regional lamprey supplementation plan that includes adult translocation with the following general objectives (CRITFC 2011a):

- Continue translocation in accordance with tribal guidelines.
- Develop and implement lamprey translocation as a component of a regional supplementation plan.

Tribal translocation strategies will:

- Utilize historical and tribal records of lamprey distribution, abundance and habitat to help determine outplanting priorities.
- Use the best available knowledge to evaluate if translocation is necessary.
- Choose donor sources wisely and make efforts to minimize negative effects on donor groups.
- Monitor and improve collection, transport, and holding protocols and facilities.
- Evaluate and select target streams, release locations, and timing of releases using the best available knowledge.
- Closely monitor and evaluate translocations at a variety of spatial and temporal scales.
- Accurately record and sufficiently share translocation results with the region.

4.2.2 Larval and Juvenile Outplanting

4.2.2.1 Background

The biological features of lamprey (especially after hatching) require new innovative ideas and methods to improve culture success. Formative work on lamprey propagation in Finland, research on sea lamprey from the Great Lakes region, and research on Arctic lamprey from Japan provide important insights on how artificial propagation of Pacific lamprey could be used in the CRB. Some experimental work on the artificial propagation of Pacific lamprey has already been conducted within the CRB; however, the primary focus in the past has been on propagating small number of lamprey for research purposes and the processes and techniques applied were not scaled for aquacultural use.

In 2012, the Yakama Nation and Umatilla Tribe joined forces and collaborated on the artificial propagation of Pacific lamprey. Over a 10-week period between April and June, 2012, 41 adults were spawned successfully primarily at Marion Drain and Prosser hatcheries. Some of the individuals (both male and female) spawned repeatedly, resulting in a total of 55 propagation events. Over 40% of the adults, however, did not mature in 2012 and were overwintered for another year. Fertilization and hatching success varied widely (0-99%). The success of fertilization and hatching depended chiefly on four variables: 1) seasonality; 2) quality of gametes; 3) water quality; and 4) incubation methods.

Many tribal and federal agencies experimented with larval rearing in 2012 using propagated age 0+ larvae. Different feeds and substrate types were tested, and the effects of temperature and feeding regime on growth and survival were evaluated. Most studies demonstrated that larvae can attain positive growth and relatively high rates of survival under active dry yeast feed. However, a certain combination of feeds in addition to active dry yeast (such as hatch fry feeds or marine larvae feed) appeared to be potentially effective in producing even better growth and warrants further research. Larvae appeared to show preference for natural fine substrates, such as clay, silt, sand, detritus and straw. However, considering the enormous difficulty in separating larvae from clay/silt, detritus, and straw, fine sand appears to be the most promising substrate to date.

Protocols for rearing larvae and juveniles for extended periods of time (years) are lacking. Growing lamprey to larger sizes will be particularly challenging partly due to 1) the length of time they spend as larvae (3-7 years) and 2) their cryptic nature (i.e. burrowing under fine sediment), which makes any type of monitoring both very time-consuming and difficult.

4.2.2.1 Rationale and Assumptions

Once developed, artificial propagation could be an important management action to aid in the restoration of Pacific lamprey, especially in areas of low abundance or extirpation. A primary role of larval propagation and outplanting besides increased larvae/juvenile production would be to maintain and increase pheromone cues to attract returning adults. Increased numbers of larvae are likely needed to occupy available habitat, release pheromones, and begin reversing declines in numbers of returning adults.

Propagated larval lamprey may also be valuable as study organisms. Larval lamprey behavior is secretive and larvae are elusive (i.e. burrowed in sediments), making them difficult to study in their natural environments. Rearing and evaluating lamprey in a controlled laboratory environment and connecting this work with controlled research in the natural environment may be the most effective way to better understand various life stages efficiently, both in time and expense.

Juvenile (macrophthalmia) outplanting may not be the most effective strategy for supplementation because larvae are needed in the streams to produce pheromones that attract adults and the economic cost of growing larvae for 3-7 years would also be substantial. Raising lamprey to the juvenile stage may have some benefits, however. For example, if the facility is in a suitable location, pheromones released by larvae being reared over long periods may serve to attract returning adults. Continued holding of fish may facilitate refinement of rearing techniques. Finally, survival rates of outplanted juveniles are most likely going to be higher than that of larvae.

Hatchery-raised lamprey could also be used for other research programs other than re-stocking in streams. Very little is known about lamprey juvenile passage and migration, but the diminished abundance and distribution, and the unique size and shape of the lamprey make any kind of sizeable tagging studies extremely difficult, if not impossible, to implement. Therefore, artificial propagation of Pacific lamprey may be extremely valuable for research purposes to better understand their early life history and biology, and to meet the critical need of samples required for such studies. Hatchery lamprey could be raised to various life stages and used as test organisms for determining screen design, screening efficiencies, survival through hydroelectric projects, and other juvenile studies of critical importance.

Using propagated fish in the natural environment provides several distinct research opportunities because lamprey could be placed in selected stream reaches or reservoir deltas at desired densities. For example, this type of lamprey placement allows for opportunities to test sampling protocols against a known sample. Larval lamprey placed in cages in certain streams could evaluate if their presence will attract adults via pheromones, or alternatively, their tolerance to certain levels of contaminant loads. In general, experiments using hatchery-raised lamprey will aid in the understanding of lamprey behavior and guide future restoration actions without the need to extract and harm existing lamprey from the natural environment.

4.2.2.2 Critical Uncertainties

Substantial obstacles must be overcome to achieve a scale necessary for hatchery production. Critical knowledge gaps at the hatchery production level include

- Optimal temperature regime for holding adults
- Best management practice for successfully spawning and incubating lamprey
- Disease and fish health issues specific to lamprey
- Tolerance level of adults/eggs/larvae to disease/fungus controlling chemical treatments
- Influence of rearing density on larval growth; larval food quality, quantity, and feeding methods
- Methods to efficiently separate larvae from fine sediment for counting and monitoring

Although many knowledge gaps exist at the hatchery production level, these questions can be answered relatively easily by the use of targeted experiments. In fact, from the first year of propagation efforts by the CRB tribes and federal agencies, many of these knowledge gaps are beginning to get answered (such as spawning and incubation techniques, chemical treatment effects, effective types of feed and substrate media, etc.).

Growing lamprey to larger sizes will be particularly challenging partly due to 1) the length of time they spend as larvae (3-7 years) and 2) their cryptic nature (i.e. burrowing under fine sediment), which makes any type of monitoring both time-consuming, difficult, and stressful for the larvae. For example, in a salmon hatchery, large mortality events are obvious to the hatchery personnel because the fish are directly visible in the water tanks. In the case of larval lamprey, even if a significant larvae mortality event occurs, this event may go unnoticed for some time because they all live under the sediment and remain invisible most of the time. As larvae increase in size, their weight density will continue to increase, most likely requiring more and more space to rear them successfully.

Significant critical uncertainties related to post hatchery production remain. The release of propagated larvae into the natural environment has taken place in Finland, Japan and other countries, but very little monitoring has been conducted to successfully validate its effectiveness in increasing and boosting natural reproduction levels. Critical knowledge gaps post hatchery production include

- Optimal release sites
- Optimal larval release life stages (0+ ~ 7+ larvae)
- Optimal release density
- Changes in growth and survival of propagated larvae after release
- Dispersal rates after release
- Interactions with naturally produced larvae and juveniles.

In addition to larval habitat in mainstem and side channels of rivers and streams, potential release sites include salmon acclimation ponds, hatchery pollution abatement ponds, and irrigation diversions and canals. To determine the optimal larval release life stage, we will need to have a much better understanding on the life stage survival model for Pacific lamprey and the corresponding "bottleneck" life stage. If the primary bottleneck is in the egg incubation and prolarvae stage, being able to rear them past this stage should increase the larvae production immensely (at least in quantity). On the other hand, if the primary bottleneck takes place in later life stages as larvae, it would become crucial to rear them past this stage. The optimal density levels of the larval release also require more information on the life stage survival model. At what density of larval outplanting (per watershed size) are we able to see noticeable increases in larvae production? Can larval lamprey adapt quickly to the natural environment after being reared in the hatchery settings for over a year? How many of the larvae would stay put within the release site vs. others that disperse to other habitat? How would the outplanting affect naturally produced larvae? Salmon and trout hatcheries have learned from 100+ years of experience. All these questions will require intense monitoring that will span multiple years.

4.2.2.3 Research and Monitoring Objectives

The four Columbia River treaty tribes proposed creating this Framework with the following general objectives (CRITFC 2011a):

- Immediate evaluation of potential regional lamprey aquaculture facilities.
- Consolidation and synthesis of existing lamprey propagation information.
- Development and refinement of husbandry techniques for Pacific lamprey.
- Continued research on lamprey genetics, potential population substructure, and source locations.
- Assessment of appropriate release locations and strategies for propagated lamprey within the region.
- Monitoring and evaluation of supplementation using artificially propagated lamprey.

These objectives are intended to answer basic questions on the feasibility of large scale lamprey propagation in the northwest. The next steps in research should focus on basic observations in nutrition, growth, rearing densities, survival, and habitat preferences. Preferably, efforts should build on previous propagation research on other lamprey species, especially related to collection of brood stock, fertilization techniques, incubation conditions, and release timing, for the efficient and cost-effective development of propagation programs in the CRB. The Yakama Nation and the CTUIR has begun initial efforts for propagation starting the spring of 2012 by hatching and rearing several thousand Pacific lamprey larvae at their facilities. In 2013, propagation and rearing experiments ensued by the Yakama Nation and CTUIR to assess critical questions, such as 1) how to improve fertilization and incubation rates, 2) how to maximize survival of newly hatched larvae during facility-to-facility transfer, 3) how to efficiently count eggs and hatched larvae, and 4) how to effectively feed and rear larvae in large tanks under high density (>50,000) conditions.

4.3 Monitoring and Evaluation Approaches

4.3.1 Adult Translocation

4.3.1.1 Adult Survival

Monitoring questions

- How many translocated adults moved out of the release areas?
- How far and in what direction did translocated adults move following release?
- How many translocated adults moved to spawning areas?
- How did release timing and location affect spawn timing?
- What environmental factors (e.g., flows, temperature, etc.) may have caused translocated adults to leave the target areas?

Performance metrics

- Number of adults released
- Direction of movement
- Rate of movement
- Distance moved
- Adult maturation rate
- Estimated percentage of released adults that successfully reached spawning areas

Performance may be influenced by variables including water temperature and stream flow.

Approach

A tagging study (e.g., radio telemetry) is needed to determine the movement and habitat use of translocated adult Pacific lamprey. If water conditions allow and no lamprey are in the area, visual observations without tagging studies can be used to determine if translocated adults use the target spawning areas. This, however, is a less robust approach than using tagging studies.

Analysis

If a tagging study is used, the analyses are straightforward for estimating direction of movement (fraction moving upstream and downstream), rates of movement (distance moved per week), numbers leaving the target area, and numbers of adults spawning within the target area. Correlations between environmental factors (flows and temperatures), time and location of release, and spawn timing can be evaluated.

4.3.1.2 Adult Spawning

Monitoring questions

- How many translocated adults constructed redds and engaged in reproduction within target areas?
- What was the distribution of spawners within target areas?
- What habitat conditions (e.g., flows, temperature, substrate, etc.) favored the construction of redds and reproductive success within target areas?
- How many adults successfully spawned and contributed offspring?
- What are the effects on spawning success of multi-year over-wintered adults?
- What are the effects of an individual's genetic background on spawning success?

Performance metrics

- Number and distribution of redds
- Number of adults engaged in reproduction
- Number of eggs per red
- Presence of live eggs and larvae within redds
- Number of live eggs and larvae within redds
- Number of offspring assigned back to translocated adults

Performance may be influenced by a number of variables including water temperature, stream flow, water velocity, water depth, cover, and substrate composition.

Approach

An important assumption of translocation is that the translocated Pacific lamprey are ready to spawn shortly after release. This means that the translocated adults will successfully find mates, select suitable spawning sites, construct redds, and reproduce. For indirect measures of reproduction, if water conditions do not allow for visual observations, a tagging study may be needed to determine the number and distribution of spawners within the target areas. If water conditions allow, visual observations can be used to determine the number, distribution, and reproductive activities of translocated adults within the target areas. Ideally, spawning surveys should occur weekly throughout the spawning period (i.e., from time of release to the end of spawning). Field observations can be used to document redd construction and reproductive behavior. The location and timing of redds can be mapped using GPS. The size (width, length, and depth) of each redd can also be recorded. Habitat conditions (temperature, depths, velocities, cover, and substrate composition) can be measured at the locations of redds within the target areas. Stream flows can be downloaded from nearby gauging stations. Note that lamprey spawning surveys can be coupled with steelhead spawning surveys.

A genetic tagging study can be used to evaluate reproductive success metrics. Hess et al. (in prep) have developed and evaluated a set of genetic markers for Pacific lamprey that can accurately assign offspring to their parents. Tissues from ALL translocated lamprey adults must be collected for this tagging approach to be possible to execute for efficient monitoring.

Analysis

Descriptive analyses can be used to describe the number, distribution, and spawning activities of translocated adult lamprey within the target areas. Correlation and regression techniques can be used to assess the relationships between habitat conditions and the abundance and distribution of redds in the target areas. These relationships can then be used by biologists to fine-tune their selection of appropriate release locations. Based on the distribution of redds, biologists can sample a random number of redds to determine the total number of eggs deposited per red; randomly sampling redds for the presence of viable eggs and larvae over a specified time interval (e.g., weekly). To the extent possible, biologists should count the total number of viable eggs and larvae within a redd to gain a better understanding of the natural survival mechanism during early life history (methods may need to be developed to measure viable eggs and larvae over time).

Because the sampling of redds can alter the survival of eggs and larvae over time, biologists will need to determine if sampling with or without replacement is appropriate. That is, should a given redd be sampled more than once over time? Ideally, the total number of redds sampled should be no more than 10% of the total redds within the target area. Habitat conditions (temperature, water depth, egg-pocket depth, redd size, velocities, and substrate composition) can be measured at the locations of redds within the target areas.

4.3.1.3 Larval Survival and Growth

Monitoring questions

- Did translocated adults produce viable larvae in target areas?
- What fraction of the eggs survived to emergent larvae?
- What habitat conditions (e.g., flows, temperature, substrate, etc.) were associated with larvae survival and production?
- What is the survival rates for various age classes of larvae (i.e. 0+, 1+, 2+, 3+,etc.)
- Is genetic makeup associated with larval growth and survival?

Performance metrics

- Egg-to-larvae survival rates
- Larval survival and growth rates at various age classes
- Size, age, and abundance of larval lamprey identified as offspring from translocated adults

Performance may be influenced by a number of variables including water temperature, stream flow, water velocity, water depth, and substrate composition.

Approach

If translocation is to be successful in increasing the status of Pacific lamprey within a subbasin, then translocated adults must produce viable offspring. Therefore, measuring successful hatching and surviving larvae is critical to the assessment of translocation. If hatching and larvae production is successful, biologists will be equipped to re-establish lamprey in areas currently void of Pacific lamprey. Larval and juvenile lamprey of particular age classes will be able to be assigned back to translocated adults using genetic analyses. Offspring will be able to be assigned to adults translocated in 2013 and onwards.

Analysis

Descriptive analyses can be used to describe the mean number of eggs per redd, mean number of viable eggs and larvae per redd, and egg-to-larvae survival rates, as well as number of viable offspring per spawner pair. Correlation and regression techniques can be used to assess the relationships between habitat conditions and survival rates.

An important assumption of propagation is that planted larvae will use intended rearing areas over time. Biologists will identify suitable release sites based on rearing conditions within those sites. If biologists are able to identify suitable rearing areas that are used successfully by propagated larvae, it may improve the status of Pacific lamprey within the subbasin. It will also be possible to track propagated larvae via parentage analysis at various stages of maturity as they continue their continuous migration downstream.

4.3.1.4 Larval Abundance and Distribution

Monitoring questions

- How many larvae were produced by translocated adults?
- What size distribution is represented by each cohort of lamprey?
- How many larvae remained within the target areas over time?
- Did the distribution of larvae expand into areas outside the target areas?
- How did release timing and location affect the density and distribution of larval or juvenile lamprey within the target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval distribution and abundance?

Performance metrics

- Density of larvae (CPUE or fish/m^2)
- Distribution and abundance of larvae
- Presence and proportion of various size classes of larvae

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

Approach

Annual larval sampling within treated and untreated areas before and after supplementation activities will determine the relative abundance and size classes of larvae within the target areas. Parentage analysis will identify which larvae originated from which translocated adults, thereby providing a way to verify larvae were derived from translocation efforts and to measure distance traveled from last known spawner release site.

Electrofishing techniques modified for sampling larval lamprey may be the most appropriate method for estimating relative abundance, size classes and distribution. However, recent research from Europe shows that a significant proportion of lamprey populations (especially anadromous lamprey) can be found in deep water habitat that are not normally targeted with the standard electrofishing methods for lamprey. Alternative methods may need to be evaluated further (such as deep water shocking, suction dredging, passive traps, and infra-red cameras) to target these other areas that larvae may use extensively. Locations of juveniles can be mapped using GPS. Lamprey biologists will need to identify a protocol for sampling habitat conditions.

Analysis

A time series of the densities (CPUE or fish/m^2) of larval lamprey and numbers of transformers can be constructed to show how densities and numbers changed before and after supplementation efforts. Distribution maps can be generated that show how the spatial extent of larvae expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and larval abundance and distribution.

4.3.1.5 Larval and Juvenile Outmigration

Monitoring questions

- How many larvae or juveniles transformed and migrated downstream?
- What ages are larvae or juveniles at particular maturation stages during their migration?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with outmigration?

Performance metrics

- Number of outmigrating larvae and transformers
- Rate of movement
- Distance moved
- Genetic diversity of larvae and macrophthalmia

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

Approach

Rotary screw traps or other traps can be used to estimate the number (or presence) of downstream migrating transformers. Field research suggests that transformers can be caught by electrofishing techniques as well, focusing on coarse sediment near Type I and Type II larval lamprey habitat in late summer / early fall season. Lamprey biologists will need to identify a modified protocol for electrofishing transformers and their associated habitat conditions. Locations of juveniles can be mapped using GPS. Juveniles will be assigned to particular brood years of translocated adults via parentage analysis, and thereby provide an accurate age for each fish.

Analysis

A time series of the numbers of transformers can be constructed to show how densities and numbers changed before and after supplementation. Distribution maps can be generated that show how the spatial extent of larvae and transformers expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and transformer abundance and distribution. Parentage-based ages can be related to juvenile size and life-stage to refine our knowledge of size-at-age relationships.

4.3.1.6 Adult Returns

Monitoring questions

- Are supplementation strategies influencing adult returns to specific streams and watersheds?
- What is the status and trend of returning adults in experimental and control streams and watersheds?
- What percentage of offspring derived from translocations return to the interior Columbia River as adults?

Performance metrics

- Number of returning adults
- Number of returning adults that were offspring of translocated lamprey
- Historical estimates of returning adults

Performance may be influenced by a number of variables including river conditions (e.g. water temperature, stream flow, water velocity) and basin-wide adult returns (e.g. adult counts at Bonneville Dam).

Approach

Addressing the adult life history stage will require a variety of monitoring techniques. Pacific lamprey do not appear to be philopatric (in the strict sense we use for salmonids), which makes associating changes in adult returns to specific supplementation strategies problematic. The simplest approach will be to actively and passively monitor adult returns, in specific streams and watersheds, through a combination of active adult trapping, video and visual monitoring, or spawning/redd surveys. Many of these approaches require "bottleneck" locations (e.g. dams/diversions, waterfalls, manmade weirs) to facilitate passage/return estimates. Other approaches, such as spawning/redd surveys, may require significant manpower to complete.

Regardless of the approach used, any estimates of adult returns would need to be compared to historical estimates/counts to evaluate changes in adult returns in relation to specific supplementation strategies. Alternatively, if a long-term monitoring timeframe is utilized, in ~7+ years (around 2019) we could conceivably begin identifying returning adults that were derived from these translocation efforts. These adults would be tissue sampled as they pass Bonneville Dam and identified as translocation offspring through parentage analysis, utilizing our translocation broodstock genetic dataset (broodyears 2012-2015).

Analysis

Evaluating changes in adult returns will require a time series analysis of adult returns/estimates to specific streams and watersheds before, during, and after the implementation of supplementation strategies. Comparisons of adult returns/estimates before and after specific supplementation strategies would provide a qualitative assessment of adult returns. An assessment of adult returns in relation to supplementation strategies may be influenced by a number of variables including river conditions (e.g. water temperature, stream flow, water velocity) and basin-wide adult returns (e.g. adult counts at Bonneville Dam). These variables will need to be taken into account during analysis.

4.3.2 Larval and Juvenile Rearing

4.3.2.1 Broodstock survival

Monitoring questions

- How many adults survived and sexually matured in the second spring/summer season after collection?
- What water temperature regimes, water source (river vs. well water), and holding conditions (density, tank type and size, substrate, flow rates, diel light conditions, etc.) are optimal for increasing survival and sexual maturation?
- Does pheromone from larvae and adults (opposite sex) stimulate sexual maturation?
- Can sexual maturation be stimulated and synchronized using insulin-like growth factor and other hormonal chemicals?
- Under natural conditions, what proportions of adults spend more than a year to sexually mature?

Performance metrics

- Transportation and holding survival rates

- Sexual maturation rates
- Timing of sexual maturation
- Spawning rates (ability to successfully utilize gametes before they lose viability)

Performance may be influenced by a number of variables including water temperature, flow rates, water velocity, water depth, and substrate composition.

Approach
The primary goals of broodstock holding is to increase transportation and holding survival rates, increase sexual maturation rates, and enhance spawning success.

Efforts to collect, transport, and hold adult Pacific lamprey from the lower Columbia River have been largely successful with few observed mortalities. However, there are still important questions regarding the potential effects of artificial holding on the sexual maturation of adult lamprey. Although adults overwintering for multiple years may be a natural phenomenon, it is likely that the artificial holding conditions may negatively impact the rates of sexual maturation. It will be important to test and experiment the effects of various holding conditions (temperature, water source, lighting, etc.) strategically and systematically at various holding facilities to investigate the best conditions for successful sexual maturation.

Availability of larval and adult pheromone scents in the water may have an impact on this as well. An individual's genetic makeup may also affect its successful use in propagation. Sexually mature adults are often times covered with fungus and are extremely fragile and vulnerable and as a result, adults have a relatively short timeframe for successful spawning and propagation. If the sexual maturation is not in synchrony between males and females, gametes can often remain unused and go to waste. Insulin-like growth factor and other hormonal chemicals can be tested for its efficacy on synchronizing sexual maturation. It is important to note that what we learn from these propagation experiments will also help us improve the holding conditions for adult lamprey that are part of the translocation programs.

Analysis
Correlation and regression techniques can be used to assess the relationships between holding conditions, genetic makeup, and rates of survival and sexual maturation. It is important to compare the survival and sexual maturation rates among all the facilities that hold the adults and from that determine the key factors that drive success (namely high rates of survival and sexual maturation). Every year, certain tank conditions can be modified strategically within and among the various facilities to evaluate the effects.

4.3.2.2 Fertilization to hatch survival

Monitoring questions
- What spawning methods maximize the fertilization rates (methodology of gametes and water mixing, holding time, amount of water, chemical treatment, etc.)?
- What incubation methods maximize the hatching rates (McDonald jars, upwelling and downwelling jars, flow rates, chemical treatment, mesh size, etc.)?
- How long can gametes (eggs and milt) be preserved and remain viable using refrigeration, cryopreservation, etc.?
- How can we quickly count egg numbers to evaluate production levels and survival rates

Performance metrics
- Fertilization rates and successional egg development
- Hatching rates

- Genetic diversity and fitness

Ability of incubation methods to separate gametes (so that fertilization and hatching rates can be assessed for each spawner group)

Approach
Maximizing the fertilization and hatching rates are fairly easy tasks, given that we can emulate and fine tune the propagation protocols that already exist for other lamprey species in other countries as well as salmon species in general. The Yakima Nation and CTUIR have worked collaboratively since 2012 to investigate fertilization and hatching success and many improvements in protocols have been made since then (see section 4.2.2 for more information). A wide variety of incubation methods were compared and contrasted in 2012 to evaluate the success rates of various incubation methods. In 2013, more in-depth questions related to propagation were investigated to continue to refine and improve fertilization and hatching success.

Genetic diversity of Pacific lamprey is influenced by two main sources: 1) the pool of adults that were originally collected from lower Columbia river dams and 2) the degree to which mixing of adults occur in propagation (for instance, 3x3 or higher breeding matrices of males and females can enhance genetic diversity of offspring). Genetic fitness will need to be evaluated on a long-term basis as we collect more information on survival rates and eventually return rates in future years. Lamprey eggs and newly hatched prolarvae are extremely small, allowing them to slide through the smallest gaps in incubation trays and tank dividers. If we were to evaluate fertilization and hatching success accurately for each spawner group, it is important that we use an incubation method or holding vessels that minimize the unanticipated movement of eggs and prolarvae between trays and tank sections.

Analysis
Correlation and regression techniques can be used to assess the relationships between propagation and incubation conditions, genetic makeup, and rates of fertilization and hatching. Every year, certain elements of the protocols can be modified strategically to evaluate the effects on propagation success. Increasing the genetic diversity of off spring can be achieved by increasing the breeding matrices as well as the diversity of the source adult population. Subsequent genetic diversity of hatched larvae in the hatchery can be compared to that of hatched larvae from wild and/or translocated adults in the rivers and streams. Due to the limited number of adults and larvae present in many of the supplemented areas, striving to attain higher levels of genetic diversity appear important, but we may also discover later that certain genetic traits may be important fitness traits for survival in the upper Columbia reaches (such as large body lengths and weights).

4.3.2.3 Hatch to outplant survival

Monitoring questions
- What is the best conditions for maximizing prolarvae and larvae survival (density, water temperature, cover material, lighting conditions, etc.)?
- What type of holding tanks (circular, trough, inlet and outlet styles, etc.) provide the best conditions for prolarvae and rearing larvae?
- What substrate media (clay, silt, sand, artificial media, etc.) will be optimal for survival, growth, and monitoring of larvae?
- What type of feeds will be optimal for survival, growth, and the overall health of larvae?
- How can larvae be separated from substrate media in a timely manner with the least amount of stress incurred to them for monitoring and transfer/transportation?
- How can we quickly count larvae to evaluate survival and growth rates?

- What is the best way to maximize genetic diversity of the offspring?

Performance metrics

- Survival rates of prolarvae
- Survival and growth rates of feeding larvae
- Genetic diversity

Approach

Although experimental rearing of larvae in laboratory settings have been conducted for many decades, cases where lamprey were reared from eggs to larger larvae are rare. Based on the fact that Pacific lamprey has very high fecundity (~100,000 eggs per female), the survival rates of Pacific lamprey from egg to larva may be relatively low in the natural environment. In laboratory settings, however, there may be ways to greatly enhance the survival rates at this critical life history stage from eggs to larvae.

The Yakima Nation, CTUIR, USGS, and USFWS have worked collaboratively since 2012 to investigate larval rearing as well as the survival between egg/prolarva and larva life stages. Life stages between egg and prolarva is fairly easy to monitor as they do not require fine substrate for survival and many of the conventional fish hatchery tanks and equipment can be used effectively with small minor modifications. However, once the larvae is ready to feed, it appears that the presence of fine sediment, a medium through which larvae burrow and feed, is vital for their survival. On the flip side, this means that larvae will remain invisible for the majority of time, and monitoring for survival and growth becomes considerably difficult.

Newly hatched prolarvae and young larvae are extremely small (6~10mm long) and refining ways to enumerate them quickly and efficiently is crucial in evaluating the hatching success and survival in general. In 2013, The Yakama Nation has begun testing and calibrating XperCount device (an automated enumerating device for small fish/organisms by XpertSea, Inc - see http://www.xpertsea.com/ for more information) to find effective ways of counting these small larvae with minimal stress on fish.

Many questions still remain about appropriate feed for larvae in terms of survival, growth, and general fish health. Although active dry yeast has proven to be effective in attaining relatively high survival and growth within a short (<1 year) time frame, a certain combination of feeds in addition to active dry yeast (such as hatchfry feeds or marine larvae feeds) may be potentially effective in producing healthier fish and warrants further research. Protocols for rearing and monitoring larvae for extended periods of time (months and years) will need to be developed with ideally minimum handling impacts on larvae.

Analysis

Correlation and regression techniques can be used to assess the best methods to hold and rear prolarvae and larvae in terms of survival, growth, and general fish health. The variables of interest are tank settings, density, media substrate, feed type, feed amount and delivery system. Coordination and collaboration on these unique arrays of experiments among various agencies and tribes will be key to maximize our progress in this field of research. The genetic makeup of the surviving larvae will also be investigated to evaluate whether any natural selection is at work within the lab settings. Furthermore, genetic diversity of larvae in the hatchery can be compared to that of larvae from wild and/or translocated adults in the rivers and streams.

Various larvae extraction methods should also be compared and evaluated from the perspective of fish stress and survival as well as time efficiency. Unlike most other hatchery fish, lamprey larvae will need to be separated from the sediment in order to monitor them, so refining the methodology for this task will be important. Use of automated enumeration tools (such as XperCount) may be needed to effectively count and sort the hundreds of thousands of progeny produced from each female.

4.3.3 Larval and Juvenile Outplanting

4.3.3.1 Larval Survival and Growth

Monitoring questions

- How do the survival rates of propagated larval lamprey compare to naturally-produced lamprey?
- Did release timing and location negatively affect the growth and survival of larval lamprey within target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval growth and survival?
- Is genetic makeup associated with larval growth and survival?

Performance metrics

- Size, age, and abundance of larval lamprey
- Number of immigrants and emigrants
- Survival and growth rates

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

Approach

For propagation to be successful, released larvae need to grow and survive to the juvenile stage. Ideally, growth and survival rates would be compared to values for "wild" fish. If growth and survival are similar to or better than those measured for "wild" fish, propagation of larval lamprey would be considered a valid approach to improve the status of lamprey populations within subbasins. Growth and survival rates can be measured using parentage analysis. If all parents of propagated larvae are genetically sampled, then routine sampling of the juveniles while they mature in the wild could be used to track the offspring of adults that were spawned for the propagation efforts. These offspring could then be compared to wild larvae in the same area though confirming the age classes of the wild larvae may be difficult.

Alternative techniques to assess growth and survival rates of larval lamprey are not currently available. Visible Implant Elastomer (VIE) markings have been tested for various size classes of juvenile and larval lamprey (down to 30mm size) and appears to be a promising technique for marking early life stage lamprey. VIE marks appear to last for a long term. Survival appears to be very high but effects on feeding and growth requires further investigation. Fin clips have also been used to mark larval and juvenile lamprey, but their impacts on both survival and growth have not been evaluated extensively to date. Genetic analysis may be the best available approach for monitoring movement of larvae in and out of sites, aging larvae, and assessing handling effects.

Annual larval sampling within treated and untreated areas before and after propagation will be needed to assess growth and survival rates. This work should be done within target areas and areas supporting natural production of Pacific lamprey. This will allow the comparison of growth and survival rates between the two areas, especially if mark and recapture studies can be incorporated into the sampling.

Electrofishing techniques modified for sampling larval lamprey may be the most appropriate collection method for shallow water. Collected fish would be measured for length and weight, aged (method yet to be developed), and marked or tagged (standard method yet to be developed). A separate study would be needed to determine the effects of shocking, handling, and marking/tagging on larval lamprey growth and survival. This work would likely be conducted in a laboratory. Finally, lamprey biologists will need to identify a protocol for sampling habitat conditions.

Analysis
An appropriate model would be used to estimate growth and survival from mark-recapture data. These rates would then be compared between propagated and naturally produced larvae. Alternatively, we can also focus sampling in areas where the propagated and naturally produced larvae are well isolated from each other, if we can assume that immigration and emigration rates are minimal between the sampling dates. Because data will be collected annually, a time series of annual growth and survival rates can be generated and compared between populations and laboratory studies. Correlation and regression techniques can be used to assess the relationships among habitat conditions, larval abundance, growth rates, and potentially survival rates.

Although techniques are not currently standardized for continuously measuring growth and survival rates, length, weight, and condition factors can be compared among areas or groups of fish. In addition, using correlation and regression techniques, these factors can be evaluated to see if they are associated with densities (density-dependent effects) and habitat conditions.

4.3.3.2 Larval Abundance and Distribution

Monitoring questions
- How many larvae remained within the target areas over time?
- Did the distribution of released larvae expand into areas outside the target areas?
- Did release timing and location negatively affect the density and distribution of larval or juvenile lamprey within the target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval distribution and abundance?

Performance metrics
- Density of larvae (CPUE or fish/m^2)
- Distribution and abundance of larvae
- Presence and proportion of various size classes of larvae

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

Approach
An important assumption of propagation is that planted larvae will use intended rearing areas over time. Biologists will identify suitable release sites based on rearing conditions within those sites. If habitat is not suitable for rearing, propagated larvae may leave the area or die. Even if the habitat is suitable, larvae may naturally migrate downstream over time. If biologists are able to identify suitable rearing areas that are used successfully by propagated larvae, it may improve the status of Pacific lamprey within the subbasin.

Annual larval sampling within treated and untreated areas before and after propagation will determine the relative abundance of larvae within the target areas. Electrofishing techniques modified for sampling larval lamprey may be the most appropriate method for estimating relative abundance and distribution in shallow water. Locations of juveniles can be mapped using GPS. Lamprey biologists will need to identify a protocol for sampling habitat conditions.

Analysis

A time series of the densities (CPUE or fish/m^2) of larval lamprey and numbers of transformers can be constructed to show how densities and numbers changed before and after the propagation and release of larvae. Direct assessment of the abundance and distribution of planted larvae can be implemented via parentage analysis to identify offspring of adults that were spawned in the hatchery. Distribution maps can be generated that show how the spatial extent of larvae expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and larval abundance and distribution.

4.3.3.3 Larval and Juvenile Outmigration

See Section 4.3.1.5 for information on monitoring questions, performance metrics, approach and analysis.

4.3.3.4 Adult Returns

See Section 4.3.1.6 for information on monitoring questions, performance metrics, approach and analysis.

4.3.4 Experimental Controls

For supplementation to be successful, larvae produced by translocated adults or released from hatcheries need to survive, grow, and eventually transform and migrate. Ideally, survival, growth, and transformation rates would be compared to values for areas not being supplemented. If survival, growth, and transformation rates are similar to or better than those measured for areas not being supplemented, then translocation or propagation would be considered a valid approach to improve the status of lamprey populations within subbasins. Feasible approaches may range from simple comparisons of adult returns among areas to actual comparisons of larval survival, growth and transformation among areas. Non-supplemented "control" areas might be distinct watersheds within a subbasin being supplemented elsewhere, or a nearby subbasin considered a suitable control. The use of experimental controls is implicit in most of the approaches described above.

4.3.5 Genetic Monitoring and Analysis

Recently, a set of 96 high-throughput genetic assays (single nucleotide polymorphisms, SNPs) have been developed for Pacific lamprey and have been demonstrated to perform the following three critical functions: 1) species identification, 2) parentage assignment, and 3) characterization of adaptive variation (Hess et al. in prep). These functions have important implications for the conservation of Pacific lamprey, and have already been applied successfully to specific management questions. For example, 1) species identification via genetic analysis has been utilized to document a natural reintroduction of Pacific lamprey in a tributary in which this species was thought to be extirpated (Hess et al. in prep). The putative Pacific lamprey larvae that were collected were all 0-year age class, which is a particularly challenging age class to morphologically distinguish Pacific lamprey from other species such as Western brook lamprey, however in this case all larvae were confirmed as Pacific lamprey. 2) Parentage assignment has been utilized to verify reproductive success of translocated adults that had been released in 2007 into Newsome Creek (Snake River Basin). A smolt trap was used in 2012 to collect over a hundred juvenile lamprey of which nearly 100% were successfully assigned back to their parents that had been translocated in 2007 (Hess et al. in prep). Therefore, types of information that parentage assignment can provide includes a direct measure of reproductive success of a group of adults (e.g. number of viable offspring per spawner pair) and an accurate method for aging offspring. This latter piece of information is particularly critical for refining our understanding of the relationship between larval size and age distributions, and the age-timing of juvenile lamprey life-stage transformations (i.e. ammocoete to macropthalmia). 3) Adaptive variation that was found to be associated with morphology, run-timing, and geography (Hess et al. 2013) can be characterized using the 96 high-throughput assays, and was demonstrated to reflect differences in body-size and run-timing among adults collected at Willamette Falls in the Lower Columbia River. Specific adaptive genetic markers will be characterized in the adults used for supplementation to assess how the genotypes of individuals may help predict their reproductive success at particular supplementation sites. Therefore, these three central functions of the 96 SNPs will provide critical pieces of information needed to implement effective monitoring of these Pacific lamprey conservation efforts.

5 Supplementation Research Plans for Ceded Area Subbasins -- General Outline

This section provides a template for Subbasin Supplementation Plans that will be integral components of the RME Framework. Development of these plans is anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan (CRITFC 2011a), (2) USFWS Conservation Agreement for Pacific Lamprey (Lamprey Conservation Agreement; USFWS 2012) and (3) Northwest Power and Conservation Council Fish and Wildlife Program (NPCC 2009). Plans provide information specific to a subbasin regarding lamprey status, limiting factors, ongoing and planed actions, and rationale for those actions. Plans describe supplementation actions and RME actions associated with supplementation, including metrics, parameters, etc. Although plans will vary in scope and content among subbasins, each plan should provide a minimum of information described here to facilitate consistency and continuity of important methods, analysis, and reporting formats. An example plan for the Yakama River Subbasin is provided for further guidance in Appendix A.

5.1 Introduction

5.1.1 Subbasin Overview

Provide general information about the subbasin such as location, drainage size, annual and seasonal discharge, major topographic features, and important human population centers. Include information about major natural lakes and reservoirs, diversions, and other facilities potentially affecting passage or habitat quantity/quality. Briefly describe changes from the natural seasonal hydrograph, if any, and how changes in passage, habitat, and the hydrograph have affected Pacific lamprey.

5.1.2 Importance of lamprey in the ecosystem and as a cultural resource

Describe importance of Pacific lamprey to the ecosystem and tribal culture within the subbasin. Provide information on historic harvest sites, numbers, etc. if possible.

5.1.3 Brief Historic and Current status and USFWS findings for subbasins

Briefly summarize subbasin-specific information from the 2011 USFWS Conservation Assessment. Include information on potential population groupings and historic and current status and trends. If available, include information on limiting factors and critical uncertainties. Summarize information in tables as appropriate.

5.1.4 Ultimate goals and vision: natural production and harvest

State the overall goals or vision of the supplementation research plan. Demonstrate how these are consistent or complimentary with those of existing plans or programs. Examples may include the Tribal Restoration Plan, the Conservation Agreement, NPCC subbasin plans, or goals or plans of pertinent management entities.

5.2 Summary of Pacific Lamprey Status in the Subbasins

5.2.1 Adult abundance, run timing, and spawning locations

Summarize as much historical and current information as possible to document information on adult Pacific lamprey abundance and distribution in the subbasin. Use tables as appropriate. Discuss the implications of continuing downward trends when relevant. Summarize information on run timing if available.

5.2.2 Juvenile abundance and run timing (focusing on macrophthalmia)

Summarize as much historical and current information as possible to document information on juvenile Pacific lamprey abundance and distribution in the subbasin. Use tables as appropriate. Discuss the implications of continuing downward trends when relevant. Summarize information on migration timing if available.

5.2.3 Ammocoete abundance and distribution

Summarize as much historical and current information as possible to document information on ammocoete abundance, distribution, and habitat use in the subbasin. Use tables as appropriate. Note if information is specific to Pacific lamprey or includes brook lamprey. Discuss the implications of continuing downward trends when relevant.

5.3 Analysis Units (Optional)

Provide justification for partitioning Pacific lamprey within the subbasin into analysis units if applicable. Preference would be to adopt USFWS groupings. Additional justification for groupings may include management areas, passage constraints, differences in habitat quality/quantity, or others. Provide a map of the subbasin highlighting the various analysis units.

5.3.1 Analysis unit descriptions

Use subsections to define and describe each analysis unit. These should be referenced from existing documents if possible to avoid the need to define new geographic units. Include geographic bounds (e.g., watersheds included), and general descriptions of Pacific lamprey abundance and distribution.

5.4 Summary of Pacific Lamprey Primary Limiting Factors

Describe known limiting factors and critical uncertainties for Pacific lamprey in the subbasin. Use a different subsection for each analysis unit if applicable. For each unit, describe factors for adults, juveniles, and ammocoetes when possible. Use tables to summarize information. Example of limiting factors may include passage at dams and diversions (including juvenile or ammocoete entrainment), water quality, habitat quantity/quality, and others.

5.5 Lamprey Supplementation Research Actions over the Next 5-10 Years

Describe both ongoing and anticipated supplementation RME actions. Provide sufficient detail to fully describe and justify actions. Ensure that critical uncertainties, key hypotheses, and general monitoring strategies have been described. Include a summary of potential comparisons to assist in evaluating effectiveness of supplementation actions (Table 5-1). Describe any cross-regional efforts that are addressed. Examples of potential actions for the Grande Ronde, Tucannon, Walla Walla, Umatilla, and John Day subbasins, including comparisons and timelines, are provided (Table 5-3).

Table 5-1. Numerical codes for monitoring and evaluating the three supplementation research strategies described in section 4.3 of the *Framework for Pacific Lamprey Supplementation Research in the Columbia River* Basin.

4.3.**1**	Adult Translocation	4.3.**2**	Larval and Juvenile Rearing	4.3.**3**	Larval and Juvenile Outplanting
4.3.**1.1**	Adult Survival	4.3.**2.1**	Broodstock survival	4.3.**3.1**	Larval Growth and Survival
4.3.**1.2**	Adult Spawning	4.3.**2.2**	Fertilization to hatch survival	4.3.**3.2**	Larval Abundance and Distribution
4.3.**1.3**	Larval Survival and Growth	4.3.**2.3**	Hatch to outplant survival	4.3.**3.3**	Larval and Juvenile Outmigration
4.3.**1.4**	Larval Abundance and Distribution			4.3.**3.4**	Adult Returns
4.3.**1.5**	Larval and Juvenile Outmigration				
4.3.**1.6**	Adult Returns				

Table 5-2. Comparison chart displaying all potential comparison pairs of the different supplementation and research strategies. T = Translocation; larval/juvenile lamprey from translocated adults. P = Propagation; larval/juvenile lamprey born and reared in a hatchery environment. O = Outplanting; larval/juvenile lamprey artificially propagated and released into the natural environment. C = Control; larval/juvenile lamprey born and rearing in the natural environment.

Comparison	**T**ranslocation	**H**atchery	**O**utplanting	**C**ontrol
Translocation	TxT	HxT	OxT	CxT
Hatchery	TxH	HxH	OxH	CxH
Outplanting	TxO	HxO	OxO	CxO
Control	TxC	HxC	OxC	CxC

Table 5-3. Lamprey supplementation research actions over the next 5-10 years within the ceded areas of the Confederated Tribes of the Umatilla Indian Reservation. See Tables 5-1 and 5-2 for Research Comparison and Monitoring and Evaluation Approach codes.

Subbasin	Stream	Location	Supplementation Research Strategy								Timeline
			Adult Translocation (T)		Hatchery Rearing (H)		Larval and Juvenile Outplanting (O)		Control (C)		
			M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison	
Umatilla	Umatilla River	mainstem Umatilla River	4.3.1. **1, 4-5**	*xT, xH, xC*							1-3 years
			4.3.1. **2**								5+ years
		Upper Maxwell Diversion					4.3.3. **1-2**	*xH, xO*			1-3 years
Walla Walla	Walla Walla	upper Walla Walla	4.3.1. **1-3**	*xC*							10 years
		lower Walla Walla					4.3.3. **1**	*xT, xH*			5+ years
							4.3.3. **2**	*xH*			10 years
Tucannon	Tucannon	upper Tucannon					4.3.3. **1-2**	*xT, xC*			5+
							4.3.3. **3**	*xO*			10 years
Grande Ronde	Grande Ronde	mainstem Grande Ronde	4.3.1. **1, 3**	*xT, xC, xH*							1-3 years
			4.3.1. **2**	*xO*							5+ years
John Day	John Day	mainstem John Day							4.3.4	*xT, xH, xO, xC*	Ongoing
		Mukilteo*			4.3.2. **1-3**	*xH*					1-3 years
		Walla Walla Community College (WEC)*			4.3.2. **1-3**	*xT, xH, xO, xC*					1-5 years

**indicates rearing in artificial settings*

Appendix C. Pacific Lamprey Restoration and Supplementation Research Plan – Umatilla River Subbasin

Pacific Lamprey Restoration and Supplementation Research Plan – Umatilla River Subbasin

Confederated Tribes of the Umatilla Indian Reservation

November 2013

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Contents

Tables

Figures

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1 Introduction

1.1 Subbasin Overview

The Umatilla River originates in the Blue Mountains of northeastern Oregon and flows north and west to enter the Columbia River in Umatilla, Oregon at river mile (RM) 289 (Figure 1-1and Figure 1-2). The mainstem Umatilla River is 89 miles long and drains an area of nearly 2,290 square miles (Phelps et al. 2004). Elevations in the Umatilla River subbasin range from about 5,800 feet near Pole Springs on Thimbleberry Mountain to 260 feet at the confluence with the Columbia River.

The subbasin experiences strong seasonal fluctuations in both temperature and precipitation. In summer the days are warm and nights are cool (summer highs and lows in Umatilla are 88 ^{o}F and 61 ^{o}F, respectively), whereas winters are much colder, with average temperatures often only slightly above freezing. Most precipitation in the subbasin falls during fall, winter and spring. Precipitation falls mainly as rain in the northwestern, low elevation portion of the subbasin and averages approximately nine inches annually. Up to 55 inches of precipitation falls in high-elevation areas of the Blue Mountains with much of this occurring as snowfall.

Water development for irrigation has had a large impact on both the hydrology and ecology of the Umatilla River Subbasin. Irrigated agriculture is served by six diversion dams found in the lower Umatilla River (from RM 4.1 to RM 32.4) and two reservoirs, Cold Springs and McKay Creek. During the summer months, discharge in the lower Umatilla River decreases with water withdrawals and increases slightly with irrigation return water. Water is released from McKay Reservoir at RM 50.5 during peak irrigation periods. The impact of water storage in McKay Reservoir and releases during summer is to lower mean monthly instream flows during winter when water is stored and increase flows during the summer when stored water is released for irrigation.

The Umatilla Basin Project Act passed by Congress in 1988 allows irrigators to exchange Umatilla River water for Columbia River water. This allows water historically appropriated for irrigation to remain in the Umatilla River during times when flows are critical for juvenile and adult steelhead and salmon in spring and fall. Despite this progress, irrigation still removed approximately half of the instream flows from June through September. Beginning in 2006, an extension of the pumping period during July and the first half of August has provided minimum passage flows for adult Pacific lamprey during their peak migration period when flows have normally been near zero. One important effect of water use by agriculture is an increase in summer water temperatures, which decreases the availability of the lower river as habitat to lamprey and salmonids, although releases from McKay Reservoir from June to September have a beneficial impact on temperature and flow from June through September.

1.2 Importance of Pacific Lamprey

Historically, Pacific lamprey were used both as food and for medicinal purposes by Native Americans throughout the Columbia basin (Close 1999). Lamprey numbers have declined dramatically in the subbasin over the past century and there is no longer a tribal harvest of these animals. From a tribal perspective, the decline of lamprey continues to have at least three negative effects: (1) loss of cultural heritage, (2) loss of fishing opportunities in traditional fishing areas, and (3) necessity to travel great distances to lower Columbia River tributaries for ever-decreasing lamprey harvest opportunities. As a

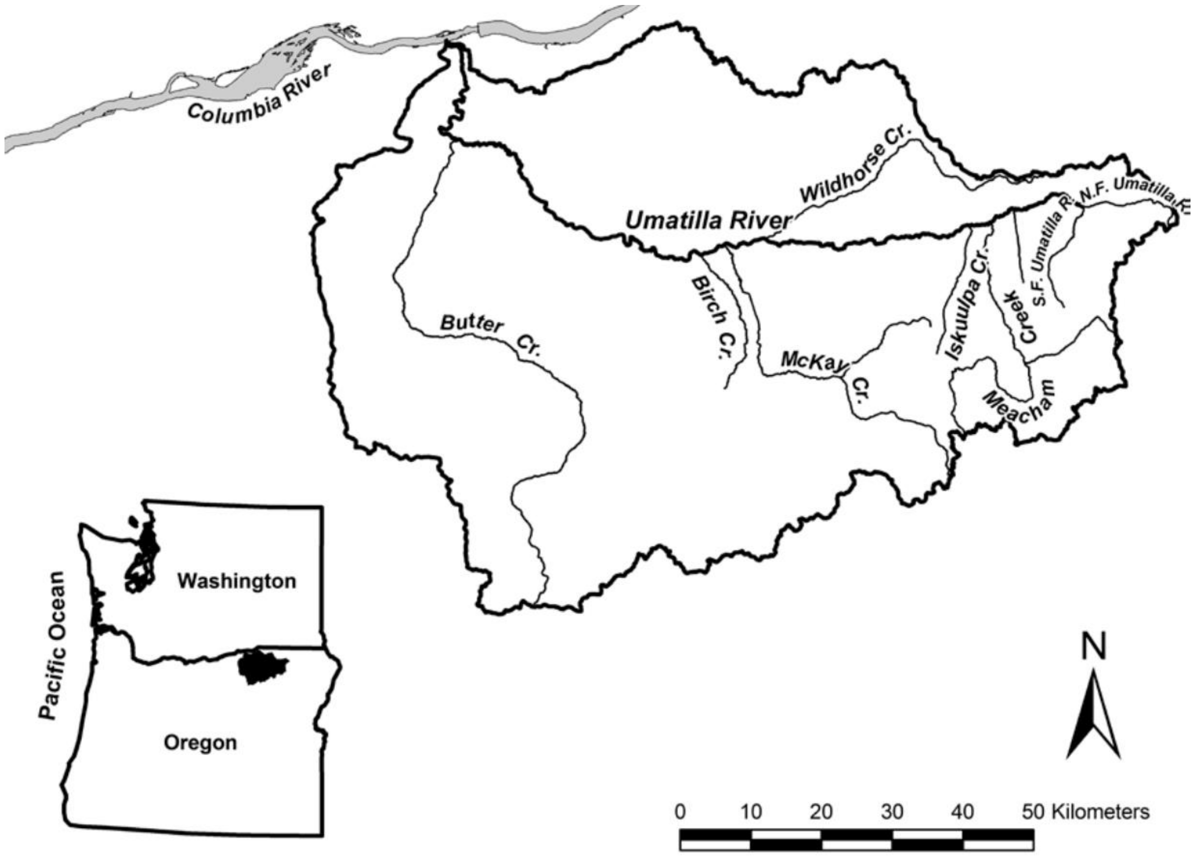

Figure 1-1. Map of the Umatilla River Subbasin in northeastern Oregon (from Jackson and Moser 2013).

consequence of restriction or elimination of harvest in interior Columbia River tributaries, young tribal members are losing historically important legends associated with lamprey because they have not learned how to harvest and prepare them.

For countless generations people of the CTUIR have depended on lamprey for food and medicine. Tribal members historically harvested lamprey in a sustainable manner, taking only what their families needed for subsistence. Through the years, many stories and legends surrounding the eel were passed down from generation to generation and this important species has become an integral part of tribal culture. And, the tribes clearly recognize that restoration of lamprey populations is necessary for the restoration of the ecological health of Pacific Northwest watersheds, along with salmonids and other native fish populations.

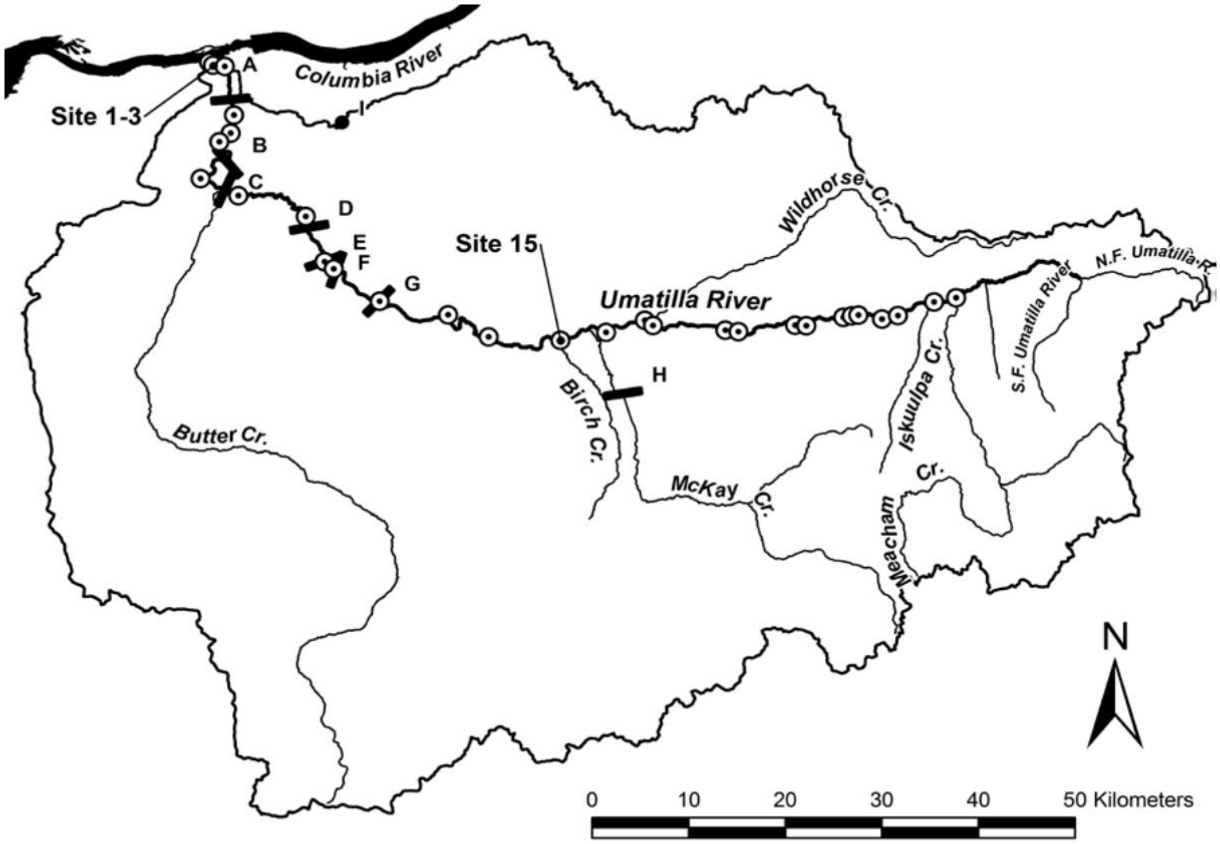

Figure 1-2. Location of irrigation diversion dams (black rectangles) and larval lamprey sampling sites (circles) in the Umatilla River Subbasin. Three Mile Falls Dam = A, Boyd Hydro Dam = B, Maxwell Diversion Dam = C, Dillion Dam = D, Westland Diversion Dam = E, Feed Canal Dam = F, Stanfield Dam = G, McKay Dam = H, Cold Springs Dam = I.

1.3 USFWS Conservation Assessment Findings

The 2011 USFWS Pacific Lamprey Assessment and Template for Conservation Measures (Luzier at al. 2011) characterized the status of Pacific lamprey as "imperiled to critically imperiled" for the Umatilla River subbasin. The ratio of current to historic distribution within the subbasin was assigned a value of 0.5. Primary factors limiting Pacific lamprey and habitat in the subbasin include passage, dewatering and flow management, stream and floodplain degradation, water quality, predation, and small population size (Table 1-1).

Table 1-1. Limiting factors for Pacific lamprey and habitat in the Umatilla River subbasin, as identified and ranked by participants in regional meetings. Scores range from high (4) to insignificant (1). From Luzier et al. (2011).

Threat	Scope	Severity
Passage	4	3.5
Dewatering and flow management	3	3.5
Stream and floodplain degradation	4	4
Water quality	3.5	3
Small population size	3	3

1.4 Vision and Goal

The Vision for this Restoration and Supplementation Research Plan is consistent with the Vision outlined in the 2004 Umatilla Subbasin Plan (Phelps et al. 2004):

"*The vision for the Umatilla/Willow subbasin is a healthy ecosystem with abundant, productive, viable, and diverse populations of aquatic and terrestrial species, which will support sustainable resource-based activities that contribute to the social, cultural, and economic well-being of the communities within the subbasin and the Pacific Northwest*."

This strategy is also consistent with the goal of Restoration Plan for Pacific Lampreys in the Umatilla River, developed by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) (Close 1999). That goal was to restore natural production of Pacific lampreys in the Umatilla River to self-sustaining and harvestable levels. The Umatilla River basin was chosen by the CTUIR as an initial pilot project because: 1) the Umatilla River historically produced a fishable population of lampreys, 2) restoration efforts for salmonids in the basin may accelerate Pacific lamprey restoration, and 3) the current population of Pacific lampreys in the Umatilla River is extremely low.

2 Summary of Pacific Lamprey Status in the Umatilla Subbasin

Through oral interviews with tribal members and former state and federal agency fisheries personnel, Jackson and Kissner (1997) determined that Pacific lamprey were historically abundant, and that fishing occurred throughout the Umatilla Subbasin. No records were kept of lamprey counts, but former agency personnel noted that "there were so many adult Pacific lamprey in the Umatilla River that they were a nuisance." Tribal members and agency personnel stated that abundance decreased dramatically after rotenone treatments in 1967 and 1974. Throughout the 1990's very few Pacific lamprey were observed, although 12 adult Pacific lamprey were found in the ladder at Three Mile Falls Dam during dewatering in 1996. No Pacific lamprey were collected during numerous electroshocking surveys upstream from the dam in the 1990s. Kostow (2002) noted that lamprey production in the Umatilla appeared to be restricted to the lower few miles of the subbasin, and that Pacific lamprey may be gone from the upper subbasin.

2.1 Adult Abundance, Run Timing, and Spawning Locations

2.1.1 Abundance

In 1999, the CTUIR developed and began implementing a peer-reviewed restoration plan for Pacific lamprey (Close 1999). The restoration plan called for 1) locating an appropriate donor stock for translocation of adult Pacific lamprey, 2) identifying suitable and sustainable habitat within the subbasin for spawning and rearing, 3) translocating up to 500 adult lampreys annually, and 4) long-term monitoring of spawning success, changes in larval density and distribution, juvenile growth and outmigration, and adult returns. Translocations of adults began in 2000 (Table 1-2). The number of adults observed in the Umatilla River increased beginning four years after the first translocations, with a clear increase beginning after six years (Figure 2-1), although the total number of individuals entering the Umatilla River remained relatively low through 2010.

Table 1-2. Releases of adult Pacific lamprey into the Umatilla River Subbasin, 2000-13, as part of a translocation program. Rkm = river kilometer.

Year	Number released	Umatilla River			Iskúulktpe Creek	Meacham Creek	South Fork Umatilla River
		Rkm 98.8	Rkm 118.4	Rkm 139.9			
2000	600	--	150	300	--	150	--
2001	244	--	82	81	--	81	--
2002	491	150	100	141	--	100	--
2003	484	--	90	110	54	230	--
2004	133	--	--	63	--	70	--
2005	120	--	--	50	15	55	--
2006	198	--	--	90	21	87	--
2007	394	--	--	200	25	169	--
2008	68	--	--	26	--	42	--
2009	337	--	--	100	25	150	62
2010	291	--	--	128	13	150	--
2011	89	--	--	40	10	39	--
2012	232	--	--	130	12	90	--
2013	259	--	--	126	10	123	--

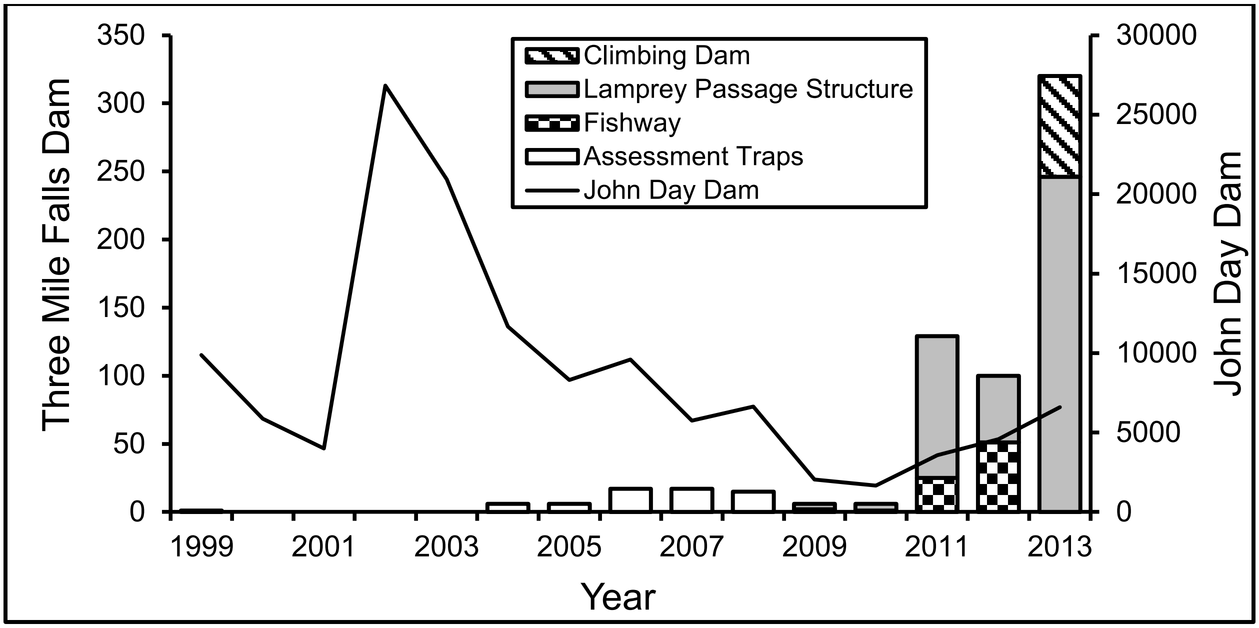

Figure 2-1. Number of adult Pacific lamprey counted at Three Mile Falls Dam on the Umatilla River (bars) and at John Day Dam on the Columbia River (line).

To be proactive and with expected increased returns of adult lamprey forthcoming, an adult radio telemetry study was initiated in 2005 to identify adult passage bottlenecks at low-elevation diversion dams within the subbasin. Results from the radio telemetry study identified where adults were having difficulties passing these structures and helped prioritize which diversion dams needed improvement first. After installation of a lamprey passage structure at Three Mile Falls Dam, the number of adults counted increased substantially in 2011 (Figure 2-2).

2.1.2 Run Timing

Information on adult run timing into the Umatilla River Subbasin is limited to what can be concluded from counts at Three Mile Falls Dam since adults began entering the Umatilla River again in 2004. Information collected since adults began returning in greater numbers in 2011 indicates that numbers of returning adults appears to peak in May and then again in August/September (**Error! Reference source ot found.**). During these same years, adults were generally observed at John Day Dam from May through October, with counts peaking in early August. It is likely that the adult lamprey observed at Three Mile Falls Dam in May had passed John Day Dam the previous year and held in the Columbia River prior to ascending the Umatilla River to spawn. Fish observed at three Mile Falls Dam in August/September likely passed John Day Dam the same year, and some may over-winter in the Umatilla River before spawning.

2.1.3 Spawning Locations

Little is known about the current extent of Pacific lamprey spawning in the Umatilla River Subbasin; however, in 2001, 2002, 2009, and 2010 surveys were conducted by foot on the Umatilla River and Meacham Creek to locate lamprey redds. Surveys were conducted in 1) the mainstem Umatilla River

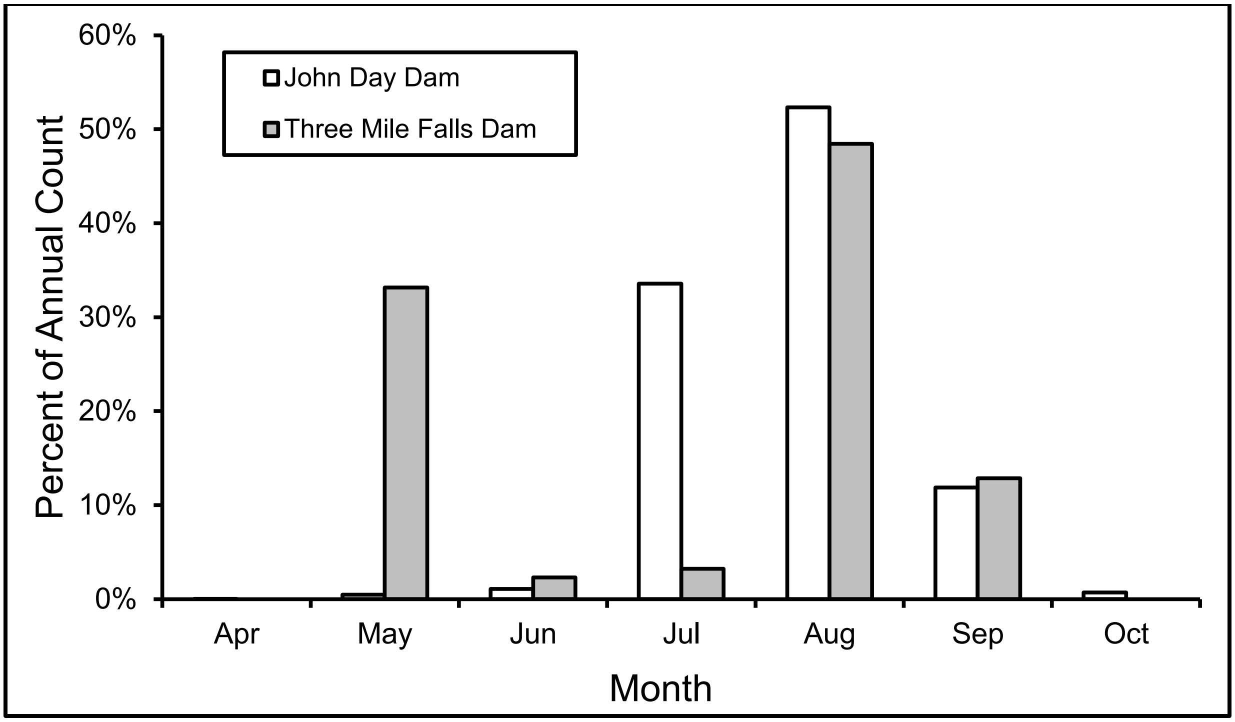

Figure 2-2. Average 2011-2013 run timing of adult Pacific Lamprey at John Day and Three Mile Falls dams expressed as mean percent of annual counts.

above river kilometer 90 to the confluence of the north and south forks, 2) the lower 4 km of North Fork Umatilla River, 3) the lower 4 km of the South Fork Umatilla River and 4) the lower 24 km of Meacham Creek.

Translocated lamprey spawned and produced viable eggs. In 2001, 19 viable redds were found in the Umatilla River and 30 were found in Meacham Creek. In 2002, 21 viable redds were found in the Umatilla River and 46 were found in Meacham Creek. Mean egg viability per redd was 93.4% in the Umatilla River and 81.4% in Meacham Creek. No redds were found in the North Fork or the South Fork of the Umatilla River.

Eighty one and 85 redds were identified during surveys in 2009 and 2010, respectively. In 2009, redds were located above release locations in Iskúulktpe Creek, and above and below release locations in the Umatilla River and in Meacham Creek (Figure 2-3).

2.2 Juvenile Abundance and Run Timing

The out-migration of larval and metamorphosed lampreys has been monitored from approximately October through May using rotary-screw trap located about 1.2 miles upriver from the mouth. Abundance of outmigrating lamprey in the Umatilla River has increased in most years since restoration efforts began (Figure 2-4).

Captured juvenile lamprey are counted and identified to life stage and species. Periodic past examinations of the captured lamprey between 2010 and 2013 indicate that the majority of these outmigrating juvenile lamprey during the winter high flow conditions are Pacific lamprey macrophthalmia; hence, these counts

Figure 2-3. Locations of Pacific lamprey redds observed during surveys in 2009 and 2010 relative to locations where translocated adult Pacific lamprey were released.

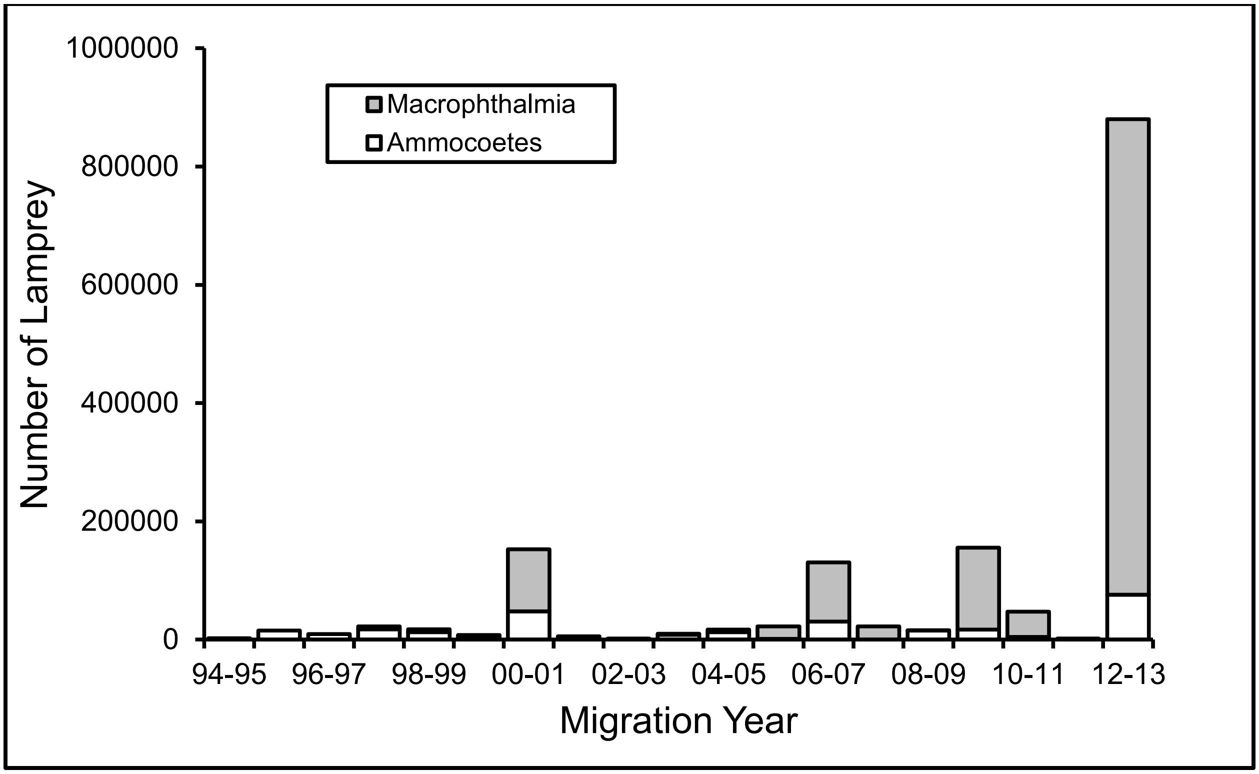

Figure 2-4. Yearly estimates of the number of migrating Pacific lamprey ammocoetes and macrophthalmia in the lower Umatilla River.

could potentially be used as an index for juvenile lamprey abundance. Additionally, a large proportion of ammocoetes are captured in the trap. It is likely that these lamprey are completing the juvenile rearing stage in the mainstem Columbia River. Catches of larval and juvenile lamprey are highest from December through March, with catch (both life history forms combined) in 2013 peaking in March (Figure 2-5).

2.3 Ammocoete Abundance and Distribution

Thirty sites have been sampled in the Umatilla River in August and September annually since 1999 to document ammocoete densities and distribution. All sites were 7.5 m^2 in area with silt substrates where ammocoetes are typically most abundant. Ammocoete density in these index plots sharply increased one year after translocation of adult lamprey (Figure 2-6). Mean densities remained elevated through 2012.

Larval distribution also increased through time (Figure 2-7). In the years prior to translocation of adults, no larvae were found in the upper Umatilla River. One year after translocation of adults, larval densities increased and the distribution of larvae moved downstream. By 2007, larval distribution extended downstream to the middle reaches of the Umatilla River, with little change in larval densities in the lower river. Distribution in 2011 was similar to that in 2007.

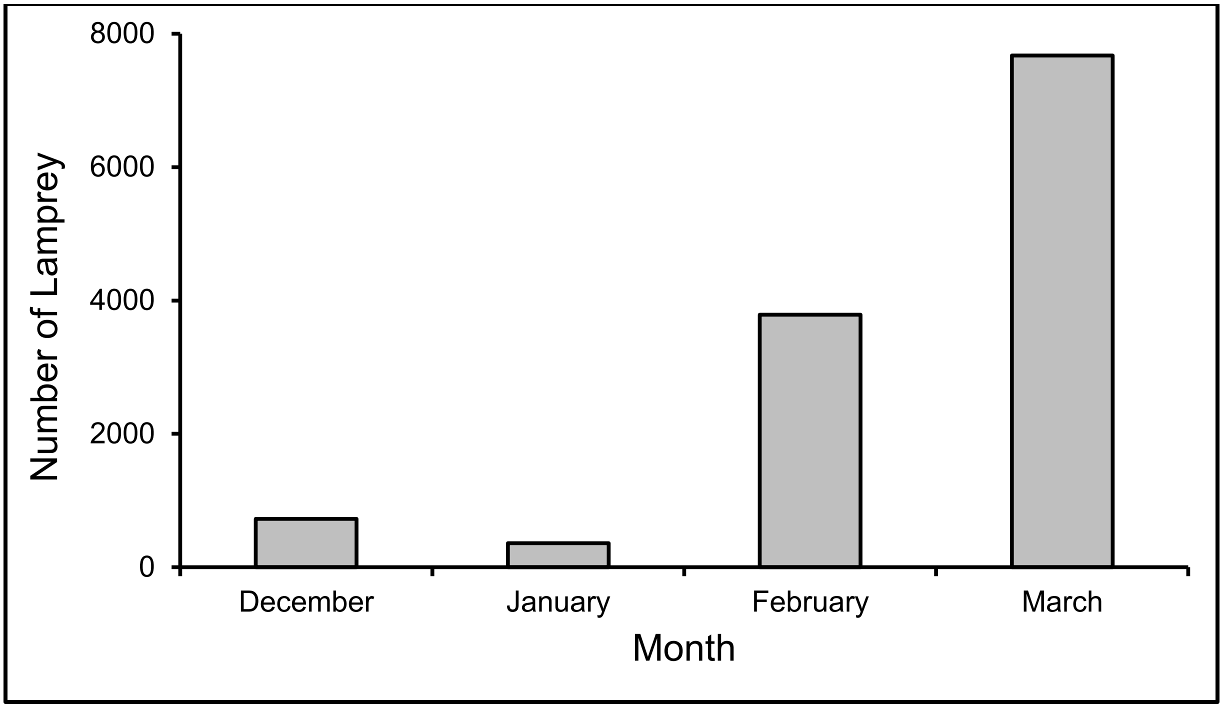

Figure 2-5. Number of lamprey ammocoetes and macrophthalmia captured in the lower Umatilla River from December 2012 through March 2013.

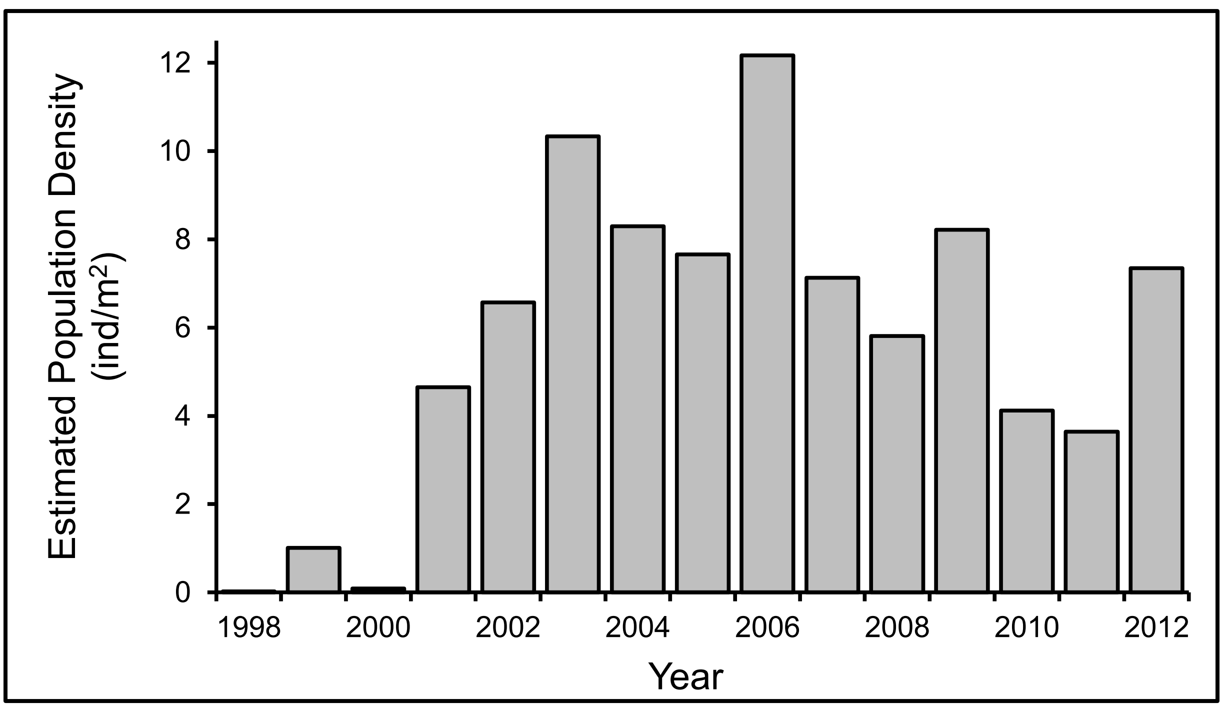

Figure 2-6. Changes in ammocoete densities (mean of 30 index sites), 1999-2012.

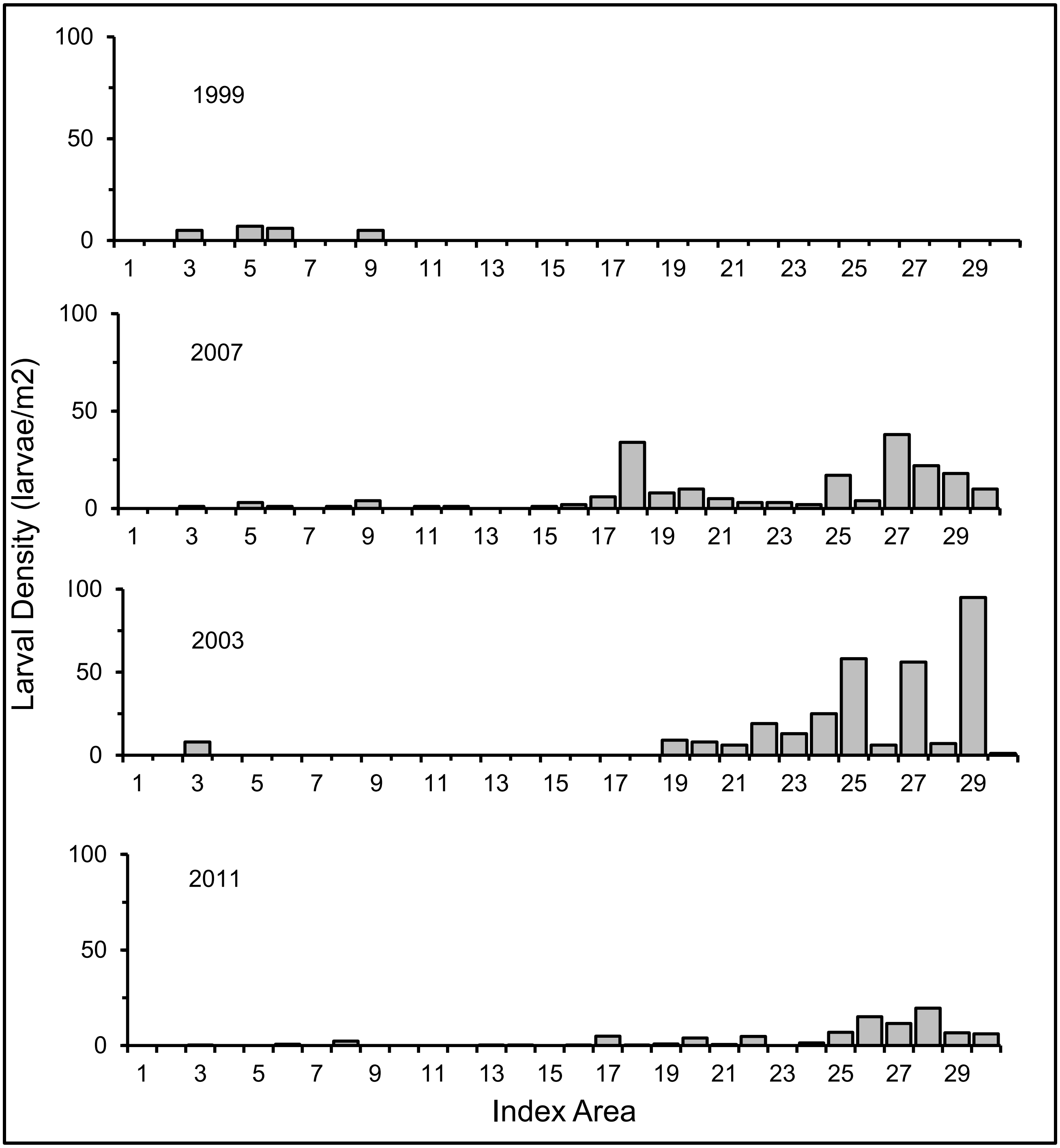

Figure 2-7. Density of Pacific lamprey ammocoetes in the Umatilla River, 1999-2011. Index plot 1 is near the mouth and index plot 30 is in the upper Umatilla River.

3 Summary of Pacific Lamprey Limiting Factors

3.1 Upstream Passage: Adults

Dams are known to be a challenge to Pacific lamprey passage, whether large head hydroelectric dams of the Columbia River or irrigation dams along smaller tributaries, such as the Umatilla River. In 2005, a radio telemetry study was initiated to determine if seven low elevation dams on the Umatilla River impede upstream passage of adult Pacific lamprey (Jackson and Moser 2012). Results indicated that fewer than 50% of the lamprey that approach Three Mile Falls Dam were able to pass successfully. The removal of Boyd's Diversion dam in fall of 2006 resulted in a substantial improvement in lamprey passage through this area, particularly for spawning-phase fish. Some lower elevation dams (< 2m) such as Dillon and Westland diversions were found to impede passage, whereas others such as Maxwell and Stanfield diversions allowed higher rates of passage. Recommendations based on results from the telemetry studies included fitting Three Mile Falls, Maxwell, Dillon, Westland, Feed, and Stanfield diversion dams with lamprey passage structures. Considerations for Boyd's diversion would be made if FERC relicenses this facility.

3.2 Downstream Passage: Juvenile Entrainment

Juvenile lamprey are likely entering many irrigation diversion ditches within the Umatilla River Subbasin and getting behind various screens designed for salmonid criteria. To date, only preliminary work has commenced to understand how juvenile lamprey are actually getting behind these screens. Investigations are currently underway to understand this issue and to develop and implement new screening criteria. The CTUIR will continue to survey irrigation ditches throughout much of the subbasin over the next five years, and expand juvenile outmigrant PIT tagging as a measure to evaluate current screen effectiveness. However, resources for this work are extremely limited.

3.3 Dewatering and Flow Management

Water management has substantially changed flow conditions throughout much of the Umatilla River Subbasin (Phelps et al. 2004). Multiple diversions still remove approximately half of the instream flows from June through September. Much of the flow in the Umatilla River was diverted at Three Mile Falls Dam, preventing continuous flow from reaching the Columbia River. The lack of flow during peak migration periods may explain why few adults were detected at Three Mile Falls Dam.

Beginning in 2006, an extension of the Umatilla Basin Project Act implemented pumping from the Columbia River during July and the first half of August to provide recommended passage flows for adult Pacific lamprey during their peak migration period when flows have normally been near zero. The "year round" exchange period is now necessary because increased numbers of adult lamprey are expected as a result of the ongoing restoration program.

3.4 Stream and Floodplain Degradation

Land use practices have improved significantly over the past few decades. Land managers, local land owners, and others have improved habitat management to enhance watershed conditions to support anadromous salmonids. Actions to improve watershed conditions from the uplands to the floodplain are allowing, in some cases, natural ecosystem functions to recover. Although many steps have been taken, many more are needed. Habitat degradation from past and/or present land use remains a key concern. Pacific lamprey have been adversely affected by degraded channel structure and complexity (including riffles, pools and large woody debris), loss of riparian vegetation, and reduced floodplain connectivity. Threats contributing to these factors include agricultural, forestry and grazing practices, roads, railroads and channel manipulations.

3.5 Water Quality: Temperature

Water temperature is a concern throughout most of the Umatilla River subbasin during periods of low flow from May through early November (Phelps et al. 2004). The highest water temperatures have been recorded in late July and early August when ambient air temperatures are high. During this period, the Umatilla River warms rapidly from the headwaters to the mouth, reaching sub-lethal (64-74 °F) and incipient lethal temperatures (70-77 °F) for its entire length (Phelps et al. 2004). Summer water temperatures in Meacham Creek are frequently in the high 60s ºF. However, maximum summer temperatures drop further downstream as a result of cold water releases from McKay Reservoir for the benefit of irrigation and fish. Excessive stream temperatures in the Umatilla River Subbasin are influenced primarily by non-point sources including riparian vegetation disturbance (reduced stream surface shade), summertime diminution of flow (reduced assimilative capacities), and channel widening (increased surface area exposed to solar radiation).

3.6 Small Population Size

Pacific lamprey abundance in the Umatilla River subbasin is critically low, and in some watersheds, presumed extirpated. Although ongoing translocation has helped alleviate the problem, low adult counts excluding those translocated raises the questions "can adults successfully find a mate?" and "what are the genetic risks associated with such a low brood population?".

3.7 Critical Uncertainties

In addition to these known primary limiting factors, many other critical uncertainties exist that may play a significant role in the abundance of Pacific lamprey in the Umatilla River Subbasin. The effects of water quality including contaminants and toxicants are largely unknown at this point. Because of the early life history of lamprey (burrowing in fine sediment in low gradient channels for several years), the likelihood that ammocoetes are exposed to a high level of toxicants is high. Predation is also a potential threat to Pacific lamprey. The number of native and non-native piscivorous predators (fish, avian, mammal) has increased greatly in the Columbia River Basin. Because of the lamprey's lack of bone structure, most studies examining the stomach content of predators miss clues about juvenile lamprey predation, especially for ammocoetes because they also lack teeth. Global climate change appears to be eminent and will likely affect the flow dynamics and temperatures of watersheds in the Umatilla River Subbasin. Some prediction models indicate that the timing of snow melt floods will arrive earlier than it has been in the past, further reducing flow in late summer. This may further hinder the upstream migration of adult Pacific lamprey.

4 Ongoing / Planned Lamprey Restoration Actions over the Next 5-10 Years

Restoration actions are intended to address priority limiting factors across the Umatilla River Subbasin. Recognizing that lamprey need to use habitats that extend widely, our strategy views the Umatilla River subbasin holistically, and recommends priority actions across the subbasins as part of the overall recovery strategy. See Section 5 for more specific information.

- **Passage.** Complete fitting priority diversion dams with passage structures specific to adult Pacific lamprey. Passage structures have been installed at Three Mile Falls, Maxwell, Dillon, and Feed dams. Current priority actions include installing a passage structure at Westland Dam, and modifying passage features at Feed, Brownell, and Stanfield diversions. Continue to evaluate passage at all diversions to obtain information needed to maximize efficiency of passage structures.
- **Entrainment.** Continue to evaluate the degree that entrainment is occurring within irrigation diversion ditches, identify priority locations to focus near-term work and implement corrective actions.
- **Supplementation.** Continue to implement the adult translocation program initiated by the CTUIR in 2000). Monitoring has demonstrated that released individuals survive, breed, and produce offspring. Translocated lamprey were able find suitable spawning habitat, construct nests and deposit viable eggs; their larvae were able to feed, grow, and migrate downstream; and the geographical distribution and abundance of larvae expanded in the Umatilla River. Adults subsequently returned to the river, although more monitoring is needed to determine whether these were the results of the introductions. Long-term monitoring will be required to track trends in abundance, distribution, and diversity, and to be able to assess persistence and the need to intervene further.
- **Biological Surveys**. Continue to document current status of adult and juvenile lamprey presence, distribution, and relative abundance. Continue to identify, describe and monitor key Index Sites for long-term status and trends at the reach, watershed and at the subbasin context.
- **Habitat Surveys**. Identify habitat characteristics that are preferred at various life stages (habitat quality) and determine the extent (habitat quantity) these areas are available and are being utilized.
- **Habitat Restoration**. Consider certain types of in-stream restoration efforts to benefit salmonids and to monitor potential benefits towards lamprey productivity. Habitat quality and quantity may not be limiting population growth at this time because of relatively low lamprey abundance. However, some restoration activities in key stream reaches (Meacham Creek, Birch Creek, and the mid to upper Umatilla River) will benefit both salmonid and lamprey recovery.
- **Coordination and Collaboration**. Continue to work directly and collaboratively with local and regional land and resource management agencies and entities to develop and implement a well-founded public involvement and information strategy and to gain efficiencies in both time and resources in implementing lamprey restoration actions.

5 Ongoing / Planned Lamprey Supplementation Research Actions over the Next 5-10 Years

As described in the restoration plan for Pacific lamprey (Close 1999), supplementation in the Umatilla River Subbasin is focused on translocation of adults and long term monitoring of success. Over 3,900 adult Pacific lamprey were translocated into the subbasin from 2000 through 2013. Lamprey are held until they are considered sexually mature and then released into spawning habitat that has been determined to be suitable for adult spawning. This is typically the same type of spawning habitat that is utilized by summer steelhead and spring Chinook.

Monitoring the success of translocation efforts has been underway since 2000. Pacific lamprey require extensive post-reintroduction management and a well-designed monitoring program. This is in part due to the long life cycle of Pacific lamprey and the likelihood that they do not home to natal streams. Current research and monitoring efforts therefore follow guidelines described in the Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin (Table 1-3 through Table 1-5).

Table 1-3. Numerical codes for monitoring and evaluating supplementation research strategies. Strategies are described in Section 4.3 of the Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin; codes reflect the section number in the Framework document.

Translocation		Hatchery		Outplanting	
4.3.1	Adult Translocation	**4.3.2**	Larval and Juvenile Rearing	**4.3.3**	Larval and Juvenile Outplanting
4.3.1.1	Adult Survival	**4.3.2.1**	Broodstock survival	**4.3.3.1**	Larval Survival and Growth
4.3.1.2	Adult Spawning	**4.3.2.2**	Fertilization to hatch survival	**4.3.3.2**	Larval Abundance and Distribution
4.3.1.3	Larval Survival and Growth	**4.3.2.3**	Hatch to outplant survival	**4.3.3.3**	Larval and Juvenile Outmigration
4.3.1.4	Larval Abundance and Distribution			**4.3.3.4**	Adult Returns
4.3.1.5	Larval and Juvenile Outmigration				
4.3.1.6	Adult Returns				

Table 1-4. Comparison chart displaying all potential comparison pairs of the different supplementation and research strategies. T = Translocation; larval/juvenile lamprey from translocated adults. H = Hatchery; larval/juvenile lamprey born and reared in a hatchery environment. O = Outplanting; larval/juvenile lamprey artificially propagated and released into the natural environment. C = Control; larval/juvenile lamprey born and rearing in the natural environment.

Comparison	Translocation	Hatchery	Outplanting	Control
Translocation	TxT	HxT	OxT	CxT
Hatchery	TxH	HxH	OxH	CxH
Outplanting	TxO	HxO	OxO	CxO
Control	TxC	HxC	OxC	CxC

Table 1-5. Lamprey supplementation research actions over the next 5-10 years within the Umatilla River Subbasin. See Error! Reference source ot found.**and** Error! Reference source not found. **for the monitoring and evaluation (M&E) and comparison codes.**

Location	Supplementation Research Strategy								Start Timeline	End Timeline
	Adult Translocation (T)		Hatchery Rearing (H)		Larval and Juvenile Outplanting (O)		Control (C)			
	M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison		
Mainstem Umatilla River	4.3.1.1 – 4.3.1.5	TxC TxH TxT	--	--	--	--	--	--	Ongoing	1-3 years 5+ years 1-3 years
Upper Maxwell Diversion	--	--	--	--	4.3.3.1 - 4.3.3.2	OxH OxO	--	--	Ongoing	1-3 years 1-3 years

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INVENTORY OF ADULT TRANSLOCATION SITES IN THE UMATILLA RIVER SUBBASIN

ADULT TRANSLOCATION SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
EXAMPLE		**Owner name**	**Habitat type/configuration, known flow levels, access limitations**	**Currently extirpated, unknown, population verified (relative size of population, if known)**	**Include existing/ongoing/previous monitoring efforts and potential for future monitoring. (E.g., existing survey data, plans for future surveys, locating antenna arrays, dam counting, screw traps)**	**This column is for any pertinent goals that would be specifically addressed by supplementation at this particular location.**
Reith	Umatilla River, Rkm 67.92, accessed via dirt road off Umatilla River Rd (Reith Rd) Lat: 45.659783° Long: -118.971669°	Private	Large deep pool at release site.	Larvae (electrofishing) and adults (radio telemetry) documented in the area.	Has not been used as translocation site in last decade.	
Reith (2)	Umatilla River, Rkm 74.7, accessed via dirt road off Umatilla River Rd (Reith Rd) Lat: 45.648743 Long: -118.904941	Private	Large deep pool at release site.		Has not been used before.	

ADULT TRANSLOCATION SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Thornhollow	Umatilla River, Rkm 117.65, access off Thornhollow Rd Lat: 45.685041° Long: -118.454287°	Private CTUIR	Glide habitat in perennial stream. Transition area from bedrock controlled channel to deeper alluvial deposit.		Used for translocation in 2001-2003, but not since.	
Iskuulktpe	Iskuulktpe Creek, Rkm ~11.45, no vehicle access – access from Iskuulktpe Creek road via 4-wheeler Lat: 45.612712° Long: -118.424938°	CTUIR	Large pool in perennial stream, good spawning habitat both upstream and downstream, good steelhead spawning reach. Creek is the subject of a watershed model for the Umatilla Basin and therefore use of the area is highly regulated.	Larvae (electrofishing) and adults (translocated) documented in the area.	Site currently used for translocation. Current monitoring includes electrofishing surveys, redd surveys, and a screw trap in the lower portion of Iskuulktpe Creek. Ongoing temperature monitoring data available.	
Meacham Creek at Camp Creek	Meacham Creek, Rkm ~17.35, access off Meacham Creek Rd Lat: 45.574666° Long: -118.324654°	Private	Large pool in perennial stream, good spawning habitat both upstream and downstream, good steelhead spawning reach. Use of the area is highly regulated.	Larvae (electrofishing) and adults (translocated) documented in the area.	Site currently used for translocation. Current monitoring includes electrofishing surveys, redd surveys, and a screw trap in the lower portion of Meacham Creek. Ongoing temperature monitoring data available.	

ADULT TRANSLOCATION SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Umatilla River at Bear Creek	Umatilla River, Rkm 139.68, access off Umatilla River Rd Lat: 45.742899° Long: -118.224675°	ODF/Bar-M Ranch	Large pool in perennial stream, good Chinook & steelhead spawning habitat throughout reach. High public use area.	Larvae (electrofishing) and adults (translocated) documented in the area; lamprey spawning documented in area (translocated fish).	Site currently used for translocation. Current monitoring includes electrofishing surveys, redd surveys, and a screw trap downstream at Fred Grays site (aka Imaques).	
South Fork Umatilla River Translocation Site	SF Umatilla River, Rkm 1.20, access off FS-32 Lat: 45.716521° Long: -118.190158°	USFS	Manmade habitat pool (USFS installed grade control) next to road, cobble substrate. High public use area.	Larvae (electrofishing) and adults (translocated) documented in the area; lamprey spawning has been documented in tailouts of pools in the area.	Site occasionally used for translocation depending on availability of adults for translocation program. Current monitoring includes electrofishing surveys, redd surveys, and a screw trap downstream at Fred Grays site (aka Imaques).	
Wildhorse Creek Potential Translocation Site	Wildhorse Creek, Rkm 42.43, access from CR 652 Lat: 45.745955° Long: -118.385578°	Private (within boundary of reservation)	Pool habitat prevalent at and adjacent to site; predominantly redband trout/steelhead habitat.	Currently extirpated (adults & juvenile).	Has not been previously used for lamprey translocation; good candidate site for monitoring limiting factors of newly introduced population, but may require increased survey/monitoring efforts.	Habitat characteristics and use by steelhead indicate a viable self-sustaining population could become established if passage conditions in lower river (including Umatilla River) are improved.

ADULT TRANSLOCATION SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
East Birch Creek Potential Translocation Site	East Birch Creek, Rkm 20.10, access from East Birch Creek Rd Lat: 45.395392° Long: -118.717456°	Private w/ ODFW habitat conservation easements	Steelhead habitat – wild fish basin without supplementation; extensive in-stream habitat restoration work completed by ODFW; good water temperature and quantity parameters in this reach.	Currently extirpated.	Has not been previously used for lamprey translocation; good candidate site for monitoring limiting factors of newly introduced population. Current monitoring includes effectiveness monitoring of habitat features, redd surveys for steelhead, electrofishing for steelhead and salmon, and a screw trap in lower mainstem Birch Creek operated by ODFW.	Habitat characteristics and use by steelhead indicate a viable self-sustaining population could become established if passage conditions in lower river (including Umatilla River) are improved.

INVENTORY OF JUVENILE RELEASE/REARING SITES IN THE UMATILLA RIVER SUBBASIN

JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
EXAMPLE	**Stream name, nearest road access, Rkm** **Lat: XX.XXXXX°** **Long: -XXX.XXXXX°**	**Owner name**	**Habitat type/configuration, known flow levels, access limitations**	**Currently extirpated, unknown, population verified (relative size of population, if known)**	**Include existing/ongoing/previous monitoring efforts and potential for future monitoring. (E.g., existing survey data, plans for future surveys, locating antenna arrays, dam counting, screw traps)**	**This column is for any pertinent goals that would be specifically addressed by supplementation at this particular location.**
Stanfield Diversion	Umatilla River, Rkm 51.6 Access from Reith Rd Lat: 45.691322° Long: -119.119877°	Bureau of Reclamation	Uppermost irrigation project in basin; headrack, fish bypass & screens; sections of concrete and earthen bottom canal.	Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts.	No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies.	Focus on entrainment research studies.

JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Feed Diversion	Umatilla River, Rkm 45.13 Access from Ramos Lane Lat: 45.721003° Long: -119.176364°	Bureau of Reclamation	Headrack, fish bypass & screens; earthen bottom section behind headracks; feeds Cold Springs Reservoir.	Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts.	No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies.	Focus on entrainment research studies.
Westland Diversion	Umatilla River, Rkm 43.54 Access on private road off Snow Rd Lat: 45.727954° Long: -119.193768°	Westland Irrigation District	Largest water user in basin; headrack, fish bypass & screens; concrete canal.	Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts.	No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies.	Focus on entrainment research studies.

JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Dillon Diversion	Umatilla River, Rkm 39.11 Access on private road off Correa Ln Lat: 45.758327 ° Long: -119.216328°	Dillon Irrigation Company	Point diversion for flood irrigation; smallest diversion in basin; headrack, fish bypass & screens; may be removed over next 5 years (or less).	Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts.	No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies.	Focus on entrainment research studies.
Maxwell Irrigation Canal	Umatilla River, Rkm 24.41 Access from unnamed road off Hermiston Hwy Lat: 45.795818° Long: -19.328074°	Bureau of Reclamation	Earthen bottom irrigation canal; continuous flow year round.	Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts.	No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies, as well as habitat use and survival studies in the riverine environment.	Riverine environment rearing experiments, as well as entrainment studies

JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Boyd's Hydro Diversion	Umatilla River, Rkm 16.00 Access across private land off Quick Rd Lat: 45.821371° Long: -119.326138°	Private – Go With the Flow	Currently offline. New owner is working on renewing FERC license and making upgrades to screens and fish bypass; short earthen bottom canal.	Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts.	No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies.	Focus on entrainment research studies.
West Extension Irrigation Diversion (aka 3-mile Dam)	Umatilla River, Rkm 5.70 Access from Canal Rd Lat: 45.882097° Long: -119.325868°	Bureau of Reclamation & West Extension Irrigation District	Huge concrete canal with multiple braids (secondary canal extensions); return flow at Boardman Rest Area (may be concern for lamprey pheromone attraction).	Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts.	No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies and pheromone attraction hypothesis.	Focus on entrainment research studies.

JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

Site	Location	Property Owner	Site Features	Population Status	Monitoring Opportunities	Supplementation/Research Goals
Brownell Diversion	Umatilla River, Rkm 3.14 Access from Old Hwy Lat: 45.904808° Long: -119.326961°	Brownell Irrigation Ditch Company	Primarily basalt composition; old inoperable facility needs upgrades; may be removed over next 5 years.	Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts.	No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies.	Focus on entrainment research studies.

INVENTORY OF PROPAGATION FACILITIES IN THE UMATILLA RIVER SUBBASIN

PROPAGATION FACILITIES – UMATILLA RIVER SUBBASIN

Site	Location	Owner	Current Use	Available Resources	Facility Features	Monitoring Opportunities	Other Benefits	Potential Concerns
EXAMPLE	**River** **Rkm** **Lat: XX.XXXXX°** **Long: -XXX.XXXXXX°**	**Owner name**	**Existing propagation, rearing, acclimation uses?**	**Underutilized facilities, facilities already allocated toward lamprey, future upgrades?**	**Key features and water source parameters beneficial to lamprey activities**	**Include existing/ongoing/previous monitoring efforts and potential for future monitoring. (E.g., existing survey data, plans for future surveys, locating antenna arrays, dam counting, screw traps)**	**Watershed location, water quality/quantity, accessibility to natural habitats adjacent?**	**Use conflicts, watershed position, lacking in natural habitat adjacent and/or unwanted riverine features adjacent? (e.g., diversions, entrainment potential), infrastructure deficiencies, owner problems**
Minthorn Springs	Umatilla River Rkm 101.73 Lat: 45.669290° Long: -118.620123 °	CTUIR	Steelhead spawning & acclimation; adult lamprey holding	Existing holding tanks being used for lamprey; potential to expand facility for lamprey holding & rearing	Unlimited water right			Water quality concerns (DO) during late summer

PROPAGATION FACILITIES – UMATILLA RIVER SUBBASIN

Site	Location	Owner	Current Use	Available Resources	Facility Features	Monitoring Opportunities	Other Benefits	Potential Concerns
Fred Grays (aka Imaques C-min-icum) Acclimation Pond	Umatilla River Rkm 127.15 Lat: 45.707085° Long: -118.349891°	CTUIR/BPA	Acclimation of spring Chinook	Four existing ponds; currently in use for Chinook from November through May; lots of space available on adjacent land to build additional ponds	May be able to utilize existing ponds during season not in use for other programs; may be able to construct new troughs (there is available unused space on-site); unlimited water right; good water quality/quantity	Existing screw trap nearby; ongoing electrofishing and redd surveys in vicinity.		
Pendleton Acclimation Pond	Umatilla River Rkm 90.44 Lat: 45.670796° Long: -118.743584°	CTUIR/BPA	Acclimation of steelhead, spring/fall Chinook, and coho	Four ponds, currently in use for steelhead/salmon from May to November; potential to expand facility for lamprey holding and rearing	May be able to utilize existing ponds during season not in use for other programs; may be able to construct new troughs (there is available unused space on-site); unlimited water right			

PROPAGATION FACILITIES – UMATILLA RIVER SUBBASIN

Site	Location	Owner	Current Use	Available Resources	Facility Features	Monitoring Opportunities	Other Benefits	Potential Concerns
Thornhollow Acclimation Pond	Umatilla River Rkm 117.57 Lat: 45.685041° Long: -118.454287°	CTUIR/BPA	Acclimation of spring Chinook (Carson stock – Bonneville Dam)	Two ponds, currently in use for Chinook from November through May; potential to expand facility for lamprey holding and rearing	May be able to utilize existing ponds during season not in use for other programs; may be able to construct new troughs (there is available unused space on-site); unlimited water right			
Bonifer Acclimation Pond	Meacham Creek Rkm 3.56 Lat: 45.684070° Long: -118.363384°	CTUIR/BPA	Currently unused	Natural pond with regulated outlet, no longer used as acclimation pond for steelhead program for past decade	Natural/earthen pond (wetland system) available for lamprey program; spring fed	Current monitoring includes electrofishing surveys, redd surveys, and a screw trap in the lower portion of Meacham Creek. Ongoing temperature monitoring data available.	Water quality/quantity fairly consistent – need to verify	Review water quality/quantity data to verify appropriate parameters for lamprey rearing

PROPAGATION FACILITIES – UMATILLA RIVER SUBBASIN

Site	Location	Owner	Current Use	Available Resources	Facility Features	Monitoring Opportunities	Other Benefits	Potential Concerns
Three-mile Falls Dam	Umatilla River Rkm 5.83 Lat: 45.881731 ° Long: -119.322791 °	CTUIR/BPA	Adult holding and spawning of Fall Chinook and coho; eggs incubated and reared at Umatilla Hatchery	Holding ponds used September to November for salmon programs; space available to build additional ponds; lamprey passage facility	May be able to utilize existing ponds/raceways for holding adult lamprey for translocation and rearing juveniles; potential to construct new ponds in unused gravel area;	Good opportunity to collect broodstock; opportunity for outside experiments (larval rearing experiments)		Limited space – no incubation or rearing facilities; low in basin; water quality/quantity issues during some times of year

Appendix D. Confederated Tribes and Bands of the Yakama Nation – Draft Supplementation Research Plan for Ceded Area Subbasins

1 Introduction

1.1 Subbasin Overview

The Yakima River subbasin is located in south central Washington and contains a diverse landscape of rivers, ridges, and mountains totaling just over 6,100 square miles. Along the western portion of the basin, the glaciated peaks and deep valleys of the Cascade Mountains exceed 8,000 feet. East and south from the Cascade crest, the elevation decreases to the broad valleys and the lowlands of the Columbia Plateau. The lowest elevation in the basin is 340 feet at the confluence of the Yakima and Columbia Rivers at Richland. Precipitation is highly variable across the basin, ranging from approximately 7 inches per year in the eastern portion to over 140 inches per year near the crest of the Cascades. Total runoff from the basin averages approximately 3.4 million acre-feet per year, ranging from a low of 1.5 to a high of 5.6 million acre-feet.

Six major reservoirs are located in the subbasin and form the storage component of the federal Yakima Project, managed by the Bureau of Reclamation. Total storage capacity of all reservoirs is approximately 1.07 million acre feet, total diversions average over 2.5 million acre feet. The construction and operation of the irrigation reservoirs have significantly altered the natural seasonal hydrograph of all downstream reaches of the mainstem and some tributaries. Associated with these reservoirs are numerous irrigation dams and diversions throughout the subbasin.

Historically, the hydrologic cycle in this basin was characterized by extensive and complex exchange of water between the surface, hyporheic (area of surface / groundwater exchange) and groundwater zones. Under pre-1850s conditions, vast alluvial flood plains were connected to complex webs of braids and distributary channels. These large hydrological buffers spread and diminished peak flows, promoting infiltration of cold water into the underlying gravels. Side channels and sloughs provided a large area of edge habitat and a variety of thermal and velocity regimes. For Pacific lamprey, these side channel complexes increased productivity, carrying capacity, and life history diversity by providing suitable habitat for all freshwater life stages in close physical proximity.

1.2 Importance of Pacific Lamprey

Lamprey (eels) are of great importance to Native American tribes for cultural, spiritual, ceremonial, medicinal, subsistence and ecological reasons. From a tribal perspective, the decline of Pacific lamprey continues to have at least three negative effects: 1) loss of an important nutritional source and cultural heritage, 2) loss of fishing opportunities in traditional fishing areas, and 3) necessity to travel large distances to lower Columbia River tributaries, such as the Willamette River, for ever-decreasing lamprey harvest opportunities. As a consequence of declining or elimination of harvest in interior Columbia River basin tributaries, many young tribal members have not learned how to harvest and prepare lamprey for drying. In addition, young tribal members are losing opportunities to learn historically important legends associated with lamprey and lamprey fishing.

For over 10,000 years the Yakama people have depended on lamprey for food and medicine. Tribal members historically harvested lamprey in a sustainable manner, taking only what their families needed for subsistence. During historic times, lamprey were plentiful in the Yakama Nation Ceded Lands, and specifically in the Yakima River. Through the years, many stories and legends surrounding the eel were passed down from generation to generation and this important species has become an integral part of tribal culture. And, the tribes clearly recognize that restoration of lamprey populations is necessary for the restoration of the ecological health of Pacific Northwest watersheds, along with salmonids and other native fish populations.

1.3 USFWS Conservation Assessment Findings

The 2011 USFWS Pacific Lamprey Assessment and Template for Conservation Measures (Conservation Assessment) characterized the status of Pacific lamprey as critically impaired for the Naches subbasin (the Naches and Tieton rivers above the confluence with the Yakima River) and possibly extirpated for the Upper Yakima (mainstem and all streams above the confluence with the Naches River) and Lower Yakima (mainstem and all streams below the confluence with the Naches River) subbasins. The assessment document used "population groupings" to evaluate the species status based on geographic locality, but it does not imply that there are Yakima subbasin populations that are formally recognized as being distinct from other subbasin populations. The term "population grouping," in this case, is being used loosely as a convenient term to be defined as a local assemblage of Pacific lamprey at the subbasin scale. Table 7-1 provides information contained in the USFWS Conservation Assessment outlining "Expert Opinion" of the current and historic status and trend. As is clearly indicated, Pacific lamprey populations are considered well below average historic levels. Reductions in the Yakima subbasin "population" are believed to be a cumulative result of many limiting factors - both within and outside of the subbasin. Table 7-2, also from the Conservation Assessment, identifies and ranks "Threats" to Pacific lamprey and their habitats in the Yakima subbasin.

Table 1. Categorical rank inputs and resulting NatureServe ranks for Pacific lamprey population groupings within the Yakima River Subbasin (USFWS Conservation Assessment, 2011).

Watershed (population grouping)	Calculated Risk Rank[1]	Distribution		Population Size	Threat	
		Historic (km²)	Current (km²)	(number)	Scope	Severity
Upper Yakima	SH	250 - 5,000	0	Unknown - 0	High	High
Lower Yakima	SH	100 - 1,000	0 - 0.4	0 - 50	High	High
Naches	S1	100 - 1,000	> 0 - 4	1 - 250	High	High

Table 2. Threats to Pacific lamprey and their habitat in the Yakima River subbasin, as identified and ranked by participants in regional meetings. High = 4; Medium = 3; Low = 2; Insignificant = 1. (USFWS Conservation Assessment, 2011).

Threat		Population Grouping		
		Upper Yakima	Lower Yakima	Naches
Passage	Scope	4	3	3
	Severity	4	4	3
Dewatering and Flow Mgt.	Scope	4	4	3
	Severity	4	4	3
Stream / Floodplain Degradation	Scope	2	2	2
	Severity	2	2	2
Water Quality	Scope	1	4	2
	Severity	1	4	2
Harvest	Scope	1	1	1
	Severity	1	1	1
Predation	Scope	1	2	1
	Severity	1	4	1

1.4 Vision and Goal

The Vision for this Supplementation Research Strategy is consistent with the Vision outlined in the 2004 NPCC Yakima Basin Subbasin Plan (Subbasin Plan), specifically:

"*Yakima River Basin communities have restored the Yakima river basin sufficiently to support self-sustaining and harvestable populations of indigenous fish and wildlife while enhancing the existing customs, cultures, and economies within the basin. Decisions that continuously improve the river basin ecosystem are made in an open and cooperative process that respects different points of view and varied statutory responsibilities, and benefits current and future generations.*"

Additionally, one of the guiding principles for this Subbasin Plan states "*That the natural environment including its fish and wildlife resources is the cultural heritage that is common to the diversity of human*

[1]*Definitions: SH = possibly extirpated; S1 = critically impaired; Scope – High = 71-100% of total population, occurrences or area affected; Threat – High = Near total destruction of suitable habitat and/or functional loss of Pacific lamprey from this watershed (>100 years of recovery).*

existence. The underlying premise of the Yakima Subbasin Planning Board's Mission and Vision is to prepare and implement a balanced plan of action that plays a key role in the long-term sustainability of our common cultural heritage within the Yakima Basin".

The primary Goal of the Yakama Nation, a member of this Planning Board is "*to restore natural production of Pacific Lamprey to a level that will provide robust species abundance, significant ecological contributions and meaningful harvest within the Yakama Nations Ceded Lands and in the Usual and Accustomed areas for harvest*". In both the Yakima Basin Vision and the Yakama Nation Goal for Pacific lamprey there is a strong consensus and desire to restore and support *self-sustaining and harvestable populations* of Pacific lamprey, important to the subbasin ecology and customs of the people. The Yakima subbasin has witnessed and endured decades of decline in lamprey populations and the resulting effects upon the culture. Research into the appropriate use of supplementation, along with needed habitat restoration, is an important action for the re-establishment of this local population in a timely manner.

2 Summary of Pacific Lamprey Status in the Yakima Subbasin

The U.S. Fish and Wildlife Service (USFWS) conducted a study on the "Distribution and Abundance of Fish in the Yakima River" (Patten et al. 1970)[2] between April 1957 and May 1958. The study covered the mainstem of the Yakima River from Richland, Washington upstream to Easton Dam, a total of approximately 281 kilometers (km) (174 miles). Although the report did not provide a distinction between Western Brook Lamprey (*Lampetra richardsonii*) and Pacific Lamprey (*Entosphenus tridentatus*) species (due to difficulty of juvenile identification), lamprey were noted in various sample reaches throughout the study area. The 1970 USFWS report documents catching 146 lamprey throughout 10 of the 18 sample reaches. This included the collection of lamprey from the uppermost upstream sample reach (Easton Dam 281 km) and second to lowest downstream sample reaches (16km to 24km). This information supports information from current WDFW[3] and YNPLP[4] surveys and oral histories indicating that lamprey utilized the entire mainstem Yakima River for adult migration and for juvenile rearing.

The historical extent of salmonid species and Pacific lamprey distribution are very similar in many basins within the northwestern USA (Hamilton et al. 2005; Moyle 2002; Scott and Crossman 1973) and may be the best surrogate we have available to estimate historical abundance of Pacific lamprey. The Yakima Subbasin historically supported large runs of six anadromous salmonid species (Table 7-3). Based on the estimated historic run sizes of anadromous salmonids within the Columbia Basin (NPPC 1986) and that within the Yakima Subbasin (BPA 1996), the historic run of Pacific lamprey is estimated to be between 20,656 and 31,297 adults (because summer Chinook largely went to Snake Basin historically, we exclude the estimated run based on summer Chinook). Spatial distribution of spawning habitat for Pacific lamprey is similar to many salmonid species as well. Though there is plenty of overlap in the spatial range, generally speaking, coho and steelhead tend to spawn in slightly higher gradient reaches and fall Chinook tend to spawn in slightly lower gradient reaches compared to Pacific lamprey. Based on the similar migration timing and spatial range of spawning, we hypothesize that spring Chinook salmon (where they exist) may be the best surrogate/index for historic Pacific lamprey abundance and distribution. Historic run of Pacific lamprey is estimated to be 31,297 adults based on estimated spring Chinook pre-historic runs.

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[2] *Patten, B. G., R. B. Thompson, and W. D. Gronlund. 1970. Distribution and abundance of fish in the Yakima River, Wash., April 1957 to May 1958. Special Scientific Report – Fisheries No. 603. U.S. Fish and Wildlife Service, Washington, D.C.*

[3] Washington Department Fish and Wildlife

[4] Yakama Nation Pacific Lamprey Project

Table 3. **Assessed runs of historic salmonid species in Columbia Basin vs. Yakima subbasin to estimate historic runs of Pacific lamprey within the Yakima Subbasin.**

Species	Estimated Columbia Prehistoric Run	Estimated Yakima Prehistoric Run	% (Yakima/ Columbia)	Target Species	*Columbia Historic High Run (1939-1969)	Estimated Yakima Historic High Run	Current Yakima Run (11 year ave.)	% (Current / Historic Yakima)
Spring CH	1716000	200000	11.7	Pacific Lamprey	268524	31297	23	0.07
Summer CH	3433000	68000	2.0	Pacific Lamprey	268524	5319	23	0.43
Fall CH	1716000	132000	7.7	Pacific Lamprey	268524	20656	23	0.11
Sockeye	1940000	200000	10.3	Pacific Lamprey	268524	27683	23	0.08
Coho	1328000	110000	8.3	Pacific Lamprey	268524	22242	23	0.10
Steelhead	1006000	80000	8.0	Pacific Lamprey	268524	21354	23	0.11
Overall	11139000	790000	7.1	Pacific Lamprey	268524	19044	23	0.12

*Columbia Historic High Run for Pacific lamprey is based on the average of the five high counts between 1939 and 1969.

2.1 Adult abundance, run timing, and spawning locations

2.1.1 Abundance

Adult abundance is considered very low within the Subbasin. Adult counts at the Prosser Dam Fish Counting Facilities (FCF) (river km 75.7), from Year 2000 – 2013 (Figure 7-1) indicate that, on average approximately 20 adult lamprey have entered the subbasin per year and potentially moved into upper reaches suitable for spawning. In three years zero fish were counted, and in three other years between 65 - 87 fish were counted. In five other years, the average was less than three lamprey passing Prosser Dam per year. Even if we account for the low detection rates of lamprey passing through the dam (roughly 55% based on radio telemetry results), it is reasonable to conclude that adult abundance in the Yakima subbasin is critically low and that genetic diversity has been critically impaired. Given these low counts observed in the lower Yakima River, abundance of Pacific lamprey in the upper reaches is most likely insignificant or non-existent. No adult lamprey have been observed at the counting station at Roza Dam (river km 210.5) since the new counting system was implemented in 1997 (and no positive records prior to that). However, some of the radio tagged lamprey that were transferred to upper Yakima subbasin passed the dam in 2012 and 2013.

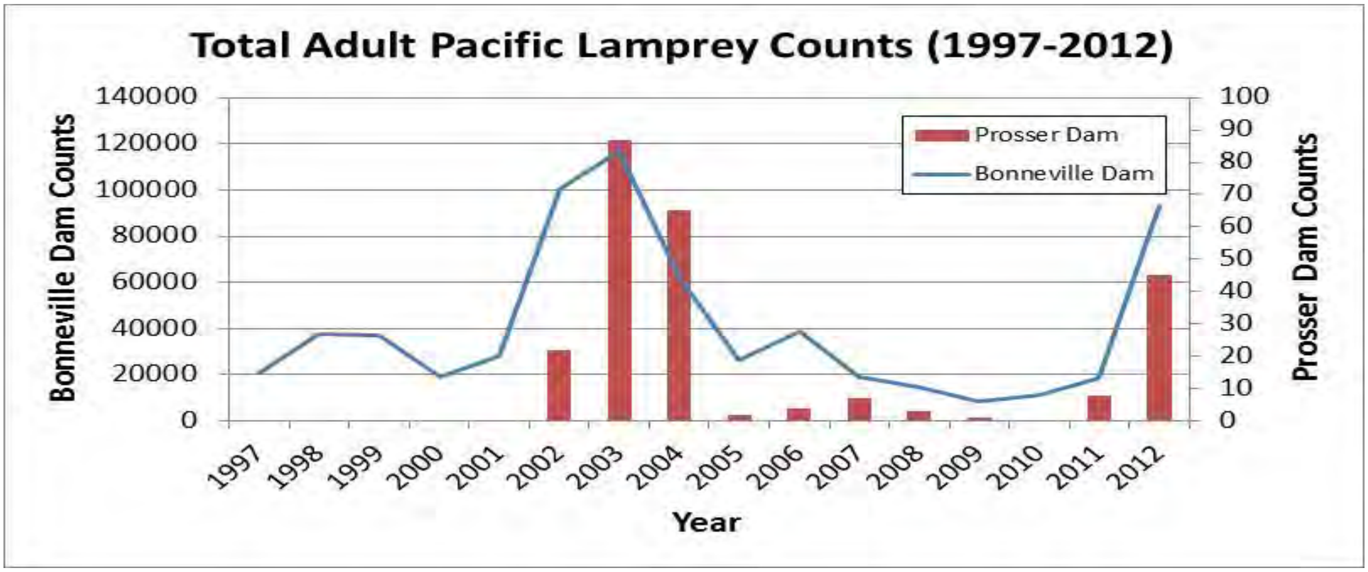


Figure 1. **Total adult Pacific lamprey counts at Prosser and Bonneville dams between 1997 and 2012.**

2.1.2 Run Timing

Little is known about adult run timing into the Yakima River subbasin other than what can be concluded from daily counts at the Prosser Dam FCF. Figure 7-2, below, illustrates that between years 2000 - 20012 there is two distinct runs of Pacific lamprey at the FCF: a larger run that span between late March and late May, and a smaller run that span between early June and early October (see the yellow line that hypothesizes the transition point between the overwintered fish vs. fresh migrants). Interestingly, during these same years, the average annual run timing of adults reaching McNary Dam began no earlier than late May and very few adults entered the Yakima River during this early summer period (particularly between late June and mid-August, which corresponds to the time period for peak water temperature). It is apparent that a large portion of adult lamprey overwinter somewhere in the Columbia River prior to their ascent up the Yakima River. It is reasonable to speculate that due to current flow management, the combined impacts of less flow reaching the lower river and higher river temperatures compared to historic conditions may deter many of the fresh migrant Pacific lamprey from entering into the subbasin during the peak run period for fresh migrants.

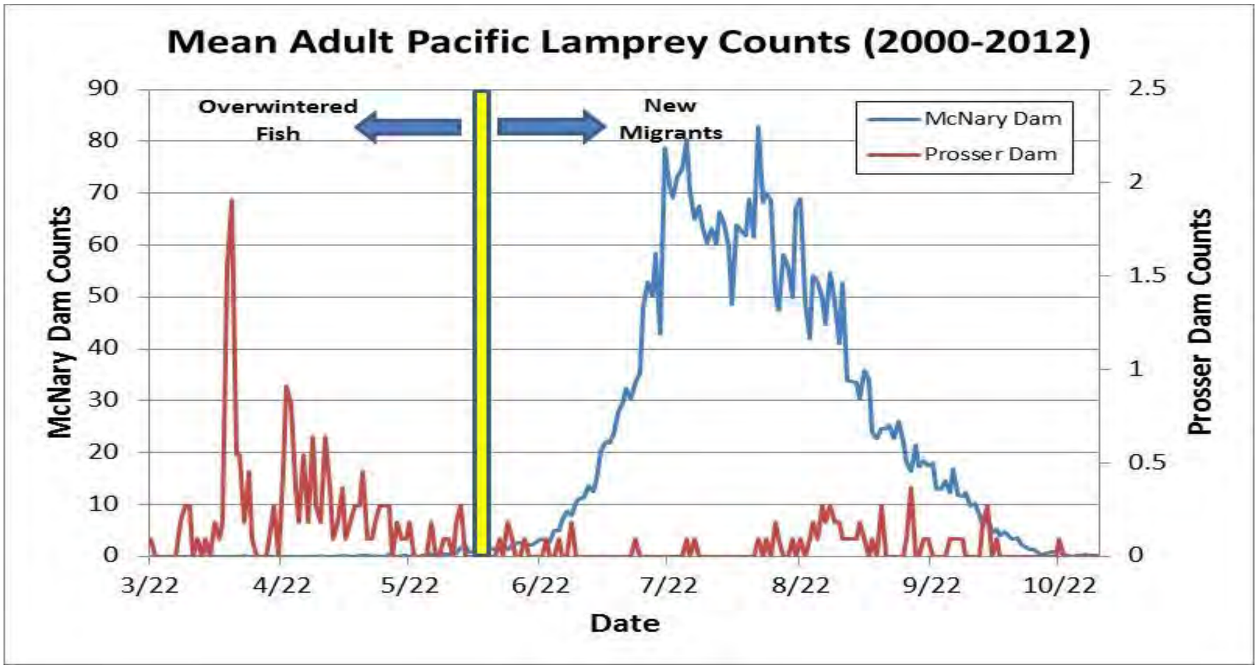


Figure 2. **Mean adult Pacific Lamprey Counts between 2000 and 2012 at Prosser Dam and McNary dams.**

2.1.3 Spawning Locations

Very little is known about lamprey spawning locations within the Yakima River. It is likely that many known spawning locations for salmonid species, such as spring Chinook, coho and steelhead, are also suitable for Pacific lamprey. These areas exist in many stream reaches throughout the entire subbasin. But due to the very low adult Pacific lamprey returns over the recent past, very little information exists that describes eye-witness accounts of significant spawning activity in any of these, or other locations. Tribal elders have shared some locations where adults were historically encountered during the spawning period, including Toppenish, Status, and middle reaches of the Yakima River. Given the combination of geomorphic characteristics (flow, gradient, and valley width), water temperature regime, and expert opinions, we suspect that Satus, Toppenish, Ahtanum, Naches, Wenas and mainstem Yakima (middle reach, such as Wapato area) will be productive streams/rivers for spawning Pacific lamprey. Tributaries in the upper Yakima, such as Taneum, Teanaway, Cle Elum, also appear to have good potential habitat and favorable conditions for Pacific lamprey.

2.1.4 Juvenile Abundance and Run Timing

Juvenile abundance is considered to be very low throughout the entire Yakima Subbasin, and essentially non-existent above Roza Dam and the upper Naches. The primary sources of information available to resource managers are site specific counts made by WDFW, juvenile lamprey surveys undertaken by the YNPLP (2010 through present) and juvenile counts at the Prosser FCF (2000 through present). Counts made by WDFW indicate that juvenile Pacific lamprey (macrophthalmia) are found primarily in the lower Yakima River during the winter season. This also matches with the data from the Prosser FCF. Juvenile lamprey counts at the

Prosser FCF have ranged between 18 and 1450 individuals between 2000 and 2012 (between 55 and 4273 for the extrapolated counts) (Figure 7-3). The facility is located within the bypass system of the Chandler Canal, which diverts roughly 30-50% of the Yakima River water during the juvenile lamprey migration season in the winter. Water is screened within this canal (5/32" mesh large drum screens, which is small enough to prevent macrophthalmia from passing through), and fish are diverted into the Facility through the bypass channel. Captured juvenile lamprey are counted, but species and life stage identification have not been recorded consistently to date. Periodic past examinations of the captured lamprey between 2010 and 2013 indicate that the majority of these outmigrating juvenile lamprey during the winter high flow conditions are Pacific lamprey macrophthalmia; hence, these counts could potentially be used as an index for juvenile lamprey abundance.

Analysis of the run timing for outmigrating juvenile lamprey is limited in scope by the Prosser FCF sampling period, which typically runs between early January and mid-July (Figure 7-4). There appears to be two peak runs; one between January and February (peak in mid-January) and one between March and June (peak in mid-May). The second peak corresponds closely in timing with the adult counts at Prosser Dam. Based on these data, it appears that juvenile lamprey are keying into high flow events for outmigration and it is unlikely that juvenile lamprey are moving out during the summer / fall season when the flow is typically much lower.

Figure 3. Outmigrating juvenile lamprey counts at Prosser Dam FCF (lamprey species not identified). Extrapolated counts use the daily subsampling rates to provide estimated overall migrants.

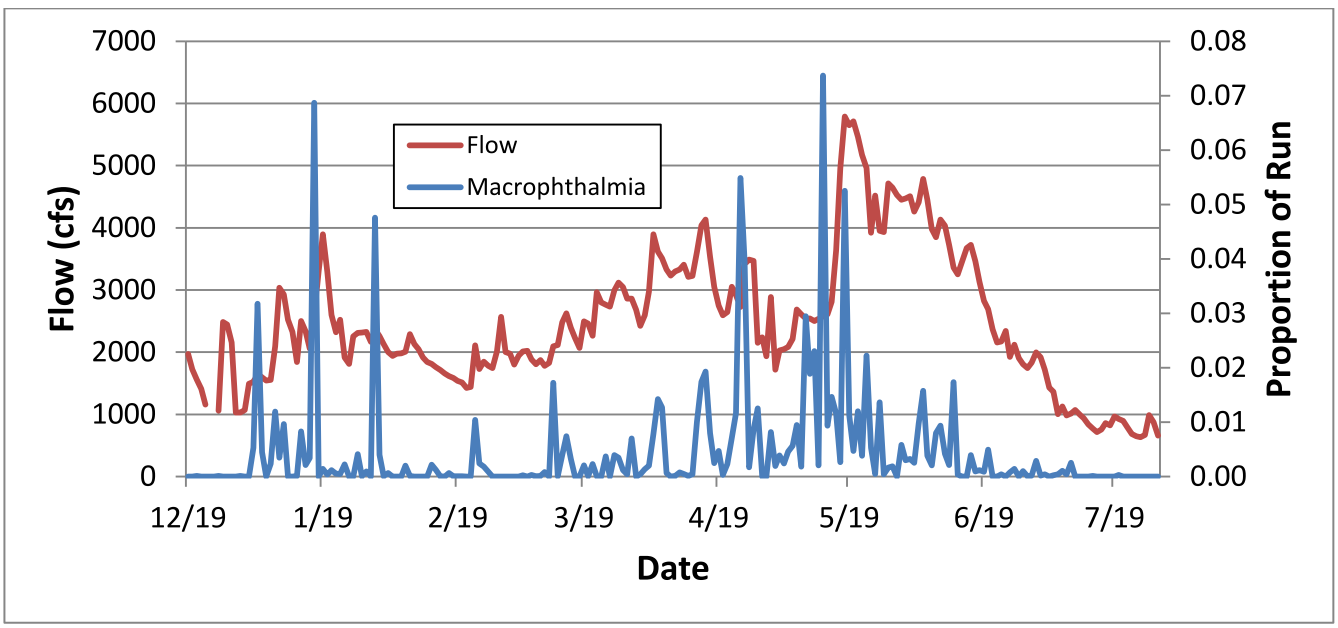


Figure 4. Mean proportion of outmigrating juvenile lamprey counts and corresponding river flow rates at Prosser Dam FCF between 2000 and 2012 (lamprey species not identified). The mean proportion is based on the extrapolated overall counts based on daily subsampling rates.

2.1.5 Ammocoete Abundance and Distribution

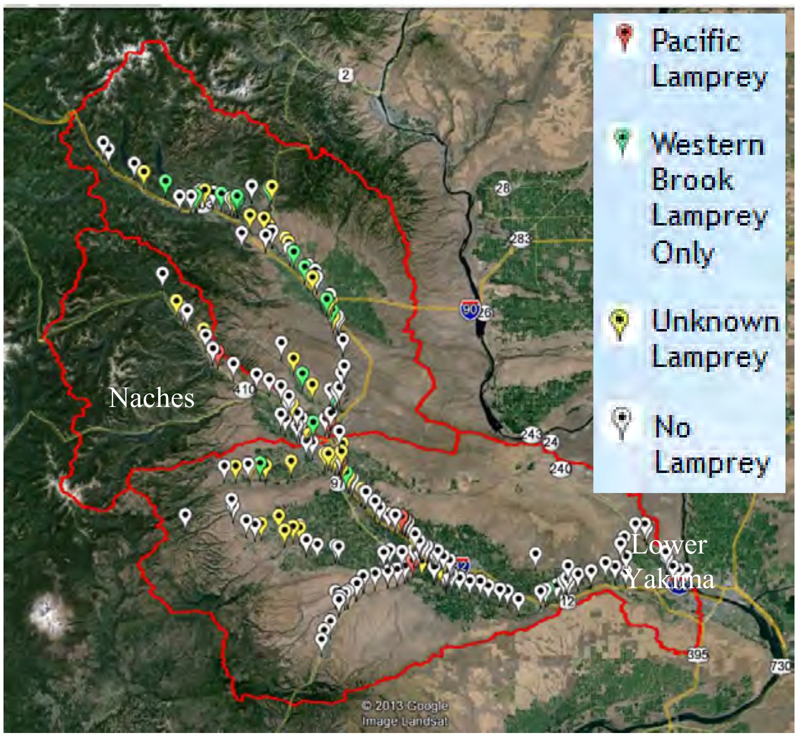
Since 2009, the Yakama Nation Pacific Lamprey Project (YN PLP) has begun conducting juvenile lamprey surveys to document their distribution and relative abundance within the Ceded Area of the Yakama Nation. In 2012, we surveyed a total of 98 sites using a backback electrofisher designed for larval lamprey. In addition, there were over 70 other sites that were surveyed quickly (quick assessments) using an electrofisher or a fine-mesh hand net to simply evaluate prescence/absence of juvenile lamprey. Juvenile Pacific lamprey were only found in the Lower Yakima and Naches subbasins and the mean ratio of Pacific lamprey (vs. Western brook lamprey) were 13.3%, 5.3%, respectfully. Within the Yakima Subbasin, we only found Pacific lamprey ammocoetes in the Yakima River, Satus Creek, Ahtanum Creek, and Naches River. The ratio of Pacific lamprey vs. Western brook lamprey in these rivers/streams were 22.0%, 8.3%, 28.6%, 7.7%, respectfully. We did not detect any juvenile lampreys in the lower reaches of the Yakima River until river km 137. 6. No juvenile Pacific lamprey have been detected upstream of river km 195.2 in the Yakima River since these surveys began in 2009. On the other hand, Western brook lamprey were detected most frequently in the Upper Yakima Subbasin (73.7% of all sites surveyed) compared to all other subbasins surveyed in 2012.

We also detected an inverse relationship between habitat availability and fish density at the subbasin scale. For instance, Naches Subbasin had the lowest amount of habitat available per site, but the mean fish density was the highest of all the subbasins. This potentially indicates that lack of habitat within the stream/river may force the lamprey to use the habitat at a higher fish density level compared to sites with more larval habitat available, and suggests that ammocoete density may not be the best indicator for fish abundance and status (i.e. it could be an indication that habitat is limiting).

All previous surveys starting in 2009 paint the general same picture for the Yakima Subbasin. That is, Pacific lamprey are rare and primarily limited to the Lower Yakima Subbasin (below Roza Dam) and the majority that we have detected were found in side channels of the Yakima River (primarily in the Wapato reach area) and the lower reaches of major tributaries, including Satus and Ahtanum Creek. Ammocoete habitat and Western brook lamprey, on the other hand, is fairly abundant in the Lower Yakima as well as in the Upper Yakima subbasins. It is important to note that Western Brook and Pacific lamprey juveniles less than 60 mm size are nearly impossible to distinguish in the field. As a result, many of the juveniles captured are categorized as “unknown” leaving a lot of uncertainties in the exact distribution of the lamprey species. Also, the survey crew has varying levels of species identification skills, and some of the identification may not have been 100% accurate.

Additionally, the Yakama Nation has surveyed various irrigation canals, shortly after annual dewatering, for juvenile lamprey presence. Although Western brook lamprey ammocoetes and transformers (equivalent to the macrophthalmia life stage of Pacific lamprey, except eyes of Western brook lamprey transformers are much smaller) have been found in large numbers in various diversions throughout the subbasin, none of the larger ammocoetes and transformers have been identified positively as Pacific lamprey. No Pacific lamprey macrophthalmia have been found to date in the streams and rivers of the Yakima subbasin during regular sampling surveys as well.

Figure 5. Juvenile lamprey survey sites within the Yakima Subbasin in 2010-2012. As shown in the legend, red balloons indicate sites that had Pacific lamprey, green balloons indicate sites that had only Western brook lamprey, yellow balloons indicate sites that had no Pacific lamprey but included some lamprey that were unidentifiable (due to small size), and white balloons indicate sites that had no lamprey.

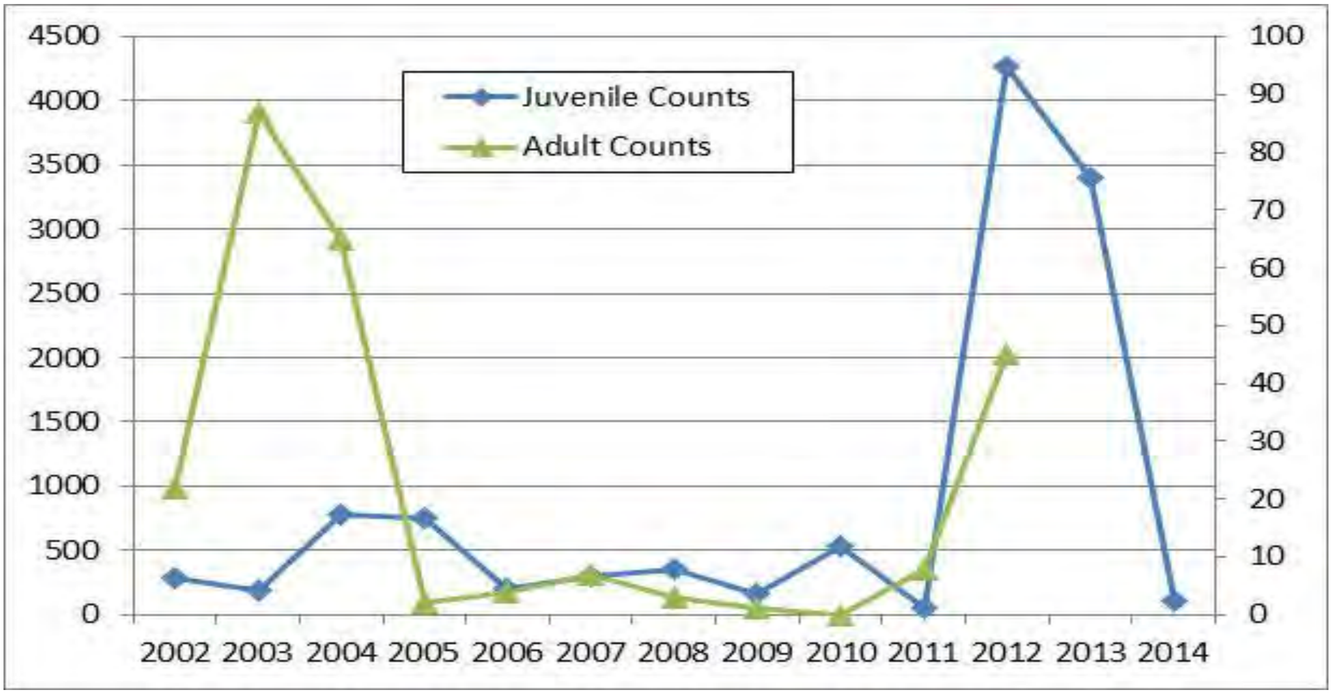


2.1.6 Life Stage Overview

There are still many uncertainties in the linkage between juvenile and adult lamprey abundance and more specifically the life stage survival model of Pacific lamprey. One primary limiting factor is that fisheries managers still do not fully understand the life span of the fish (both life stage specific and overall), which makes any modeling problematic and challenging. However, some interesting relationship surfaces based on the Prosser Dam data. Outmigrating juvenile lamprey counts from Prosser FCF (with a 7-year lag), correlate strongly with the adult counts from Prosser Dam with a 7-year lag, indicating that the adult counts can be an excellent predictor for juvenile production (Figure 7-6). Because the majority of adult lamprey passing through Prosser Dam are overwintered adults, this indicates that the outmigrating juvenile lamprey may be primarily 6-year-old lamprey. If this prediction is true, we will continue to see low depressed abundance of outmigrating juveniles all the way until 2018. Conversely, adult counts appear to have some correlation with the outmigrating juvenile counts with a 2-year lag, indicating that the juvenile counts may also be an effective predictor for adult production (Figure 7-7). For instance, the relatively high juvenile production in 2010 resulted in a relatively high adult count in 2012. According to this predication model, the adult counts in 2013 will stay relatively high, but it will drop down again in 2014.

Figure 6. Extrapolated outmigrating juvenile lamprey counts at Prosser FCF between 2000 and 2012 and corresponding adult counts with a 7-year lag to predict outmigrating juvenile lamprey production between 2003 and 2019.

Figure 7. Adult lamprey counts at Prosser Dam between 2002 and 2012 and corresponding extrapolated outmigrating juvenile counts with a 2-years prior to predict adult lamprey recruitment between 2002 and 2014.



3 Summary of Pacific Lamprey Priority Limiting Factors

3.1 Adult Migration: Passage

Dams are known to be a challenge to Pacific lamprey passage, whether large head hydroelectric dams of the Columbia River or irrigation dams along smaller tributaries, such as the Yakima River. Since 2010, the USFWS, in cooperation with the Yakama Nation, BOR and USACE (Seattle District) has been evaluating passage of lamprey at irrigation facilities in the lower and mid - Yakima River. As noted in the USFWS 2012 Annual Report (Johnsen et. al. 2013)[5] "*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"*. This telemetry research is anticipated to continue for several years to come, moving upstream to evaluate all major diversion dams throughout the Yakima subbasin.

3.2 Downstream Passage: Juvenile Entrainment

Recent surveys by the YNPLP clearly indicate that juvenile lamprey are entering many irrigation diversion ditches within the Yakima subbasin and getting behind various screens designed for salmonid criteria. The YNPLP, in coordination with the BOR, has documented these findings and annual reports are available upon request. To date, only preliminary work has commenced to understand how juvenile lampreyare actually getting behind these screens. Considerable investigations are currently underway by Dr. Matt Mesa and others at the USGS Western Fisheries Research Center in Cook, WA to understand this issue and to develop new screening criteria. Additionally, the Yakama Nation is now working closely with the WDFW, USFWS, BOR and USGS developing and implementing studies using screw traps and passive traps to determine the means for escapement below these screens and future measures to prevent these entrapments. The YNPLP, along with the WDFW and BOR will continue to survey irrigation ditches throughout much of the subbasin over the next five years, but due to the lack of resources it is anticipated that the primary focus for addressing entrainment issues in the near-term will be at the Reclamation facilities in the Mid - and Lower Yakima AU's.

3.3 Water Quantity - Flow Management

As is well established in numerous local planning documents, including the 2004 Subbasin Plan, water management has substantially changed flow conditions throughout much of the Yakima subbasin. As noted above in the Subbasin Overview, most of the entire subbasin flows are controlled by large reservoirs in the headwaters. And many smaller tributaries, once habitable for lamprey, are significantly dewatered from multiple diversions.

One of the more important issues directly affecting the upper mainstem of the Yakima River is the lowering of the river flow (stage elevation) in early September to accommodate safe spawning of spring Chinook salmon and later, the hatching of these eggs. It is well established that the relatively quick ramping rates associated with this process causes widespread mortality to a number of invertebrate populations (caddis fly

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[5] *Johnsen, A, M. C. Nelson, D. J. Sulak, C. Yonce, and R. D. Nelle. 2013. Passage of radio-tagged adult Pacific lamprey at Yakima River diversion dams. 2012 Annual Report. U.S. Fish and Wildlife Service. Leavenworth, WA.*

larvae, for example) substantially impacting the productivity of the upper reaches. Additionally, it is believed by some fishery managers that larvae lamprey residing at the stream margins are left to desiccate as the stream stage elevation is reduced in such a rapid manner. This hypothesis will be tested over the next 2-3 years in various locations throughout the upper Yakima River.

3.4 Water Quality - Temperature: Lower Yakima River

Water temperatures in the lower Yakima River typically exceed or approach 80 degrees Fahrenheit during the warmest periods in the summer months. These temperatures are known to be lethal for juvenile lamprey. Besides one Western brook larva that was found just downstream of Prosser Dam (river km 73.5) in 2011, there has been no juvenile lamprey detected below river km 136.7 (1.5 miles northwest of Granger, WA) on mainstem Yakima River between 2010 and 2012 during the summer sampling surveys. There is no clear consensus on how current water management and environmental conditions have increased river water temperature compared to historic conditions. It is widely believed by resource managers that (1) river temperatures in the lower Yakima subbasin during summer months were, in fact, relatively high in historic times but (2) river management (withdrawals) likely exacerbate these conditions, albeit to an un-quantified amount. It is likely that due to current water management, when flows are reduced from diversions during the early summer months, water temperatures are elevated. This occurs when adults migrate past the Yakima River and may be a factor that discourages entrance and assenting up to headwater tributaries.

3.5 Small Effective Population Size

As noted above, Pacific lamprey populations in the Yakima subbasin are critically low, and in some watersheds, presumed extirpated. Specifically, the last "high" adult counts at Prosser Dam were noted in 2003 and 2004 (87 and 65 adults counted, respectively). Assuming a 7-year juvenile life stage, the last of these juvenile year classes would have left the Yakima subbasin in 2011. Subsequent low adult counts between 2005 and 2011 (ranging from zero to a high of 14 in 2011) begs the questions "can adults successfully find a mate?" and "what are the genetic risks associated with such a low brood population?". Given simply the adult counts, and the very low numbers of juveniles found in the 2010 - 2012 YNPLP distribution surveys, current information establishes that Pacific lamprey populations in the Yakima subbasin are fundamentally extirpated.

3.6 Critical Uncertainties

In addition to these known primary limiting factors, there are many other critical uncertainties that exist, which may play a significant role in the population abundance of Pacific lamprey in the Yakima subbasin. The effects of water quality including contaminants and toxicants are largely unknown at this point. Due to the early life history of lamprey (burrowing in fine sediment in low gradient channels for several years), the likelihood that ammocoetes are exposed to a high level of toxicants is high. Predation is also a potential threat to Pacific lamprey. The number of native and non-native piscivorous predators (fish, avian, mammal) have increased greatly due to dams within the Yakima subbasin as well as Columbia basin at large. However, due to the lamprey’s unique physiology (lack of bone structure), most studies examining the stomach content of predators miss any clue for juvenile lamprey predation, especially for ammocoetes which lack teeth at this stage. Global climate change appears to be eminent and will likely affect the flow dynamics and temperature of the local rivers in the Yakima subbasin. Some prediction models indicate that the timing of snow melt floods will arrive earlier than it has been in the past, further reducing flow in late summer. For adult Pacific lamprey that migrate extensively during this time period, this may hinder their upstream migration.

4 Ongoing / Planned Lamprey Restoration Actions over the Next 5-10 Years

This restoration strategy intends to address priority limiting factors across the subbasin. Recognizing that lamprey need to use habitats that extend widely, our strategy views the Yakima River subbasin holistically, and recommends priority actions across the subbasins as part of the overall recovery strategy. See Appendix 7-A (Action Table) for more information.

- **Passage**. Continue to evaluate passage issues and appropriate passage structures on irrigation diversion facilities, starting with Projects lower in the subbasin and working upstream. Implement passage structures as needed and feasible.

- **Entrainment**. Continue to evaluate the degree that entrainment is occurring within irrigation diversion ditches, identify priority locations to focus near-term work and implement corrective actions. In general, actions will focus on Reclamation facilities initially but will expand to all relevant sources for entrainment over time.

- **Contaminants**. Continue taking water quality and juvenile lamprey tissue samples to determine the presence, the types and the amount of contaminants (potential threat of industrial, urban or agricultural contaminants) being ingested or otherwise absorbed into local lamprey populations. Initiate a planning strategy to identify the sources and potential remedies for toxicants determined to be detrimental to lamprey health or survival.

- **Supplementation**. Given that the Yakima subbasin population is essentially extirpated, fishery managers will be actively pursuing the use of adult and juvenile supplementation within key watersheds in a manner that will also benefit key research needs throughout the Columbia River Basin. Research in supplementation is intended to identify appropriate supplementation strategies for watersheds within the Yakima subbasin. Methodologies and biological benefits and risks of expanding this program to other subbasins will be evaluated. Over the next three-to-five years, the focus will be to explore and evaluate translocation and artificial propagation techniques of Pacific Lampreys, test juvenile growth, survival and movements in the natural environments and refine future research plans for propagation activities and propagated lamprey.

- **Biological Surveys**. Continue to document current status of adult and juvenile lamprey with regards to presence, distribution, and relative abundance. Continue to identify, describe and monitor key Index Sites for long-term status and trends at the reach, watershed and at the subbasin context.

- **Habitat Surveys**. Identify habitat characteristics that are preferred at various life stages (habitat quality) and determine the extent (habitat quantity) these areas are available and are being utilized.

- **Habitat Restoration**. Consider certain types of in-stream restoration efforts to benefit salmonids and to monitor potential benefits towards lamprey productivity. Habitat quality and quantity are not likely limiting population growth at this time - especially given the very low populations currently existing.

However, we expect that certain types of restoration activities in key stream reaches (Wapato Reach, Satus and Toppenish creeks) will benefit both salmonid and lamprey recovery, together.

Coordination and Collaboration. Continue to work directly and collaboratively with local and regional land and resource management agencies and entities to develop and implement a well-founded public involvement and information strategy and to gain efficiencies in both time and resources in implementing lamprey restoration actions.

5 Ongoing / Planned Lamprey Supplementation Research Actions over the Next 5-10 Years

Need a general overview of the supplementation effort (translocation in lower Yakima where they still exist in small numbers; supplementation in upper Yakima where they appear to be extinct as well as diversions and other settings for research purposes here

Table 4. Numerical codes for monitoring and evaluating the three supplementation research strategies described in section 4.3 of the *Framework for Pacific Lamprey Supplementation Research in the Columbia River* Basin. The codes also reflect the section number in the Framework document.

4.3.**1**	Adult Translocation	4.3.**2**	Larval and Juvenile Rearing	4.3.**3**	Larval and Juvenile Outplanting
4.3.**1.1**	Adult Survival	4.3.**2.1**	Broodstock survival	4.3.**3.1**	Larval Growth and Survival
4.3.**1.2**	Adult Spawning	4.3.**2.2**	Fertilization to hatch survival	4.3.**3.2**	Larval Abundance and Distribution
4.3.**1.3**	Larval Survival and Growth	4.3.**2.3**	Hatch to outplant survival	4.3.**3.3**	Larval and Juvenile Outmigration
4.3.**1.4**	Larval Abundance and Distribution			4.3.**3.4**	Adult Returns
4.3.**1.5**	Larval and Juvenile Outmigration				
4.3.**1.6**	Adult Returns				

Table 5. Comparison chart displaying all potential comparison pairs of the different supplementation and research strategies. T = Translocation; larval/juvenile lamprey from translocated adults. H = Hatchery; larval/juvenile lamprey born and reared in a hatchery environment. P = Propagation; larval/juvenile lamprey artificially propagated and released into the natural environment. C = Control; larval/juvenile lamprey born and rearing in the natural environment.

Comparison	**T**ranslocation	**H**atchery	**O**utplanting	**C**ontrol
Translocation	TxT	HxT	OxT	CxT
Hatchery	TxH	HxH	OxH	CxH
Outplanting	TxO	HxO	OxO	CxO
Control	TxC	HxC	OxC	CxC

Table 6. Lamprey supplementation research actions over the next 5-10 years within the Yakima Subbasin (see Table 6-3 and 6-4 for the M&E and Comparison codes).

Subbasin	Stream	Location	Supplementation Research Strategy								Start Timeline	End Timeline
			Adult Translocation (T)		Hatchery Rearing (H)		Larval and Juvenile Outplanting (O)		Control (C)			
			M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison		
Lower Yakima	Satus	Mainstem	4.3.1. **2, 4-6**	*xO, xC, xT*							Ongoing	5+ years
	Toppenish	Mainstem / Simcoe	4.3.1. **1-6**	*All*							Ongoing	5+ years
	Ahtanum	Mainstem / SF Ahtanum	4.3.1. **2, 4-6**	*xO, xC, xT*			4.3.3 **1-6**	*All*			Ongoing	5+ years
	Lower Yakima	Mainstem (Dam Passage)	4.3.1. **1-2**	*xT*							Ongoing	1-3 years
	Lower Yakima	*Prosser Fish Hatchery			4.3.2. **1-3**	*All*					Ongoing	10+ years
	Lower Yakima	*Marion Drain Fish Hatchery			4.3.2. **3**	*xO, xH*					1-3 years	5+ years
	Lower Yakima	*City of Yakima side channel restoration					4.3.3 **4-5**	*xT, xC, xO*			1-3 years	5+ years
	Lower Yakima	*Diversions (Passage Tests on Sunnyside, Wapato, etc.)					4.3.3 **3-5**	*xH, xO*			1-3 years	5+ years
Upper Yakima	Upper Yakima	Mainstem (Dam Passage)	4.3.1. **1-2**	*xT*							Ongoing	1-3 years
	Taneum	Mainstem	4.3.1. **2-6**	*xO, xC, xT*			4.3.3 **4-6**	*xT, xC, xO*			5+ years	10+ years
	Wenas	Mainstem					4.3.3 **4-6**	*xT, xC, xO*			1-3 years	5+ years
	Cle Elum	Side Channel Restoration Sites					4.3.3 **4-6**	*xT, xC, xO*			1-3 years	5+ years
	Swauk	Mainstem							4.3.1. **1, 4**	*xT, xO, xC*	Ongoing	5+ years
	Teanaway	Mainstem							4.3.1. **1, 4**	*xT, xO, xC*	1-3 years	5+ years
	Upper Yakima	*Cle Elum Fish Hatchery / Side Channel			4.3.2. **1-3**	*xO, xH*	4.3.3 **3-6**	*All*			5+ years	10+ years
	Upper Yakima	*Holmes Acclimation Pond					4.3.3 **3-6**	*All*			1-3 years	5+ years
	Upper Yakima	*Diversions (Passage Tests on Roza, Snipes Allen, etc.)					4.3.3 **3-5**	*xH, xO*			1-3 years	5+ years
Naches	Naches	Mainstem (Dam Passage)	4.3.1. **1-2**	*xT*							Ongoing	1-3 years
	Cowiche	Mainstem / SF Cowiche							4.3.1. **4**	*xT, xO, xC*	Ongoing	5+ years
	Tieton	Mainstem							4.3.1. **4**	*xT, xO, xC*	1-3 years	5+ years
	Rattlesnake	Mainstem							4.3.1. **4**	*xT, xO, xC*	1-3 years	5+ years
	Bumping	Mainstem / American							4.3.1. **4**	*xT, xO, xC*	1-3 years	5+ years
	Little Naches	Mainstem / Crow							4.3.1. **4**	*xT, xO, xC*	Ongoing	5+ years
	Naches	Eschbach Park Side Channel					4.3.3 **3-6**	*All*			1-3 years	5+ years

Subbasin	Stream	Location	Supplementation Research Strategy								Start Timeline	End Timeline
			Adult Translocation (T)		Hatchery Rearing (H)		Larval and Juvenile Outplanting (O)		Control (C)			
			M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison	M&E Approach	Comparison		
	Naches	*Diversions (Passage Tests on Wapatox, Scott Ditch, etc.)					4.3.3 **3-5**	*xH, xO*			1-3 years	5+ years
Wenatchee	Wenatchee	Mainstem (Dam Passage)	4.3.1. **1-2**	*xT*							1-3 years	5+ years
	Icicle	Mainstem	4.3.1. **4-6**	*xO, xC, xT*							1-3 years	5+ years
	Nason	Mainstem					4.3.3 **4-6**	*xT, xC, xO*			5+ years	10+ years
	Chewawa	Mainstem							4.3.1. **1, 4-5**	*xT, xO, xC*	Ongoing	5+ years
	White	Mainstem							4.3.1. **1, 4-5**	*xT, xO, xC*	1-3 years	5+ years
	Little Wenatchee	Mainstem							4.3.1. **1, 4-5**	*xT, xO, xC*	1-3 years	5+ years
	Icicle	*Leavenworth National Fish Hatchery			4.3.1. **1-3**	*xO, xH*					1-3 years	5+ years
	Wenatchee	*Wenatchee Fish Hatchery (Future Plan)			4.3.1. **1-3**	*xO, xH*					5+ years	10+ years
Upper Columbia / Entiat	Entiat	Mainstem / Mad							4.3.1. **1-6**	*All*	Ongoing	5+ years
Methow	Methow	Mainstem / Lost	4.3.1. **1-6**	*xO, xC, xT*							1-3 years	5+ years
	Twisp	Mainstem					4.3.3 **4-6**	*xT, xC, xO*			5+ years	10+ years
	Chewuch	Mainstem							4.3.1. **1, 2-4**	*xT, xO, xC*	Ongoing	5+ years
	Methow	*Winthrop National Fish Hatchery			4.3.1. **1-3**	*xO, xH*					5+ years	10+ years
Middle Columbia - Hood	Rock	Mainstem							4.3.1. **4**	*xT, xO, xC*	1-3 years	5+ years
	Wind	Mainstem							4.3.1. **4-6**	*xT, xO, xC*	1-3 years	5+ years
	White Salmon	Mainstem / Trout Lake							4.3.1. **1, 4-6**	*xT, xO, xC*	Ongoing	10+ years
Klickitat	Klickitat	Mainstem / Little Klickitat							4.3.1. **1-6**	*All*	Ongoing	10+ years

*Indicates rearing in artificial settings

Table 7. Pacific Lamprey Restoration Actions Table for the Yakima Subbasin.

ID #	Threats / Actions	Description of Actions	Subbasin / Watershed	Geographic Scale	Timing	Feasibility	Potential Funding Source	Implementing Entity
Threat #1	**Adult Migration**							
Action 1.1	**Passage Improvement**	initial focus (2013-2015) is on four lower dams (fix) and start assessments of upstream projects in near future. Also continue focus on radio telemetry to evaluate passage.	Lower Yakima (lower 4 dams), Upper Yakima (Roza Dam, Town Canal Dam)	**Point**	2 release groups [summer (September) and spring (March)] to monitor movement year round	High	BOR / BPA / USACE	Yakama Nation / USFWS
Action 1.2	**Prevention of Canal Access**	Prevent adults from entering canal (both inlets & outlets), which could be a significant issue considering the high level of pheromone attraction steming from canal waters.	Lower Yakima, Upper Yakima, Naches?, Others?	**Point**	*future project - during spawning migration (March - October)	High	BOR	Yakama Nation / BOR
Action 1.3	**Lack of Information on Status and Trend**	Limited info exist on where the historical and existing Pacific lamprey population migrate to and spawn within the Yakima Basin. Take advantage of existing radio telemetry to study their current distribution. Historical info could be supplied from elder interviews. If adult usage is hard to confirm, larval presence could be used as an indicator for assessment as well.	Region-wide	**Region**	year round	High	BOR / BPA	Yakama Nation / USFWS
Threat #2	**Downstream Passage - Entrainment**							

ID #	Threats / Actions	Description of Actions	Subbasin / Watershed	Geographic Scale	Timing	Feasibility	Potential Funding Source	Implementing Entity
Action 2.1	**Determining New Screening Criteria for Larval/Juvenile Lamprey**	Support USGS in defining new lamprey screening criteria from laboratory research.	Region-wide	**Region**	year round (lab study)	High	BOR	Yakama Nation / USGS
Action 2.2	**Monitoring of Entrainment Impacts**	Continue canal surveys to document entrainment and implement new monitoring that showcase precisely how lamprey are being entrained ("when", "how", "where", etc.). Focus is on four lower dams at this time, but expand as needed.	Lower Yakima (lower 4 dams), Upper Yakima (Roza Dam, etc.), and diversions in supplementation sites (Ahtanum, Naches, Toppenish)	**Point**	winter (October - March)	High	BPA / BOR	Yakama Nation / BOR
Action 2.3	**Reduction of Dewatering Mortality Associated with Canals**	Identify ways to reduce mortality of lamprey during dewatering periods (desiccation & predation)	Lower Yakima (lower 4 dams), Upper Yakima (Roza Dam, etc.), and diversions in supplementation sites (Ahtanum, Naches, Toppenish)	**Point**	early winter (October - November)	High	BOR	Yakama Nation / BOR
Action 2.4	**Characterize Juvenile Out-Migration**	Use Chandler (Prosser) juvenile facility to help characterize juvenile migration. Thousands of macrophthalmia (juvenile) lamprey have been documented passing through this facility during winter months (January~February) and we could effectively estimate outmigration numbers using pit tagging and other methods.	Lower Yakima (Prosser Dam)	**Point**	late winter (January - March)	High	BPA / USACE	Yakama Nation
Threat #3	**Stream and Floodplain Degradation**							

ID #	Threats / Actions	Description of Actions	Subbasin / Watershed	Geographic Scale	Timing	Feasibility	Potential Funding Source	Implementing Entity
Action 3.1	**Restoring Natural Deposition of Fine Sediment and Organic Matter**	Reduce fine sediment & organic matter (food source) collection in canals OR find ways to transport fine sediment & organic matter back into the flowing rivers at the end or beginning of the irrigation season. Also, need to refute the current paradigm which asserts that fine sediment is detrimental to stream health (in fact they are vital to stream health.	Basin wide, but focusing on: Lower Yakima (lower 4 dams), Upper Yakima (Roza Dam), and diversions in supplementation sites (Ahtanum, Naches, Toppenish)	**Point**	*future project - pilot project in 2013	Medium	BOR / SRFB	Yakama Nation
Action 3.2	**In-Channel Restoration**	Implementation of pilot in-channel restoration projects that focuses on restoring lamprey habitat & associated effectivness monitoring. For mainstem Yakima, restoration focusing on side channels may be most effective.	Lower Yakima (Wapato Reach), potentially in Taneum, Toppenish, Satus, and/or Ahtanum	**Watershed**	*future project - pilot project in 2013	High	SRFB	Yakama Nation
Action 3.3	**Riparian/Floodplain Restoration**	Restoration of natural, functioning riparian, floodplain, and side channels is a plus, but hard to find specific remedies that can fix this at a large scale (beyond what has already been done for salmon restoration). However, including lamprey as a "target species" for riparian/floodplain restoration activities is plausible.	Lower Yakima (focus on Wapato reach)	**Region**	*future project - pilot project in 2013	Medium	SRFB	Yakama Nation

ID #	Threats / Actions	Description of Actions	Subbasin / Watershed	Geographic Scale	Timing	Feasibility	Potential Funding Source	Implementing Entity
Action 3.4	**Inclusion into "Target Species" for Other Restoration Activities**	Include lamprey as a "target species" for various restoration activities, including SRFB, so that exisiting salmon restoration activities could further enhance lamprey habitat needs.	Region-wide	**Region**	*future project - start in 2013	High	SRFB	Yakama Nation / USFWS
Action 3.5	**Lack of Information on Status and Trend**	Survey for larval lamprey in high potential habitat and conduct index surveys in key locations to determine status and trend within the basin. These surveys will also aid evaluation of adult passage and effectiveness monitoring from supplementation activities.	Region-wide	**Region**	summer (June - Octoboer)	High	BPA	Yakama Nation / USFWS
Threat #4	**Water Quality - Temperature**							
Action 4.1	**Monitoring of Larval Survival in High Temperature Conditions**	Continue to document presence / absence in high water temperature reaches (to find temperature thresholds for survival). High temperature is a known problem, but remedy is difficult to find.	Lower Yakima (mainstem, lower Toppenish, lower Ahtanum, etc.), Upper Yakima (lower Wenas)	**Watershed**	summer (June - August)	High	BPA	Yakama Nation / USFWS
Action 4.2	**Monitoring of Flow Management on Thermal Dynamics during Spawning Season**	"Flip Flop" flow management can affect thermal dynamics of the river and considering that this happens during the spawning season (most critical period), it is important to understand the potential impact of this.	Upper Yakima & Naches	**Subbasin**	*future project - spring - summer (May - July)	Medium	BOR	Yakama Nation
Threat #5	**Water Quality - Contaminants & Chemistry (DO, BOD, pH etc)**						BOR	Yakama Nation

ID #	Threats / Actions	Description of Actions	Subbasin / Watershed	Geographic Scale	Timing	Feasibility	Potential Funding Source	Implementing Entity
Action 5.1	**Monitoring of Water Chemistry Effects**	No known existing threat (limited monitoring currently), but beneficial to at least monitor conditions in art. prop. / translocation areas to document potential influence	Focusing on supplementation sites	**Watershed**	summer (June - July)	Medium	BOR	Yakama Nation
Action 5.2	**Monitoring of Contaminants Effects**	Monitor areas that are more heavily contaminated (usually lower in the River) and document the effects on Pacific lamprey (at all life stages)	Lower Yakima (Prosser), Toppenish, Ahtanum, Naches, Satus, Lower Wenas	**Watershed**	summer (June - july -> in 2012, it was collected in late October and early November to capture samples from canals)	High	BOR	Yakama Nation / USGS
Threat #6	**Water Quantity - Dewatering and Stream Flow Management**							
Action 6.1	**Minimize Flow Management Impacts**	Find solutions to ameliorate impacts from "Flip Flop" (flow management that balance water between Upper Yakima and Naches reservoirs). This happens during summer which coincides with the migration, spawning, and egg hatching period, which is a critical period for lamprey.	Upper Yakima & Naches	**Subbasin**	summer (May - September)	Medium	BOR	Yakama Nation
Threat #7	**Predation**							
Action 7.1	**Predation Reduction**	Support projects (such as salmon related ones) that reduce the abundance of predacious and/or invasive species that prey on juvenile, larval lamprey at a rate much higher than the historical background rates.	Lower Yakima (lower 4 dams), and expanding as needed	**Point**	*future project - year round (as opportunity arise)	Medium	BPA / BOR	Yakama Nation

ID #	Threats / Actions	Description of Actions	Subbasin / Watershed	Geographic Scale	Timing	Feasibility	Potential Funding Source	Implementing Entity
Action 7.2	**Providing Refuge in Areas of High Predation**	Provide overwintering / refuge habitat to reduce predation risks for adults	Lower Yakima (lower 4 dams), and expanding as needed	**Point**	*future project	Medium	BPA / BOR	Yakama Nation
Threat #8	**Disease**							
Action 8.1	**Disease Monitoring**	Work in conjunction with fish pathologists during the process of art prop. and translocation activities.	Lamprey holding facilities (Prosser Hatchery, etc.)	**Point**	year round (at the hatchery)	High	BPA	Yakama Nation / USFWS
Threat #9	**Harvest**							
Action 9.1	**Harvest Monitoring**	As far as we know, no harvest is taking place within the Yakima Basin currently, but ammocoete harvest (for use as a fish bait) may be taking place in some places	Region-wide	**Watershed**	*future project - year round	Medium	BPA / WDFW	Yakama Nation / WDFW
Threat #10	**Lack of Awareness**							
Action 10.1	**Outreach and Education**	Outreach activities through student / community events.	Region-wide	**Region**	year round	High	BPA / BOR	Yakama Nation / USFWS
Action 10.2	**Community Involvement in Restoration**	Student / community involvement during restoration activities. As a result of translocation and art. prop supplementation projects, there will be many opportunities to involve local students in these activities (fish release, monitoring, etc.)	Lower Yakima (Wapato k-12), Toppenish (White Swan / Harrah / Toppenish k- 12), Ahtanum (La Salles, West Valley, Ahtanum k-12), Naches (Naches k-12), Taneum (Thorp k-12), Cle Elum (Cle Elum k-12), Wenas (Selah k-12)	**Subbasin**	year round	Medium	BPA / BOR	Yakama Nation

ID #	Threats / Actions	Description of Actions	Subbasin / Watershed	Geographic Scale	Timing	Feasibility	Potential Funding Source	Implementing Entity
Action 10.3	**Larval Lamprey in Classrooms**	Lamprey (larval) in the classroom using aquarium tanks, etc. Providing more chances for students to have hands-on experiences with lamprey will greatly enhance awareness of lamprey (and potentially how they decide to interact with lamprey in the future in whatever careers they choose.	Lower Yakima (Wapato k-12), Toppenish (White Swan / Harrah / Toppenish k- 12), Ahtanum (La Salles, West Valley, Ahtanum k-12), Naches (Naches k-12), Taneum (Thorp k-12), Cle Elum (Cle Elum k-12), Wenas (Selah k-12)	**Subbasin**	*future project - year round except summer months (September - June)	High	USFWS / BPA / BOR	Yakama Nation
Threat #11	**Climate Change**							
Action 11.1	**Assessing Climate Change Impacts on Species Distribution**	Assess climate change impacts (in terms of temperature and flow dynamics, etc.) within the Yakima Basin to further our understanding on how that may affect future lamprey distribution within the basin.	Lower Yakima (mainstem, lower Toppenish, lower Ahtanum, etc.), Upper Yakima (lower Wenas)	**Region**	*future project	Low	BPA	Yakama Nation

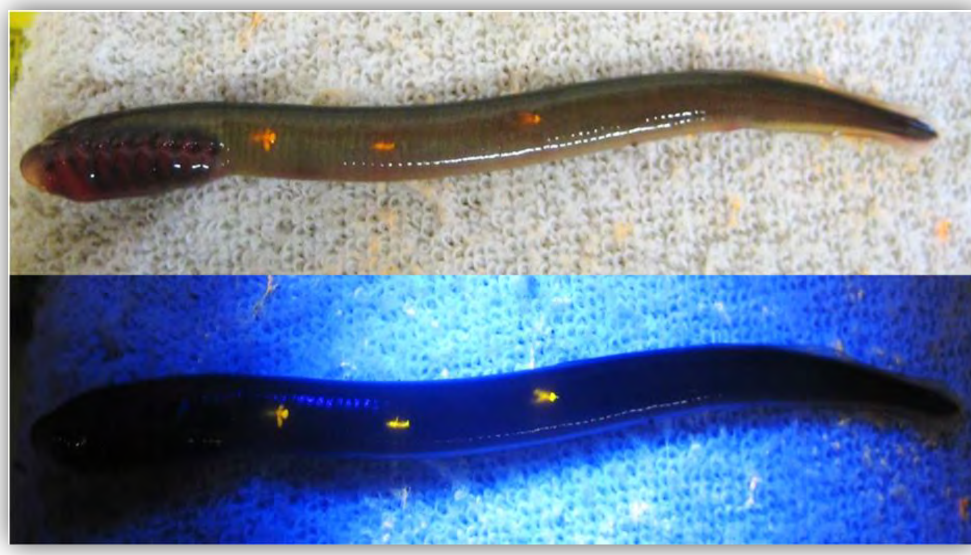
Summary Analysis of Existing Lamprey Propagation/Rearing Facilities Within the Yakima Subbasin

Assessment Unit	Site	Location	Owner	Current Use	Available Resources	Facility Features	Monitoring Opportunities	Other Benefits	Potential Concerns
Upper Yakima	Cle Elum Hatchery	Yakima River Rkm 303.0	Yakama Nation	Spring Chinook rearing	Existing raceways not being utilized, spawning channel, natural side channel for potential rearing	Water temperature modulation, high water quality	Propagation; rearing and feeding of larvae; Tests on adult and juvenile fish behavior	Located high in the watershed, good rearing habitat available in adjacent side channel, potential source of pheromone attraction into prime spawning reach	Potential interactions between spring Chinook and lamprey.
	Holmes Acclimation Ponds	Yakima River Rkm 260.7	Yakama Nation	Floodplain mitigation – pasture, residence	Currently being developed for coho program and has both spawning channels and rearing ponds	50 ac land area. Potential 12.6 ac available for facility development, approx. 4 ac wetland/floodplain meander scroll	Test rearing potential of salmon acclimation ponds; spawning recruitment relationship	Water rights on property acquired. Grant applications suggested water is to go to instream flow. Convert some to fish production?	Can coho and lamprey program goals both be achieved at this location?
Lower Yakima	Marion Drain	Yakima River Rkm 134.4	Yakama Nation	None	Current design includes construction of buildings and ponds for lamprey propagation program	Existing well water on site, infiltration gallery proposed	Collection of macropthalmia and returning adults	Potential for rearing in adjacent riverine wetland areas; proximal to Yakama Nation office	Potential attraction of adults towards Marion Drain; requires investment and development of infrastructure.
	Prosser Hatchery	Yakima River Rkm 74.4	Yakama Nation	Kelt re-conditioning, Spring/ Summer/Fall Chinook, Coho	Adequate space to implement proposed upgrades for lamprey propagation; existing spawning channel; sediment pond available for rearing; experienced staff on site	Surface and well water	Propagation; rearing and feeding of larvae; Tests on adult and juvenile fish behavior; effects of contaminants	High water quality; efficiency - potential to re-use sturgeon water; adjacent stream potentially available for modification as rearing habitat	Low in watershed; lack of good spawning and rearing habitat in immediate vicinity
	Yakima Groundwater Recharge Channel	Yakima River Rkm 182.4	City of Yakima	None	City of Yakima is studying feasibility of running treated water from a treatment facility into a constructed channel for groundwater recharge	Surface water (through inlet)	Test rearing potential of restored side channels	Great pilot site to assess survival/movement over multiple years	Can lamprey survive year round in the restored side channel?

Evaluating Persistence of Visibility with Visible Implant Elastomer Tags on Assorted Sizes of Larval and Transformer Western Brook lamprey Over a Five Month Period: Preliminary Report

Yakama Nation FRMP, Pacific Lamprey Project

January 1, 2014



Introduction

Given the rapid decline in Pacific lamprey numbers throughout the species range since the 1960s, monitoring of ammocoetes (larval lamprey) and macrophthalmia (smolt) lamprey has become an important tool to assess the status of local populations. However, without the ability to mark and recapture ammocoetes and juvenile, any of these data collected will have limited applications. For example, without understanding the trap efficiencies of screw traps, interpretation of the raw counts of lamprey becomes extremely problematic; it may translate into many or few ammocoetes. In addition, very limited information is available on how much ammocoetes move throughout their entire larval stage that range between 3-7 years. We have limited understanding on how many of the ammocoetes actively move downstream while others stay put near one place during this larva stage.

For this purpose, the ability to tag ammocoetes and macrophthalmia is essential to improve our understanding of the raw counts gained from these existing monitoring. The Yakama Nation

Fisheries (YN) has conducted tests with Visible Elastomer Implant (VIE) tags (Northwest Marine Technology, Seattle, WA) to monitor survival, health, and tag visibility over time using Western brook lamprey salvaged from irrigation diversions. If VIE tagging has limited effects on survival, growth, and health conditions of the fish while maintaining long-term optimal visibility, it may become a critical tool for future larval/juvenile research.

Methods

Thirty-two Western brook lamprey (25 ammocoetes and 7 transformers) were tagged with either orange or green colored VIE tags on February 13, 2013. These lamprey were captured from irrigation diversions within the Yakima River Subbasin in the winter of 2012 and were subsequently held and reared at Prosser Fish Hatchery in 8-ft circular tanks with fine sediment collected from irrigation diversions. The mean size of the ammocoetes was 86.1 mm, and the minimum and maximum sizes were 40 mm and 150 mm, respectively (Figure 1). The mean size of the transformers was 152.9 mm, and the minimum and maximum sizes were 144 mm and 162 mm, respectively. We tagged 12 ammocoetes and 5 transformers with orange colored VIE tags and 13 ammocoetes and 2 transformers with green colored VIE tags. The green colored VIE tag was not mixed with the curing agent on purpose to evaluate whether the lack of curing agent will negatively impact visibility during the study period.

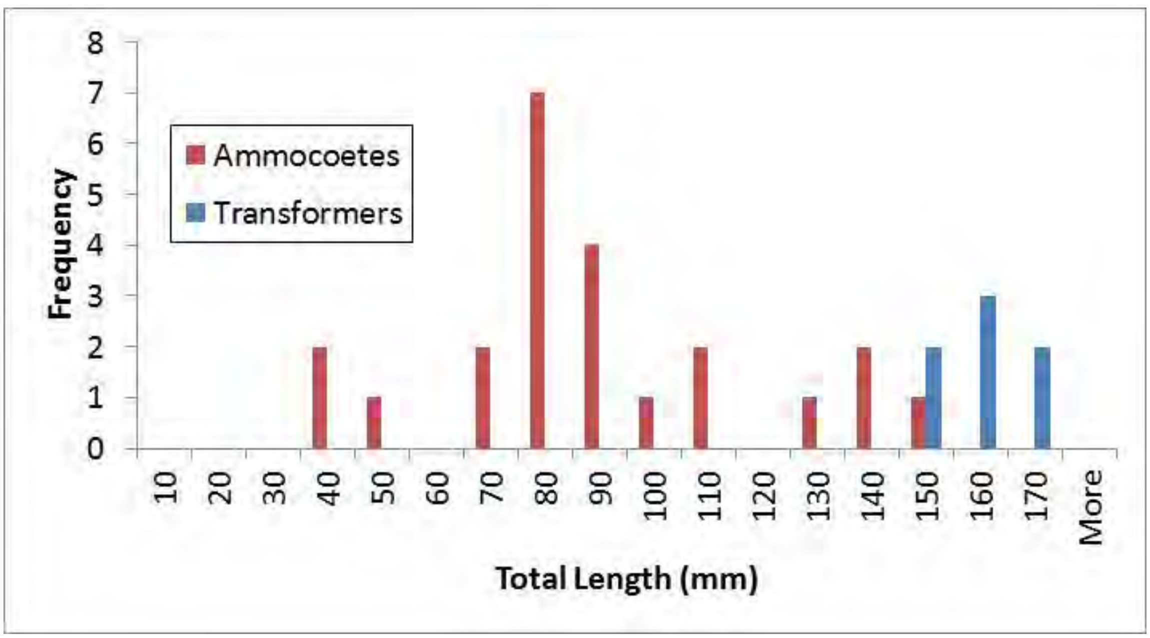


Figure 1. Frequency histogram of the total length of ammocoetes and transformers at the beginning of the study.

Based on experimentation with tag insertion throughout various parts of the body on a few individuals (such as tail ridge, dorsal insertion, ventral and dorsal areas), we found that the side of the body was the easiest place to insert the VIE tags (both sides of the body). In particular, the side of the body between immediately posterior to the last gill pore and the anterior insertion of the first dorsal fin had the best success with tag insertion (Figure 2). We separated this region into three general areas; anterior, center, and posterior. For ammocoetes, first dorsal fin was either very small or invisible, so we aimed just posterior to the center of the body as a proxy for the anterior insertion of the first dorsal fin. Twenty lamprey (19 ammocoetes, 1 transformer) were tagged only in the center position, whereas 12 lamprey were tagged in anterior and/or posterior positions generally in addition to the center position. Eight lamprey were tagged in the anterior positions (5 ammocoetes, 3 transformers), 30 lamprey (25 ammocoetes, 5 transformers) were tagged in the center positions, and 12 lamprey (6 ammocoetes, 6 transformers) were tagged in the posterior positions. Twenty-nine lamprey (24 ammocoetes, 5 transformers) were only tagged on the left hand side of the body, one (transformer) was only tagged on the right hand side of the body, while two (one ammocoete, one transformer) were tagged on both sides of the body.

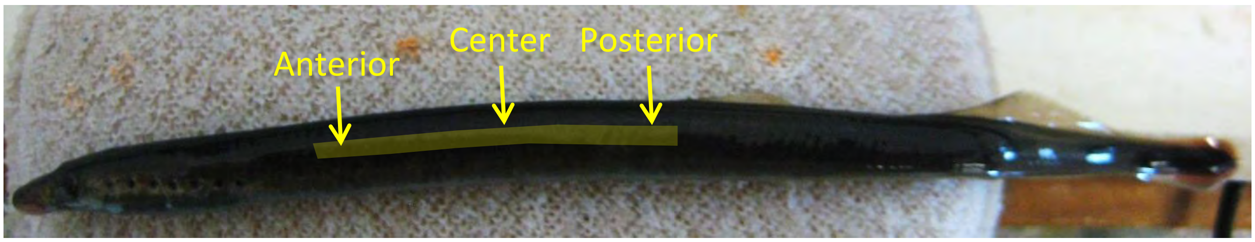


Figure 2. Yellow highlighted areas indicate the general region of the lamprey body where VIE tagging was most successful and easy. Depiction of the three positions (anterior, center, and posterior) is provided as well.

VIE tags were inserted using a 29-gauge syringe needle. The needle was first inserted just underneath the pigmented skin at a roughly 45 degree angle for initial skin penetration and subsequently at an almost parallel angle with the skin pigment for 2-3 mm. The VIE tag was then inserted as the needle was slowly withdrawn from the skin. After monitoring for the newly placed VIE tags, all 32 lamprey were placed in a 10 gallon aquarium with fine sand covering the bottom 5 cm. Flow rate was maintained at approximately 2.4 liters per minute. We fed 5 g of active dry yeast per day to the lamprey in the aquarium tank five days a week. Active dry yeast was dissolved in water using a 1-gallon MixerMate Rubbermade pitcher prior to feeding.

For monitoring, we used a 750 micron mesh netting to sift out the sand and capture the lamprey, and clove oil [0.01% concentration (100 ppm)] was used to anesthetize the lamprey. During the monitoring, the visibility of each VIE tag was rated with and without a black light (supplied by Northwest Marine Technology) using three categories - “highly visible”, “faintly visible”, and “invisible” (Figure 3). Length, weight, and notes regarding the general fish conditions were recorded in addition to photo documentation (one overall photo as well as tag close-up photos with and without black light). Sediment and lamprey were placed back into the aquarium after the monitoring. We monitored the VIE tagged fish on six separate occasions: February 13, February 20, February 28, March 6, April 2, and July 17, 2013. These monitoring events represented 0 days (immediately after tagging), 7 days, 15 days, 21 days, 48 days, and 154 days post tagging, respectively. For this analysis, we focus primarily on the differences in visibility between the first (0 days) and last two (48 and 154 days) monitoring events. The time period between February 13, 2013, and April 2, 2013, is referred to as Phase 1 whereas the time period between April 2, 2013, and July 17, 2013, is referred to as Phase 2.

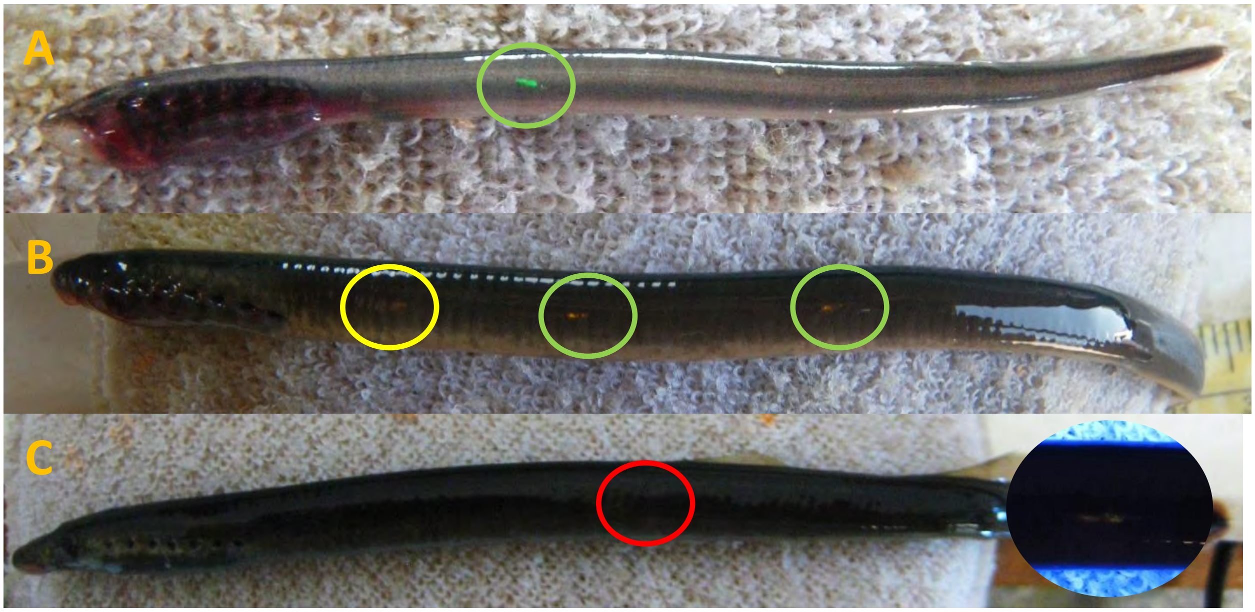


Figure 3. Examples of tags visually rated as "highly visible" (green circles), "faintly visible" (yellow circle), and "invisible" (red circle). Lamprey in Photo A has a green colored VIE tag whereas lamprey in Photo B and C have orange colored VIE tags. Photo B shows one "faintly visible" tag in the anterior position and two "highly visible" tags in the center and posterior positions. Photo C has an embedded photo to the right showing the visibility of the tag under black light.

Results

Lamprey would initially thrash around in the anesthetic water of clove oil when we first placed them. It took approximately 2-7 minutes for the lamprey to become immobile and ready for handling after placement. Recovery time was approximately 2-10 minutes. All tagged lamprey were alive and appeared healthy during and immediately after the monitoring events on February 20, February 28, March 6, and April 2, 2013. However, on June 25, 2013, all seven of the transformers and two of the ammocoetes were found dead (three more ammocoetes appeared immobile and potentially dead initially, but recovered subsequently). This was due to the inflow water being stopped accidentally on June 21, 2013. Despite the inflow water being discontinued for four days over the weekend in warm mid-summer weather condtions, 92.0% of the ammocoetes remained alive. As a result, we compared all 32 lamprey between February 13 and April 2, 2013, but only 23 ammocoetes were available for comparison between February 13 and July 17, 2013. All remaining ammocoetes available for monitoring on July 17, 2013, appeared healthy.

When the black light was not used for evaluation, there was a considerable difference in the visibility of VIE tags in ammocoetes by the tag insertion positions from the beginning of the study on February 13, 2013. Of the 26 tags used on 25 ammocoetes in the center position (one ammocoete was tagged on both sides of the body in the center position), all except one (96.2%) had a "highly visible" tag. Of the five ammocoetes tagged in the anterior position, only two fish (40.0%) had a "highly visible" tag, and of the six ammocoetes tagged in the posterior position, only four fish (66.7%) had a "highly visible" tag. The remainder of tags was only rated as "faintly visible." When the black light was used for evaluation, however, all except one ammocoete (97.1%) had a “highly visible” tag regardless of tag positions; just one ammocoete tagged in the anterior position was only rated as “visible.”

For transformers, the tag visibility was much lower without the use of the black light from the beginning of the study; out of the eleven tags used on seven transformers, only four (36.3%) were “highly visible” tags. The “highly visible” tags were found in various positions; two in the center positions, one in the anterior position, and one in the posterior position. When the black light was used, however, the visibility increased considerably, and all except one (90.9%) was a “highly visible” tag. The one tag that was rated as only “visible” was in the center position.

Of the 12 ammocoetes tagged in the center position using green-colored uncured VIE tags, all except one (91.7%) had a “highly visible” tag under regular light conditions. All of the 13 tags used on 12 ammocoetes in the center position using orange colored cured VIE had a “highly visible” tag under the same light conditions. Hence, no major difference in visibility depending on the type of VIE tags in the center position. However, none of the four tags in the anterior and/or posterior positions using green colored uncured VIE was “highly visible,” whereas six of the seven tags (85.7%) in these positions using orange colored cured VIE was “highly visible,” displaying considerable difference in visibility depending on the type of VIE tags. When the black light was used, there was minimal difference; all except one of the four tags (75.0%) with green colored uncured VIE and all except one of the seven tags (85.7%) using orange colored cured VIE was “highly visible.”

None of the visibility rating changed for ammocoetes with or without the use of the black light after 48 and 154 days. Those tags rated as “highly visible” at the beginning remained “highly visible” and those tags rated as “visible” at the beginning remained “visible” till the end of the study. The same was true for transformers when the black light was used; the visual ratings after 48 days remained the same from the beginning of the study. However, the visual ratings for tags on transformers under normal light conditions showed some worsening after 48 days. Out of the 15 tags on transformers, the visibility of four tags (26.7%) deteriorated. Tags on transformers rated as “highly visible” at the beginning remained “highly visible”, but some of the tags rated as only “visible” at the beginning deteriorated to “invisible” after 48 days (Figure 4). This deterioration in visibility for tags on transformers was observed with both green and orange colored VIE tags.

Figure 4. (A) A transformer with three "faintly visible" tags on February 13, 2013. (B) The same transformer on April 2, 2013, with three "invisible" tags. The silvery body color transformed into a much darker pigmentation during the study period.

The changes in total length of ammocoetes varied considerably by individual fish; some ammocoetes showed growth in length (maximum of 4 mm for Phase I and 3 mm for Phase 2) while some shrank at a rate three times more than the average (as much as -6 mm for Phase 1 and -8 mm for Phase 2). On average, however, ammocoetes shrank at a rate of -0.04 mm per day during the entire study period (-6.1 mm for the entire study period). This rate was consistent between Phase 1 and Phase 2, showing mean daily change rate of -0.042 mm and -0.039 mm, respectively. Maximum shrinkage was -12 mm and largest growth was 4 mm. Transformers also shrank at a similar daily rate (-0.042 mm per day) during Phase 1. One transformer remained the same length, but the other six lamprey shrank up to 6 mm.

Weight of ammocoetes and transformers increased considerably during Phase 1. The median change in ammocoete weight was 0.17 g, which equates to 32.1% of the median ammocoete weight of 0.53 g. The median change in transformer weight was 1.34 g, which equates to 41.7% of the median transformer weight of 3.21 g. However, during Phase 2, weight generally decreased for ammocoetes. The median change in ammocoete weight was -0.11 g (minimum -0.52 g, maximum 0.08 g). The overall median weight change from the beginning to end of the study period was 0.06 g (minimum -0.15 g, maximum 0.85 g). As a result of the overall shrinkage in length and increase in weight, the mean condition factor (weight x 100,000 / length^3) for ammocoetes increased from an average of 0.113 at the start of the study to 0.162 by the end of the study. The difference in the length and weight relationship in ammocoetes and transformers among the three monitoring events is shown in Figures 5 and 6.

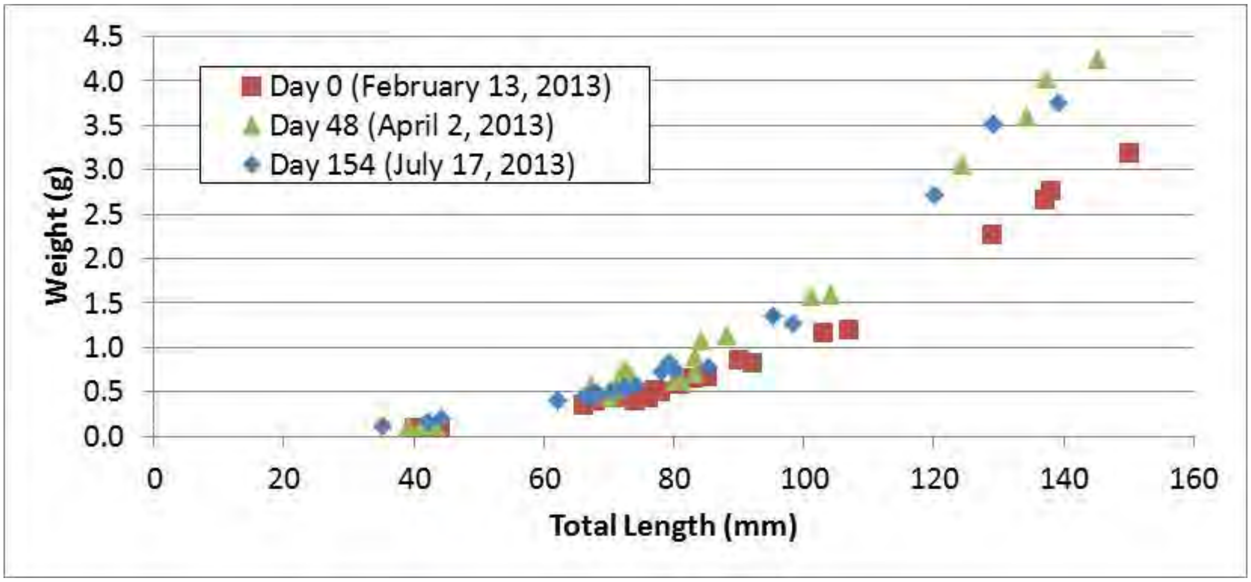


Figure 5. XY plot of total length and weight for the tagged ammocoetes at day 0, day 48, and day 154.

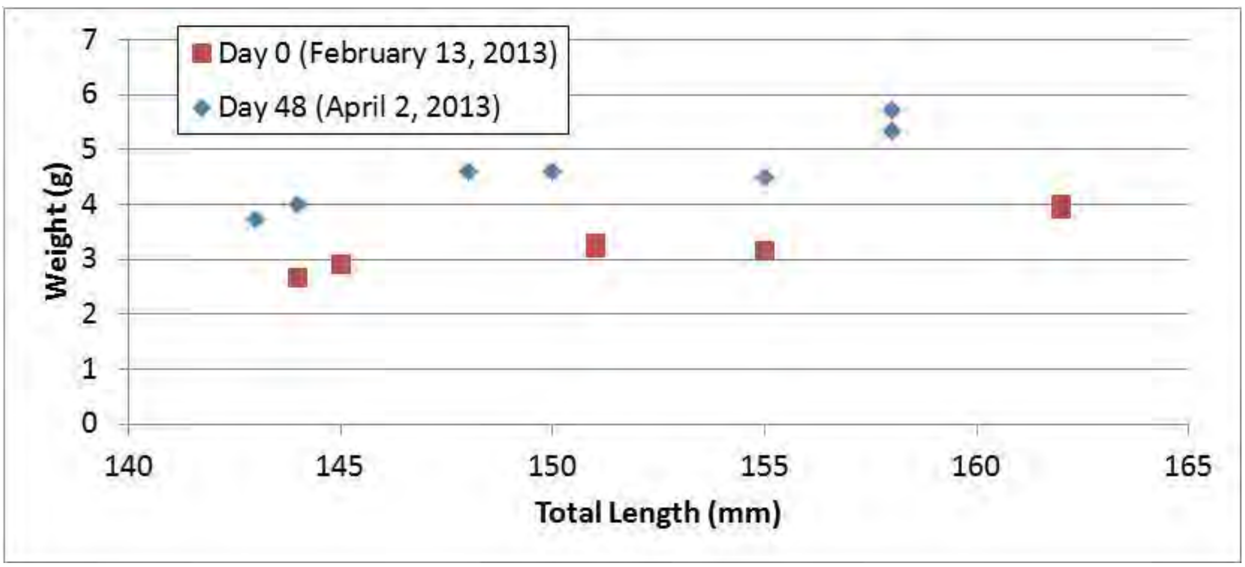


Figure 6. XY plot of total length and weight for the tagged transformers at day 0 and day 48.

Discussion

We discovered that VIE tags can be inserted just underneath the translucent skin tissue in up to six locations on an individual juvenile/larva (see Photo 4B for these general locations). On June 25, 2013, water was accidentally turned off for 4 days, killing all transformers (n=7) and two of the ammocoetes that were VIE tagged. Besides those individuals, all of the tagged larvae (n=23) survived the 154 day study period and the tags' visibility remained roughly the same for all locations. Although this accident was both undesirable and unfortunate, the survival rates of the larvae demonstrate that they are quite resilent and can survive very low oxygen conditions.

Although we did not observe any direct mortality related to the use of clove oil, the wide variability in time needed to anesthetize and recover fish from the anesthetics indicate that clove oil may not be the best anesthetic for larval lamprey. However, more accurate measurement of the amount of clove oil and improved mixing of the clove oil with water may improve the tendency we observed.

The center position (center point between the last gill pore and the first dorsal insertion area) had the best visibility for larval lamprey compared to anterior and posterior positions when examined without the black light. When examined with the black light, however, there was very little difference in visibility among the three positions. If black light is being used at all times, the difference may be insignificant, but if we are relying on tag detection under regular light conditions, the center position may be the best area for tag insertion. Transformers showed no major difference in visibility among the three tagging positions with or without the black light. Tag visibility overall was particularly low for transformers under regular light conditions (only 36.3% “highly visible”). This is most likely due to the silvery skin pigmentation that transformers have, which tend to conceal the color of the VIE tags. As a result, when monitoring for VIE transformers, the use of black light at all times is recommended.

We used two colors (orange and green) and did not cure the green VIE with a curing agent for this experiment. Although we detected no major difference in visibility between the cured orange VIE and uncured green VIE when used in the center position, we did observe considerable difference in the two tags when used in the anterior and posterior positions. Many of the orange colored cured VIE (85.7%) had “highly visible” tags in the anterior and posterior positions whereas none of the green colored uncured VIE were “highly visible” in these positions under regular light conditions. However, when the black light was used, the difference was minimal. Although this could potentially be related to whether the tag was cured or not cured, it is most likely due to the difference in the color (orange vs. green) that is causing the difference because the difference was visible immediately after tagging before the curing even takes effect. In future studies, we recommend using tags that are of the same color to evaluate the true difference between cured and uncured VIE tags. Similarly, if we were to assess the true differences among colors, colored VIE tags should be only one type (either cured or uncured).

The only change in visibility we observed over time was with transformers under regular light conditions. Approximately one quarter (26.7%) of the tags deteriorated in visibility over the 48 day period. This is most likely due to the conspicuous change in skin pigmentation of transformers between winter and spring, during which they change from silvery to darkish green color (Figure 7). As the color of the skin pigmentation changes, the VIE tags may become concealed. None of the tag visibility for ammocoetes showed any change over time.

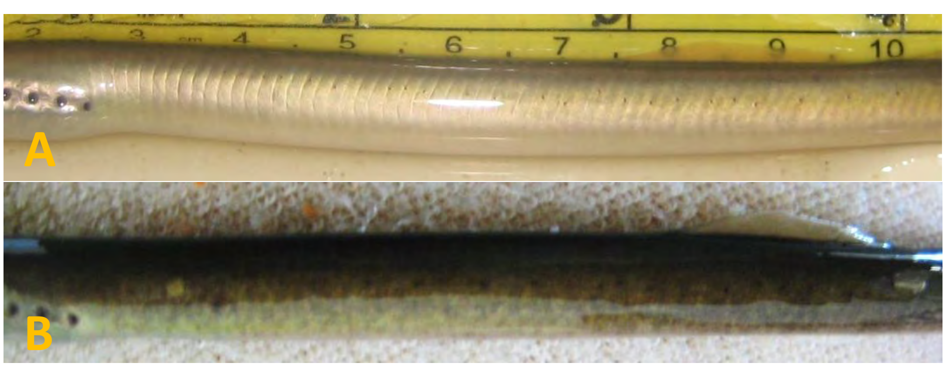


Figure 7. (A) a silvery transformer on February 13, 2013, before VIE tagging. (B) The same individual transformer on April 2, 2013, showing conspicuous change in the color of skin pigmentation.

Total length tended to shrink while weight increased for most of the ammocoetes and transformers during Phase I. For Phase II, many of the ammocoetes shrank in length but also decreased in weight, which may be attributable to the incident in which water flow stopped for four days. Except for the lamprey that died during the inflow water accident, all of the VIE tagged lamprey survived the entire study period (48 days and 154 days). Therefore, effects of VIE tags on survival appears minimal. Although the Fulton's condition factor increased considerably from 0.113 to 0.162, the assessment on whether VIE tags affected growth and health requires further investigation, preferably using control fish without any VIE tags.

In future studies, we recommend that we evaluate even more subtle changes in tag visibility and physical conditions over time. Although we did not detect dramatic changes in tag visibility (i.e. from "highly visible" to "faintly visible") for ammocoetes, there were certainly some fine changes in visibility in some of the individuals. To document this level of subtle changes over time, all photos will need to be taken using the same photo settings (no flash, etc.) and at the same light conditions. These photos will be critical evidence in addition to detailed observation notes.

Additionally, because the lamprey heart is located immediately posterior to the last gill pore on the ventral side, we recommend that the VIE tag be inserted slightly more to the dorsal side for the anterior position to avoid poking or accidentally putting excessive pressure at this key organ. In another study during which many small larvae were VIE tagged, we discovered that a few of the larvae that were tagged close to the heart died subsequently.

Collection of Larval Lamprey Close-Up Photos of Various Size Classes to Compare and Contrast Pacific Lamprey and Resident Lampetra Species

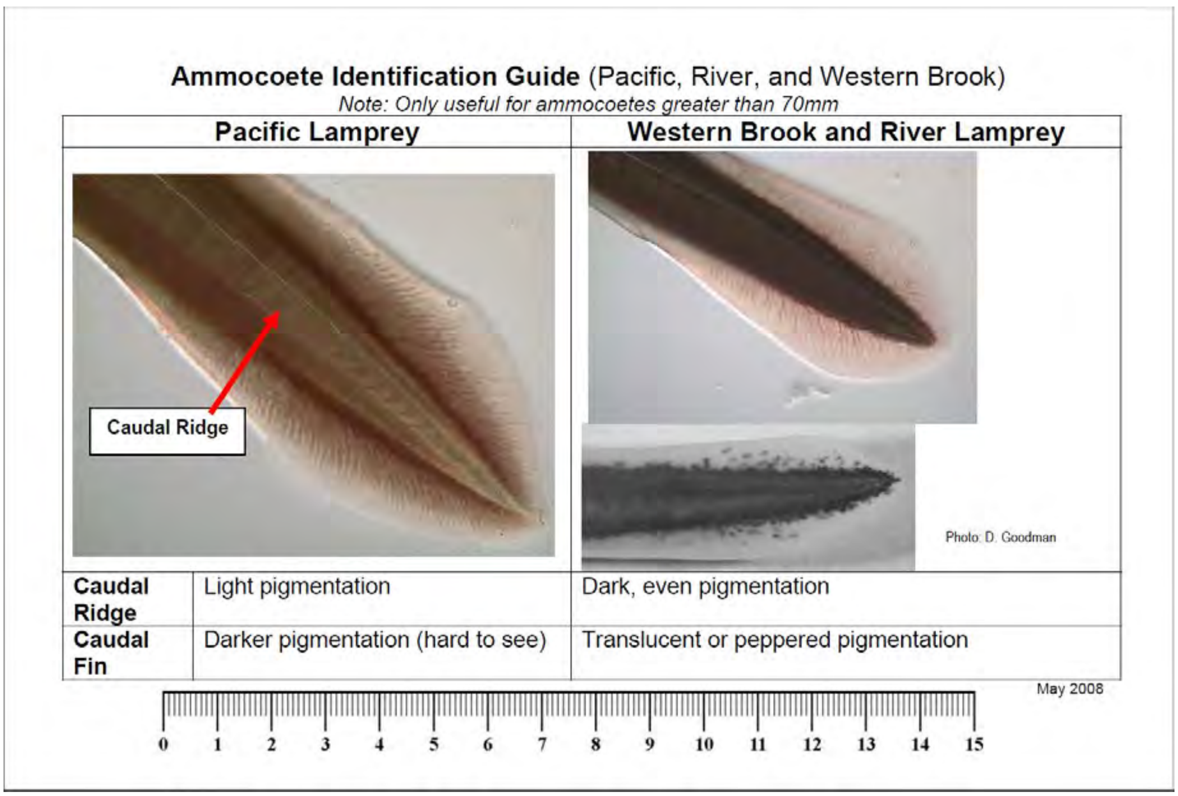
Yakama Nation FRMP, Pacific Lamprey Project

December 31, 2013

Summary:

Accurate identification of larval lamprey is a critical skillset needed for field biologists working on larval lamprey surveys and monitoring. In the Yakima River Subbasin, there are at least two species of lamprey: Pacific lamprey (*Entosphenus tridentatus*) and Western brook lamprey (*Lampetra richardsoni*). Western brook lamprey is relatively abundant and can be found throughout the Subbasin. On the other hand, Pacific lamprey population is considerably diminished today and is only found in the mid-reaches of Yakima River and its tributaries. The current one-page "Ammocoete Identification Guide" designed by Ralph Lampman (Yakama Nation) and Bianca Streif (USFWS) has helped people understand the key differences in tail characteristics between the two species (Figure 1). However, like any other fish, there are considerable individual- and size-based differences in appearances. Simplifying the identifying features can be useful and helpful for many people, but oversimplification can lead many people to misidentify the species based on misinterpretation of the key identifying features. The current ID guide does not accurately capture the subtle variations in their differences, especially as they grow from small to large larvae. Characteristics that we consider unique to one species, based on the ID guide, may be present or partially present on the other species and vice versa. In fact, we have observed and documented many larval Western brook lamprey that have features closely resembling those of Pacific lamprey (especially from the Naches River, tributary to Yakima River). The cover photo above

provides a perfect example (see also Figure 2). Based on the translucency in the caudal ridge and darkly pigmented caudal fin, most people will likely identify this 100 mm larva above as Pacific lamprey. However, this larva is actually a Western brook lamprey, which happened to have a more translucent ridge and darkly pigmented caudal fin. The key feature to distinguish is not the presence vs. absence of the translucent ridge, but rather the specific region where the ridge is translucent. Likewise, the presence of darkly pigmented caudal fin is not a distinctive identification feature for Pacific lamprey; Western brook lamprey can have a varying degree of pigmentation on the caudil fin. Therefore, we thought that creating an additional identification guide (a slightly longer version) that displays the wide variation in appearances of the two species will benefit many field biologists seeking more confirmation and validation about their identification skills. The YN over time collected many detailed photos of both Pacific lamprey and Western brook lamprey of various sizes from a wide range of locations within the Columbia River Basin to better capture the individual and size-based variation in appearances. Each species are sorted from large to small by total length (mm). For each individual fish, we provided an overall photo, close-up of the tail region, and description (species, total length, and capture location). We plan to transform this into a new ID guide (long version) in the near future to educate our crew as well as others involved in lamprey monitoring work.


Ammocoete Identification Guide (Pacific, River, and Western Brook)

Note: Only useful for ammocoetes greater than 70mm

	Pacific Lamprey	Western Brook and River Lamprey
Caudal Ridge	Light pigmentation	Dark, even pigmentation
Caudal Fin	Darker pigmentation (hard to see)	Translucent or peppered pigmentation

Figure 1. Current one-page "Ammocoete Identification Guide"

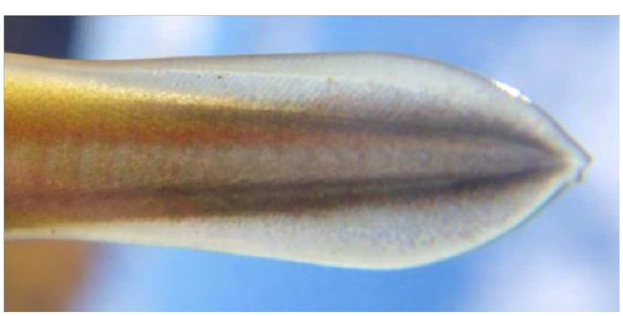
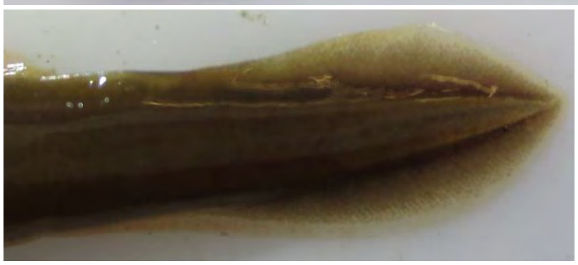


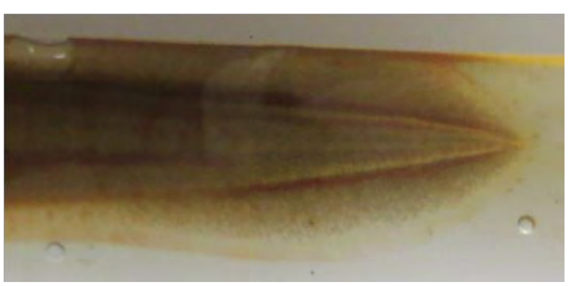
Figure 2. Tail of a Western brook lamprey captured at Wapatox Diversion along Naches River (October 31, 2013)

Pacific Lamprey, 126 mm (Fifteenmile Cr.)



Pacific Lamprey, 124 mm (Fifteenmile Cr.)

Pacific lamprey, 122 mm (Fifteenmile Cr.)

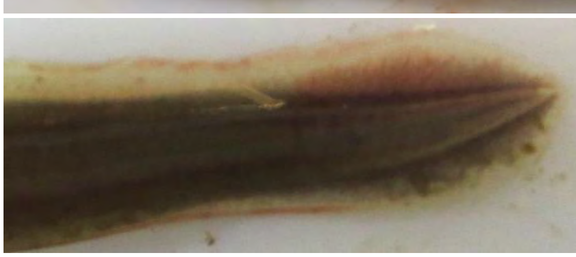


Pacific lamprey, 107 mm (Klickitat R.)


Pacific lamprey, 103 mm (Klickitat R.)

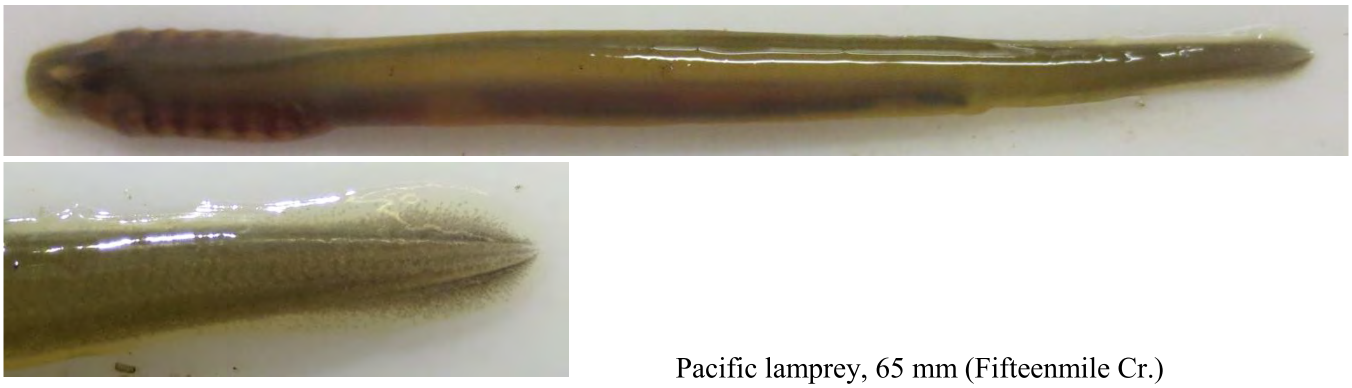

Pacific lamprey, 99 mm (Fifteenmile Cr.)


Pacific lamprey, 77 mm (Fifteenmile Cr.)

Pacific lamprey, 70 mm (Klickitat R.)

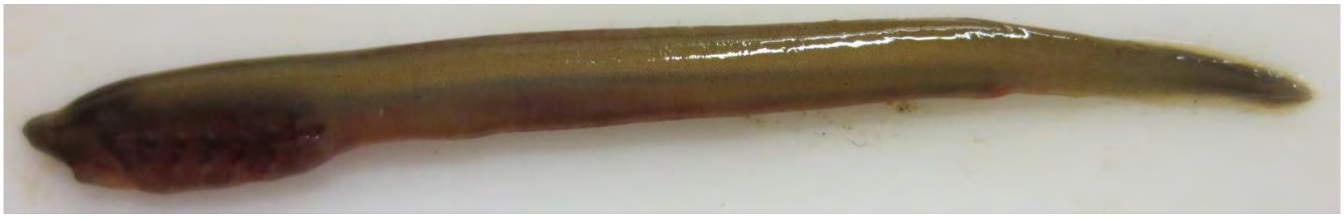
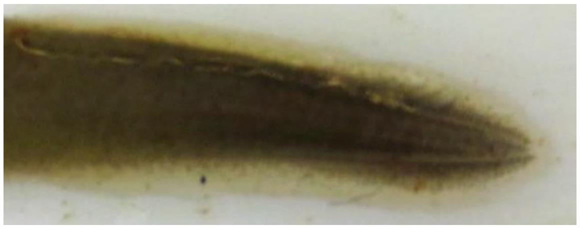
Pacific lamprey, 68 mm (Fifteenmile Cr.)



Pacific lamprey, 65 mm (Fifteenmile Cr.)

Pacific lamprey, 61 mm (Klickitat R.)

Pacific lamprey, 60 mm (Fifteenmile Cr.)

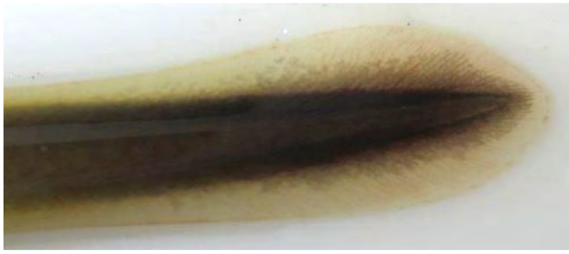



Pacific lamprey, 59 mm (Klickitat R.)


Pacific lamprey, 59 mm (Fifteenmile Cr.)


Pacific lamprey, 57 mm (Fifteenmile Cr.)

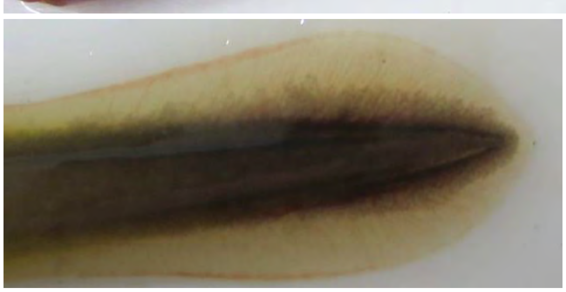

Pacific lamprey, 48 mm (Klickitat R.)

Western brook (river) lamprey, 137 mm (Naches R.)


Western brook (river) lamprey, 135 mm (Naches R.)


Western brook (river) lamprey, 134 mm (Naches R.)

Western brook (river) lamprey, 133 mm (Naches R.)

Western brook (river) lamprey, 133 mm (Klickitat R.)

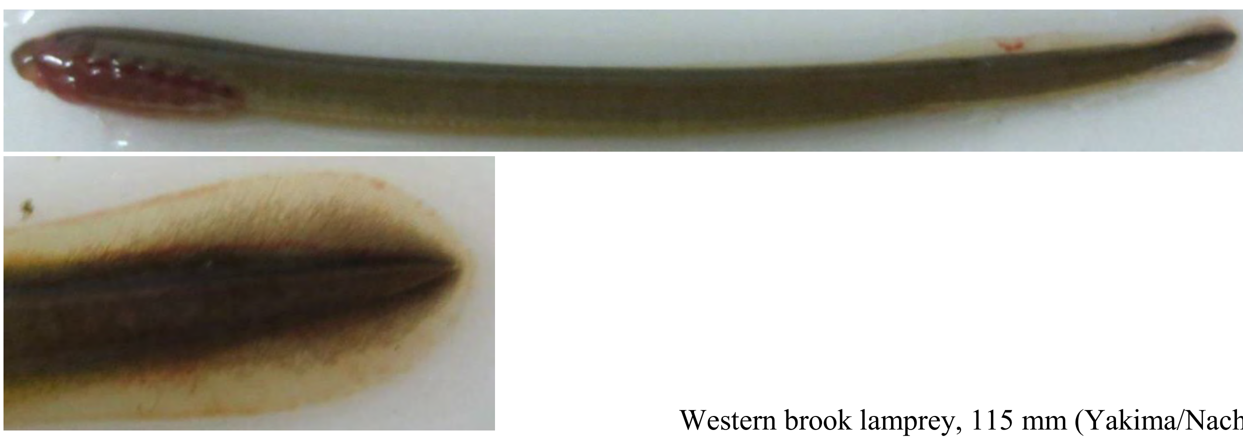
Western brook (river) lamprey, 130 mm (Klickitat R.)

Western brook (river) lamprey, 129 mm (Naches R.)

Western brook (river) lamprey, 120 mm (Naches R.)

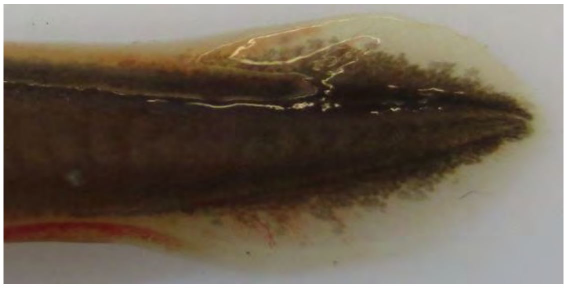
Western brook (river) lamprey, 118 mm (Naches R.)

Western brook (river) lamprey, 115 mm (Naches R.)



Western brook lamprey, 115 mm (Yakima/Naches R.)

Western brook lamprey, 110 mm (Naches R.)

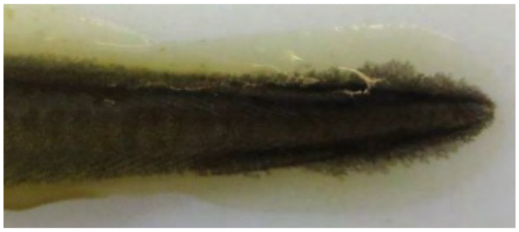


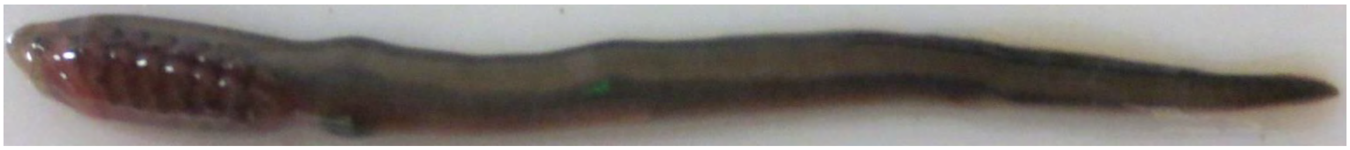
Western brook (river) lamprey, 107 mm (Klickitat R.)

Western brook (river) lamprey, 101 mm (Wind R.)

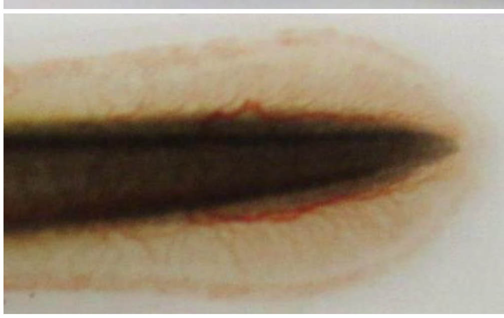
Western brook (river) lamprey, 100 mm (Yakima/Naches R.)

Western brook (river) lamprey, 95 mm (Yakima/Naches R.)



Western brook (river) lamprey, 83 mm (Klickitat R.)

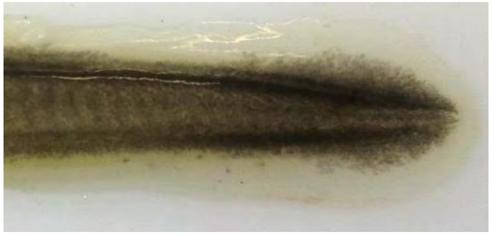


Western brook (river) lamprey, 76 mm (Yakima/Naches R.)



Western brook (river) lamprey, 72 mm (Yakima/Naches R.)

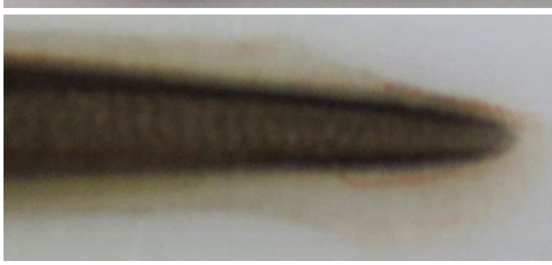


Western brook (river) lamprey, 69 mm (Yakima/Naches R.)



Western brook (river) lamprey, 62 mm (Wind R.)

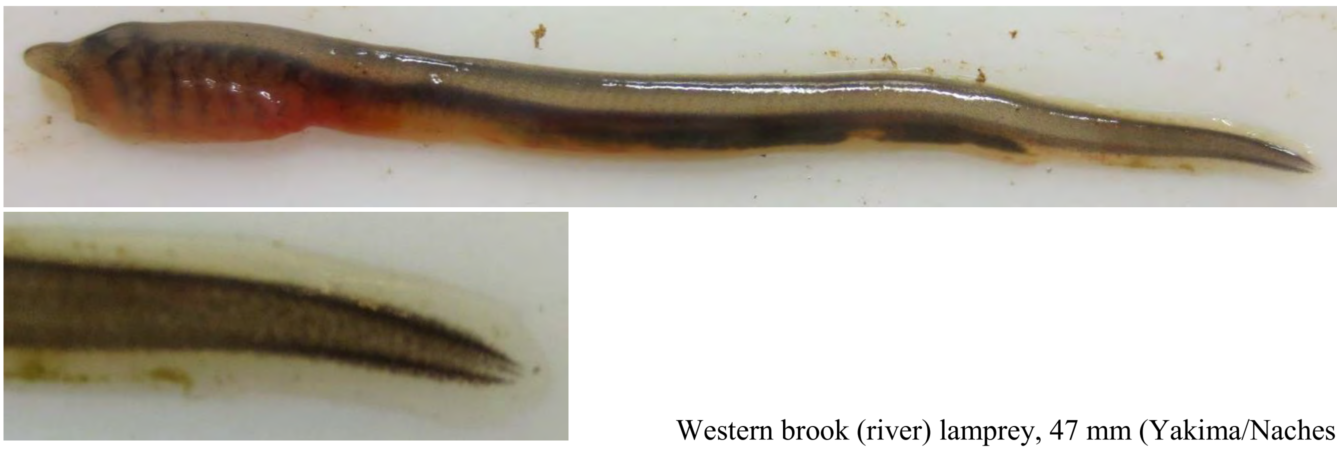
Western brook (river) lamprey, 60 mm (Yakima/Naches R.)



Western brook (river) lamprey, 59 mm (Yakima/Naches R.)

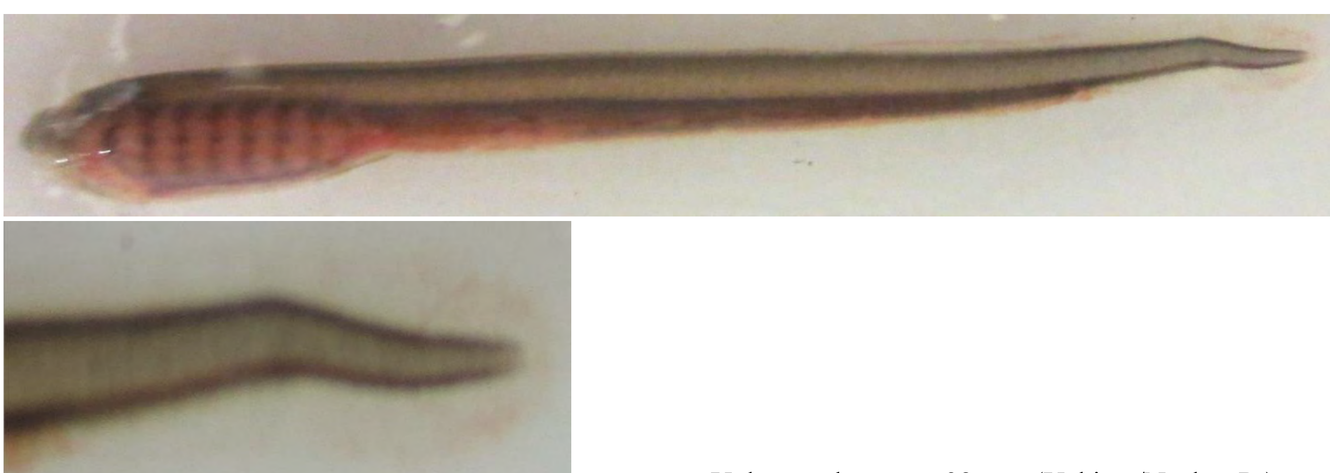
Western brook (river) lamprey, 57 mm (Yakima/Naches R.)

Western brook (river) lamprey, 53 mm (Yakima/Naches R.)



Western brook (river) lamprey, 47 mm (Yakima/Naches R.)

Unknown lamprey, 34 mm (Wind R.)



Unknown lamprey, 32 mm (Yakima/Naches R.)

Do you really know who I am? (*Entosphenus* vs. *Lampetra*)

By Ralph Lampman, Yakama Nation Fisheries, Lamprey Research Biologist

So you catch a lamprey during winter monitoring (screw trap, electrofishing, you name it). You notice that it has a set of eyes, well not just eyes, but large googly eyes (Photo 1). The body is very silvery, like a long, torpedo-shaped silver bullet, hence a smolt (or aka macrophthalmia) (Photo 2). What lamprey species is this? Pacific lamprey (*Entosphenus tridentatus*) smolt? Think again. Let's look at the tail feature carefully (Photo 3). Upon close examination, the caudal ridge (area in the middle) doesn't have a clear translucent area like typical Pacific lamprey (see "Ammocoete Identification Guide" Photo 4 - A). Additionally, the caudal fin is blotchy and is not as darkly pigmented as Pacific lamprey, and it looks more like a Western brook lamprey (*Lampetra richardsoni*) tail (Photo 4 - B). Okay, so the tail definitely looks unusual – now where else should we look? Let's move on to the mouth to see the dentition pattern (Photo 5). For this, you can either place them in a glass or clear plastic jar in water (as they will likely suck on the surface to show the dentition pattern) or you can anesthetize them (remember lamprey needs roughly twice as much on the anesthetic dosage than regular fish). Ah ha! The mouth sure looks different than Pacific lamprey (Photo 6). The best evidence is with the endolateral teeth (orange dotted circles in Photos 5 and 6); Pacific lamprey have four while Western brook or river lamprey (*Lampetra ayresi*) have three. The supraoral and infraoral lamina teeth (green and blue dotted circles, respectively, in Photos 5 and 6) are also good to examine. Pacific lamprey have 3 supraoral teeth (although at this life stage, only two may be visible) and 5-6 infraoral teeth, whereas Western brook or river lamprey has 2 supraoral teeth and 7-10 infraoral teeth. Dentition patterns of Western brook lamprey (Photo 7) and river lamprey are similar except that the river lamprey teeth are a lot more "sharp" looking (showing readiness to feed in the estuary) compared to those of Western brook lamprey, who do not feed at all as adults. Based on all these evidences (*pending genetic confirmation), this is likely an ocean-going *Lampetra* species, hence a (Western) river lamprey, which was found all the way up in Yakima River (major tributary in Mid-Columbia Basin), a place far away from the ocean where we did not expect to find them. If you are still unsure of the identification, take good photos of overall body and tail features and send it to lamr@yakamafish-nsn.gov [I'll then relay it with experts such as Steward Reid (Western Fishes) and others in this field].

Photo 1. Large eyes on the captured lamprey from Yakima River, WA.

Photo 2. Silvery body of the captured lamprey from Yakima River, WA.

Photo 3. Tail features of the captured lamprey from Yakima River, WA.

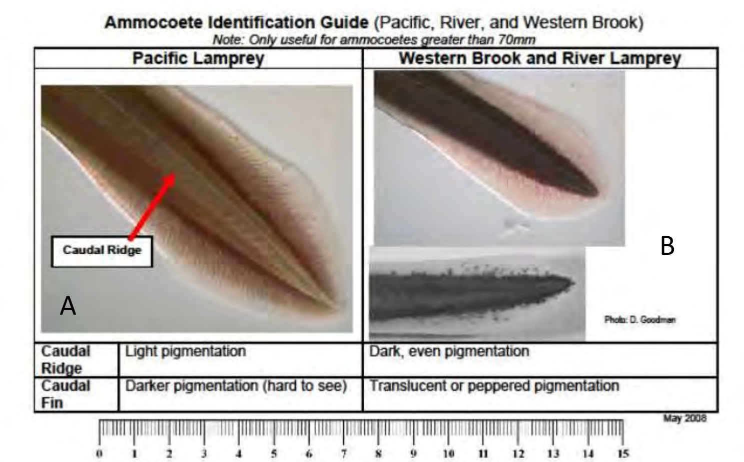


Photo 4. Tail features of Pacific lamprey and Western brook / river lamprey.

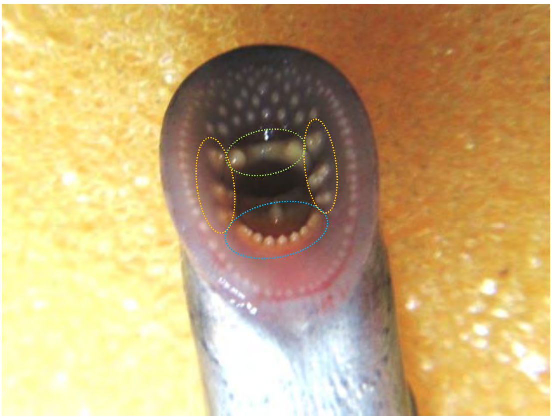


Photo 5. Dentition patterns on the lamprey from Yakima River, WA.

Photo 6. Dentition patterns on a Pacific lamprey from Klickitat River, WA (Photo by Patrick Luke).

Photo 7. Dentition patterns on a Western brook lamprey from Knowles Creek, OR (*caution – in the fall season, Western brook lamprey can appear silvery especially on the belly and have much sharper teeth).