Yakama Nation Pacific Lamprey Project
Annual Progress Report

Project No. 2008-470-00
Report was completed under BPA Contract No. 56662 REL 52

January 2014 – December 2014

Ralph Lampman, Tyler Beals, Patrick Luke,
Robert Rose, Dave'y Lumley, and Edward Johnson

Confederated Tribes and Bands of the Yakama Nation
Yakama Nation Fisheries Resource Management Program
P. O. Box 151, Toppenish, Washington 98948, USA

May 22, 2015

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

This report should be cited as follows:
Lampman, R., T. Beals, P. Luke, R. Rose, D. Lumley, and E. Johnson. Yakama Nation Pacific Lamprey Project, January – December, 2014, Annual Progress Report, Project No. 2008-470-00, 61 electronic pages (appendices 587 pages).

Table of Contents

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 January 1, 2014 through December 31, 2014.

WE165: Environmental Compliance Documentation
No report was submitted in association with this milestone: see Section III (Deliverables) for more information.

WE141: Other Reports (Cultural Information)
One report was submitted in association with this milestone: Appendix B1 (Consolidated and Summarized Cultural Oral Interviews on Lamprey Eels).

WE174: Produce Propagation and Rearing Plan
Two reports were submitted in association with this milestone: Appendix C1 (Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin) and Appendix C2 (Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research).

WE157: Collect/Generate/Validate Field and Lab Data
Two reports were submitted in association with this milestone: Appendix D1 (Yakima Basin Larval Lamprey Survey Report), Appendix D2 (Entiat Subbasin Larval Lamprey Survey Report), Appendix D3 (Methow Subbasin Larval Lamprey Survey Report), and Appendix D4 (Lower Columbia River Tributaries Larval Lamprey Survey Report).

WE28: Trap and Haul (Adult Lamprey Collection from Columbia River)
One report was submitted in association with this milestone: Appendix E1 (2014 Adult Pacific Lamprey Collection in the Columbia River Basin).

WE28: Trap and Haul (Larval/Juvenile Lamprey Salvage in Diversions)
Two reports were submitted in association with this milestone: Appendix F1 (2014 Summary Assessment of Larval/Juvenile Lamprey Entrainment in Irrigation Diversions within the Yakama Basin, Washington, USA) and Appendix F2 (Pilot Assessment of Larval Lamprey Habitat and Occupancy in the Roza Dam Reservoir and Recommendations for Improved Survey Methodology).

WE162: Data Input, Analysis and Interpretation

Ten reports were submitted in association with this milestone: Appendix G1 (Pacific Lamprey vs. Western Brook [or River] Lamprey Larvae Identification Guide), Appendix G2 (Medium Size [50-90 mm] Pacific Lamprey & Western Brook Lamprey Larvae Identification Guide and Tips), Appendix G3 (2012 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands), Appendix G4 (2013 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands), Appendix G5 (2014 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands), Appendix G6 (Establishment of Larval Lamprey Index Sites in the Yakama Nation Ceded Lands), Appendix G7 (Monitoring of Juvenile/Larval Lamprey Passage in Chandler Diversion), Appendix G8 (2014 Intensive Monitoring of Larval/Juvenile Lamprey Entrainment within the Yakama Basin), Appendix G9 (Mercury Concentrations in Pacific Lamprey [*Entosphenus tridentatus*] and Sediments in the Lower Columbia River Basin – Preliminary Report), Appendix G10 (Preliminary Report of USGS-CRITFC Toxicology Study on Lamprey and Fine Sediment Reconnaissance of Contaminants in Larval Pacific Lamprey [*Entosphenus tridentatus*] tissues and habitats in the Columbia River Basin, Oregon).

WE161: Disseminate Raw/Summary Data and Results and Participate in Regional Efforts

No report was submitted in association with this milestone: see Section III (Deliverables).

WE99: Outreach and Education

One report was submitted in association with this milestone: Appendix I1 (2014 Yakama Nation Lamprey Outreach and Education).

WE176: Produce Hatchery Fish / Research into Juvenile

One report was submitted in association with this milestone: Appendix J1 (Developing Techniques for Artificial Propagation and Early Rearing of Pacific Lamprey [*Entosphenus tridentatus*] for Species Recovery and Restoration).

WE119: Manage and Administer Projects

No report was submitted in association with this milestone: see Section III (Deliverables) for more information.

WE132: Annual Progress Report

This report herein represents the annual progress report.

WE185: Pisces Status Report

No report was submitted in association with this milestone: see Section III (Deliverables) for more information.

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

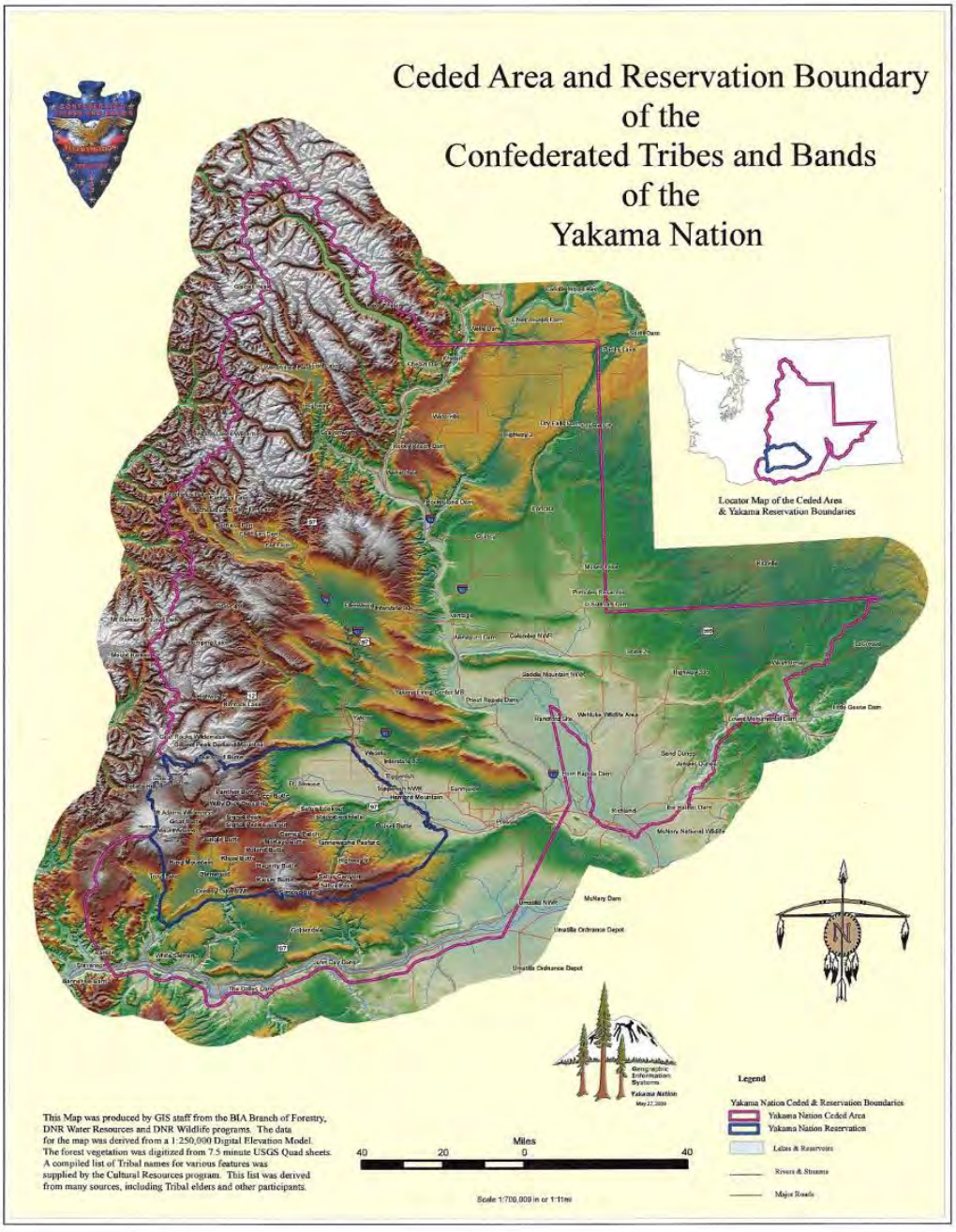

Figure 1. Ceded Lands and Reservation Boundary of the Confederated Tribes and Bands of the Yakama Nation

III. Deliverables

A. Work Element 165 – Environmental Compliance Documentation

Work Element Associated Appendix Report:
Not Applicable

This work element is part of this project's deliverables in relation to environmental laws. This deliverable requires environmental review and compliance assurance prior to contract implementation and we work in close coordination with the BPA Environmental Compliance Officer for this work element. This compliance was related to 1) invasive species and contamination protocols, if applicable, 2) the requirements for National Environmental Policy Act (NEPA) and Endangered Species Act (ESA), 3) Coordination with U.S. Fish and Wildlife Service (USFWS) on Bull Trout *(Salvelinus confluentus*), an ESA listed aquatic species, 4) Coordination with National Oceanic and Atmospheric Administration (NOAA) on steelhead (*Oncorhynchus mykiss*), an ESA listed aquatic species, 5) the requirements for National Historic Preservation Act – Section 106, and 6) public involvement.

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

Work Element Associated Appendix Report:
Appendix B1 – Consolidated and Summarized Cultural Oral Interviews on Lamprey Eels

See Appendix B1 for more information on this work element.

C. Work Element 174 – Produce Propagation and Rearing Plan

Work Element Associated Appendix Reports:
Appendix C1 – Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin
Appendix C2 – Assessment of Eschbach Park Site (Naches, WA) for Larval Pacific Lamprey Outplanting
Appendix C3 – Assessment of Lower Wenas Site (Selah, WA) for Larval Pacific Lamprey Outplanting
Appendix C4 – Assessment of Holmes Acclimation Site (Ellensburg, WA) for Larval Pacific Lamprey Outplanting

Appendix C5 – Assessment of Cle Elum Hatchery Site (Cle Elum, WA) for Larval Pacific Lamprey Outplanting

Considerable planning has occurred in preparation of pilot propagation and outplanting research activities. In 2012 and 2013, the YNPLP worked closely with the CRITFC and the Umatilla Tribes in the development of a broad scale Research, Monitoring and Evaluation (RME) Framework document towards Pacific Lamprey supplementation generally and artificial propagation specifically. The 2013 draft of the framework document was shared with federal and state agencies involved in Pacific Lamprey management (USFWS, WDFW, ODFW, and IDFG) for review. The comments were then incorporated to the final draft, which was completed in March, 2014. This Supplementation Framework document (**Appendix C1**) 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 Master Plan (Research Monitoring and Evaluation strategy) for the upper Columbia River in partnership with CRITFC and member tribes (primarily Confederated Tribes of the Umatilla Indian Reservation). 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, will 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 2015, much of this work relevant to the Yakima River basin, will be incorporated in the NPCC tri-annual Amendment Process. This Master Plan document is scheduled to be completed and submitted to the Independent Scientific Review Panel in spring/summer 2015 to initiate experimental larvae outplanting in fall 2015. See **Appendix C2, C3, C4, and C5** for the YNPLP supplemental reports that assess the four selected potential release sites in Upper Yakima (Photo C-1) and Naches subbasins.

Photo C-1. Larval lamprey habitat in Holmes Acclimation Pond, where larval outplanting is proposed.

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

Work Element Associated Appendix Reports:
Appendix D1 – 2014 Yakima Basin Larval Lamprey Survey Report
Appendix D2 – 2014 Entiat Subbasin Larval Lamprey Survey Report
Appendix D3 – 2014 Methow Subbasin Larval Lamprey Survey and Identification of Potential Adult Pacific Lamprey Release Sites
Appendix D4 – 2014 Lower Columbia River Tributaries Larval Lamprey Survey Report (for Mercury Concentration Assessment)

Yakima Basin

The Yakima Basin, a subbasin of the Columbia River, is home to diverse spawning and rearing habitat for Pacific Lamprey; a species of high cultural and ecological importance that is declining in population abundance and distribution throughout the Columbia River Basin. Also present are the more abundant Western Brook Lamprey (*Lampetra richardsoni*), a species that shares a similar larval life stage as Pacific Lamprey. Our primary objectives for the larval lamprey surveys in project year 2014 were to 1) to assess the presence/absence, relative abundance, and distribution of larval Pacific Lamprey (primary focus) and Western Brook Lamprey (secondary focus), 2) evaluate the relative abundance of larval lamprey habitat, 3) to establish new and

revisit previously established “Index Sites” for long-term status and trend monitoring and 4) to monitor the potential strengthening of Pacific Lamprey recruitment in streams where adult Pacific Lamprey have been translocated and released.

Two survey types were performed; full surveys (detailed habitat measurements) and short surveys (less detailed habitat measurements). Throughout the Yakima Basin, a total of 41 surveys (Fig. D-1) were conducted (24 full and 17 short surveys). In the Lower Yakima Subbasin (Yakima River- and associated watersheds downstream of river km 191.7) we surveyed three sites in the mainstem Yakima River (2 full and 1 short surveys). Surveys were also conducted in major tributary watersheds within the subbasin; Satus (4 full and 2 short surveys), Toppenish (5 full and 3 short surveys) and Ahtanum (4 full and 1 short surveys). In the Naches Subbasin, a total of 7 surveys were conducted in the mainstem (3 full and 4 short surveys), one survey in Cowichee Creek (1 full survey) and 2 surveys in the Little Naches River (2 short surveys). Finally, in the Upper Yakima Subbasin (Yakima River and associated watersheds upstream of river km 191.7) we performed 6 surveys (5 full surveys and 1 short survey) in the mainstem and three surveys in the Cooper River (3 short surveys), an upper tributary of the Cle Elum River.

Within the Lower Yakima Subbasin, the primary fine sediment at each site varied between clay, silt and coarse sand in the mainstem Yakima River. The average plot temperature was 22.1 °C and under-sediment temperature was 20.5 °C (on average 1.6 degrees cooler under the sediment). No lamprey were observed in the downstream most survey site (river km 6.5). Also, no Pacific Lamprey were identified among the sampled larval lamprey. In Satus Creek, the primary fine sediment at each site varied between fine sand and silt, with silt being the most prevalent. The average plot temperature (18.1 °C) was on average cooler than the under-sediment temperature (18.3 °C) by 0.2 °C. Pacific Lamprey were identified at river km 12.9 and 31.4 (7.7% and 100%, respectively). In Toppenish Creek, the primary fine sediment at each site varied between fine/coarse sand, silt and clay. The average plot temperature was 20.1 °C and under-sediment temperature was 18.6 °C (on average 1.5 °C cooler under the sediment). No lamprey were observed downstream of river km 43.3. A total of 281 lamprey were observed and 183 were identified to species in Toppenish Creek; however, no Pacific Lamprey were identified. In Ahtanum Creek, the primary fine sediment at each site varied between clay, silt and coarse sand, with the most prevalent sediment type being silt. The average plot temperature was 21.2 °C and under-sediment temperature was 18.7 °C (on average 2.5 degrees cooler under the sediment). No lamprey were observed at river km 31.1 (near Mission Park) or at a site in North Fork Ahtanum Creek. Pacific Lamprey were found at river km 4.3 (10.0% of the identified total).

In the Naches Subbasin, the primary fine sediment at each site varied between clay, silt and fine/coarse sand, with the most common fine sediment being sand and silt. The average plot temperature was 18.1 °C and under-sediment temperature was 17.4 °C (on average 0.7 °C cooler under the sediment). Larval lamprey were found at five of the seven surveyed sites (absent in

Eschbach Park and the most upstream mainstem site at river km 72.8) as well as further upstream in the Little Naches River. Pacific Lamprey were identified only at river km 14.2, composing 20.9% of the identifiable lamprey at this site.

In the upper Yakima Basin, the primary fine sediment at each site varied between clay, silt and fine sand, with the most common fine sediment being silt. The average plot temperature was 16.6 °C and under-sediment temperature was 14.9 °C (on average 1.7 °C cooler under the sediment). Larval lamprey were found at five of the six surveyed sites (absent in the Roza Dam tailrace at river km 210.5). A total of 626 lamprey were observed and 296 lamprey were identified. Pacific Lamprey were identified only near the Naches River confluence at river km 191.8, composing of 4.6% of the identifiable lamprey at this site; the only survey site downstream of Roza Dam (river km 210.6). Surveys in the Cooper River (a tributary of the Cle Elum River) were conducted downstream of Cooper Lake (river km 6.3), in Cooper Lake near the public boat launch (river km 8.0), and upstream of Cooper Lake near a hiking trail (river km 9.9). The Cooper River was previously thought of being outside of the distribution range for Western Brook and Pacific Lamprey, though Western Brook Lamprey were found within, and upstream of the lake. No lamprey were found downstream of Cooper Lake. Within Cooper Lake, four larval lamprey were observed after a survey of 10 m^2 and two were identified to species. Upstream of Cooper Lake, larval habitat was more abundant. After a survey of 11 m^2, a total of 20 lamprey were captured (19 larval lamprey and 1 transformer with eyes). For more details on the Yakima Subbasin larval lamprey surveys, see **Appendix D1**.

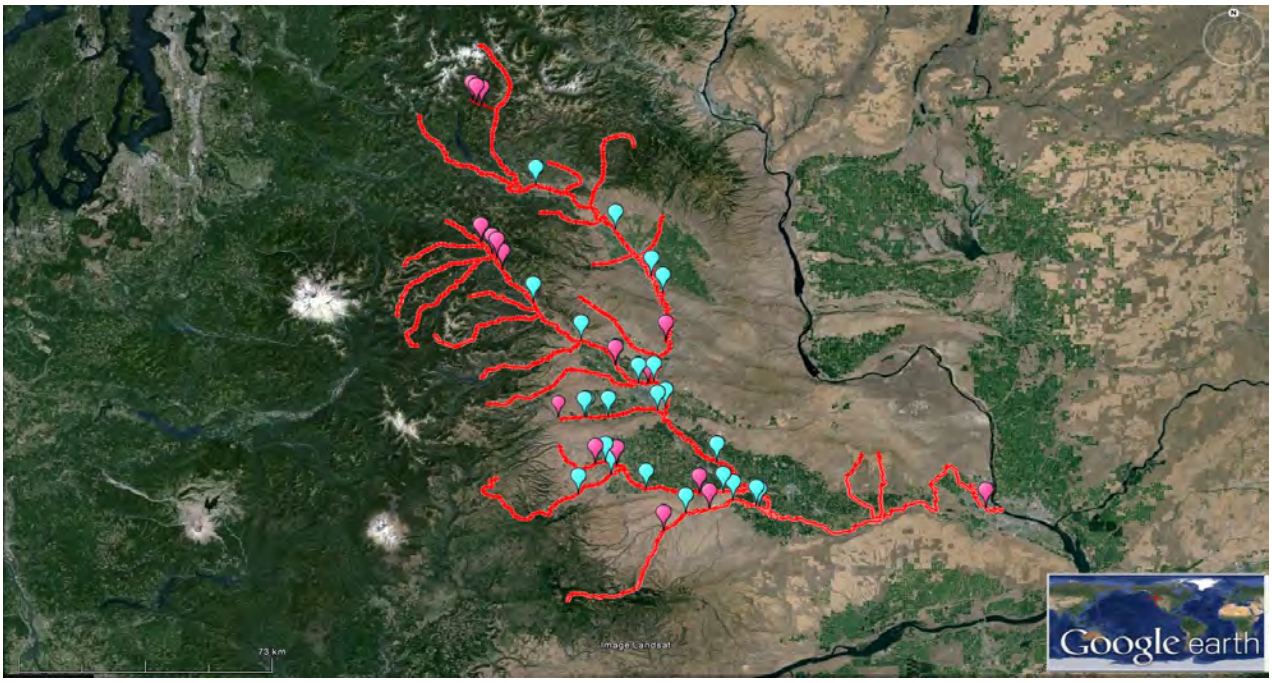

Figure D-1. Overview map of 2014 larval lamprey survey sites in the Yakima Basin, displaying full survey sites (blue) and short survey sites (pink).

Entiat Subbasin

The diverse habitat in the Entiat Basin, a subbasin to the Columbia River, appears to provide suitable rearing and holding habitat for all life stages of Pacific Lamprey. The primary goals of our 2014 survey of the Entiat Basin were to 1) assess the presence/absence, relative abundance, and distribution of larval Pacific Lamprey, 2) evaluate the relative abundance of larval lamprey habitat, 3) explore the upstream boundaries of Pacific Lamprey distribution in the mainstem and 4) establish new and revisit previously established "Index Sites" for long-term status and trend monitoring. In September 2014, a total of 9 survey sites (identified from current knowledge and aerial imaging) were surveyed for larval lamprey along the mainstem Entiat River. Of the 9 survey sites (Fig. D-2), 7 were full surveys (more detailed habitat measurements) and 2 were short surveys (less detailed habitat measurements). Larval densities as high as 90.5 lamprey/m^2 were observed and, on average, larval densities were observed to be higher in Type I habitat (36.1 lamprey/m^2) than Type II habitat (24.3 lamprey/m^2). On average the temperature below the sediment was cooler than the water temperature (13.8 °C and 14.4 °C, respectively). Young of the year larvae (10-30 mm) were primarily found in shallow fine sediment along channel margins. Larval habitat was primarily composed of silt and appeared to be patchy throughout the mainstem. Larval lamprey were found as far upstream as river km 40.2. A survey conducted upstream of Entiat Falls (river km 50.4; an assumed passage barrier for adult Pacific Lamprey) yielded no larval lamprey.

The densities of larval lamprey were relatively high at most of the survey sites. Spawning habitat is abundant; however, larval habitat is patchy throughout the mainstem. The patchy habitat may explain the high densities of larval lamprey that were observed. Silt appears to be the primary type of larval habitat, generally accumulated in backwater habitat or along channel margins. Based on preliminary findings, habitat in fine sediment, such as silt, may be especially conducive to providing thermal refuges as a result of subsurface flow that cools down water. The majority of the young of the year larvae were detected in shallow silt on top of coarse substrates, showcasing a high level of occupancy in this habitat. Focusing restoration activities to accumulate areas of silt (as opposed to coarser sand) along channel margins and near prime spawning reaches may provide more ideal rearing locations for the newly hatching larvae. The results from our 2014 survey are ongoing and will be continued in future years, including the 2015 survey year. The 2014 results provide important insight into sustainable wild densities and preferred rearing locations for larval lamprey within the subbasin. For more details on the Entiat Subbasin larval lamprey surveys, see **Appendix D2**.

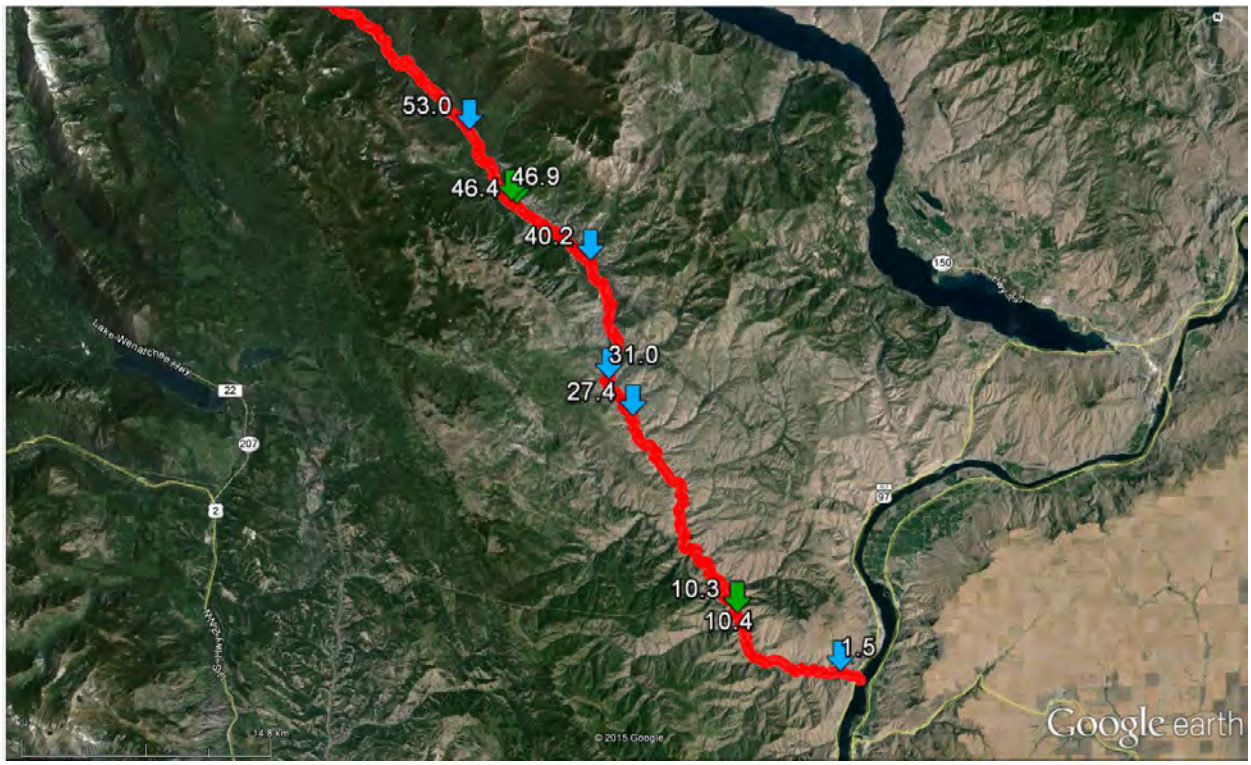

Figure D-2. Overview of 2014 larval habitat survey sites (9 sites total displayed by river km) along the mainstem Entiat River. The full survey sites are shown in blue and the short survey sites are shown in green.

Methow Subbasin

The Methow Basin flows into the Columbia River upstream of Wells Dam, where a minimal number of adult Pacific Lamprey have been detected to pass the dam in recent years. Trends from previous survey years suggest that larval lamprey numbers in the Methow Basin are decreasing rapidly. In 2009, John Crandall (Monitoring Coordinator at Methow Salmon Recover Foundation/Confluence Aquatics) established sites for annual larval lamprey surveys throughout the mainstem Methow River and connecting tributaries. The primary focus in recent years has been the lower Methow River and the Chewuch River, a major Methow River tributary. Survey sites were established for long term status and trend monitoring. In addition to status and trend monitoring sites, additional sites were established to monitor the effectiveness of a 2010 Chewuch River restoration.

Similar to the 2013 field season, the YN aided Mr. Crandall in surveying a total of six annual survey sites between August 26 and 28, 2014 (Fig. D-3); two status and trend sites in the Lower Methow River (LM-15, LM-17), two status and trend sites in the Chewuch River (C-53 and C-53), and two effectiveness monitoring sites in the Chewuch River (EM-Control and EM-Treatment). Results from the survey showed that the average total length of the observed larvae was 150.4 mm, the largest average total length recorded by Mr. Crandall over the six year period. Interestingly, none of the observed larvae were smaller than 70 mm. Approximately 150 larval

lamprey were tagged with orange Visual Implant Elastomer (VIE) tags at the EM-Treatment site in the Chewuch River to annually monitor their instream movements. In addition to larval lamprey surveys, the YNPLP identified four prospective release sites for adult Pacific Lamprey to supplement the depressed numbers of Pacific Lamprey and lack of recruitment in recent years (Fig. D-4). These release sites were selected throughout the mainstem Methow River and are located below two major tributaries (Twisp River and Chewuch River) as well as in areas where Pacific lamprey are assumed to be extirpated (Upper Methow River, upstream of the Chewuch River confluence).

In conclusion, the results from the larval lamprey surveys are alarming. In the Methow and Chewuch rivers, the large size of the lamprey observed (all larger than 70 mm and majority around 150 mm) suggests that Pacific Lamprey recruitment is severely reduced, or has not occurred at all, in the past several years. In order to supplement the depressed numbers of lamprey, translocation efforts are our best short-term option to prevent the extinction of the species in the Methow Basin. The four release sites provide access to optimal spawning reaches and for the most part allow them to choose their spawning destination: Methow River, Twisp River or Chewuch River. By PIT tagging most or all of the released lamprey, automatic detections by tag arrays in the subbasin could provide valuable insight to the ratio of lamprey that enter each tributary (Twisp, Chewuch as well as smaller tributaries). The YNPLP will continue to aide John Crandall in his ongoing monitoring efforts, as well as continue forth efforts to restore lamprey in the upcoming years, through measures such as translocation. For more details on the Methow Subbasin larval lamprey surveys, see **Appendix D3**.

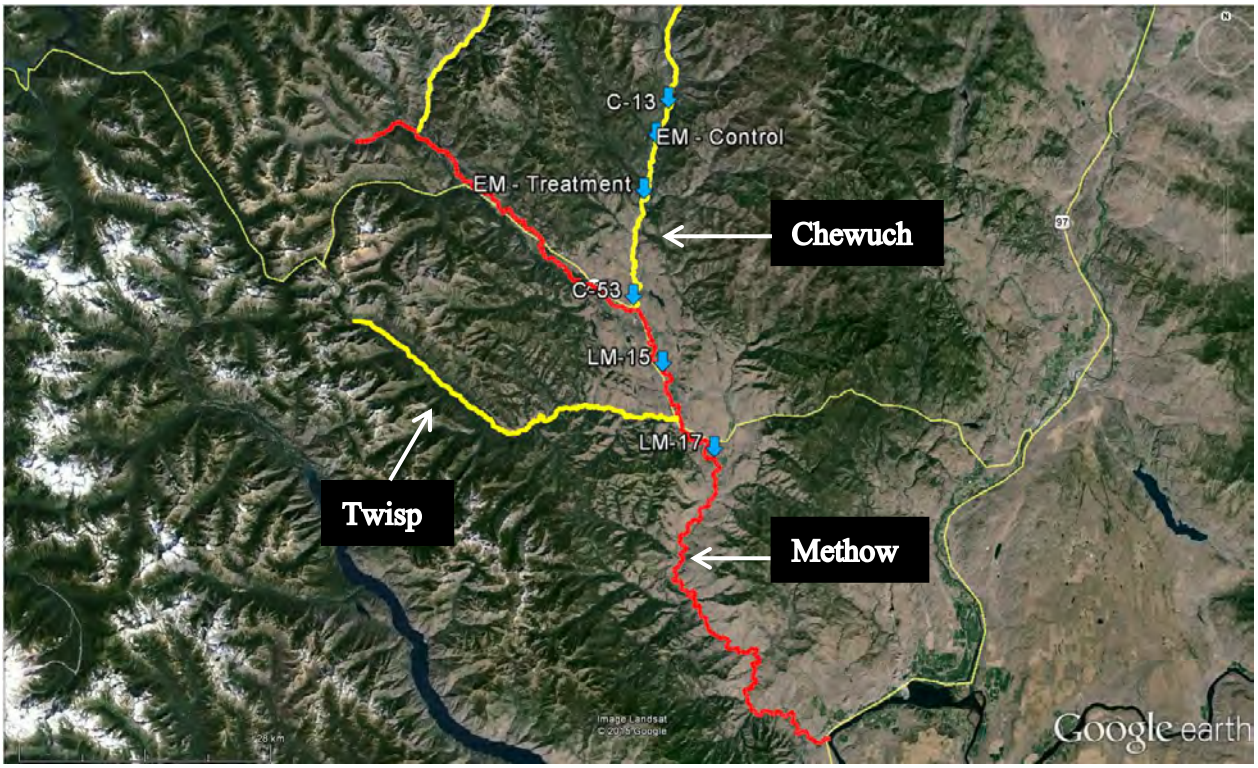

Figure D-3. Overview of Methow Subbasin status and trend and effectiveness monitoring sites surveyed between August 26 and 28, 2014.

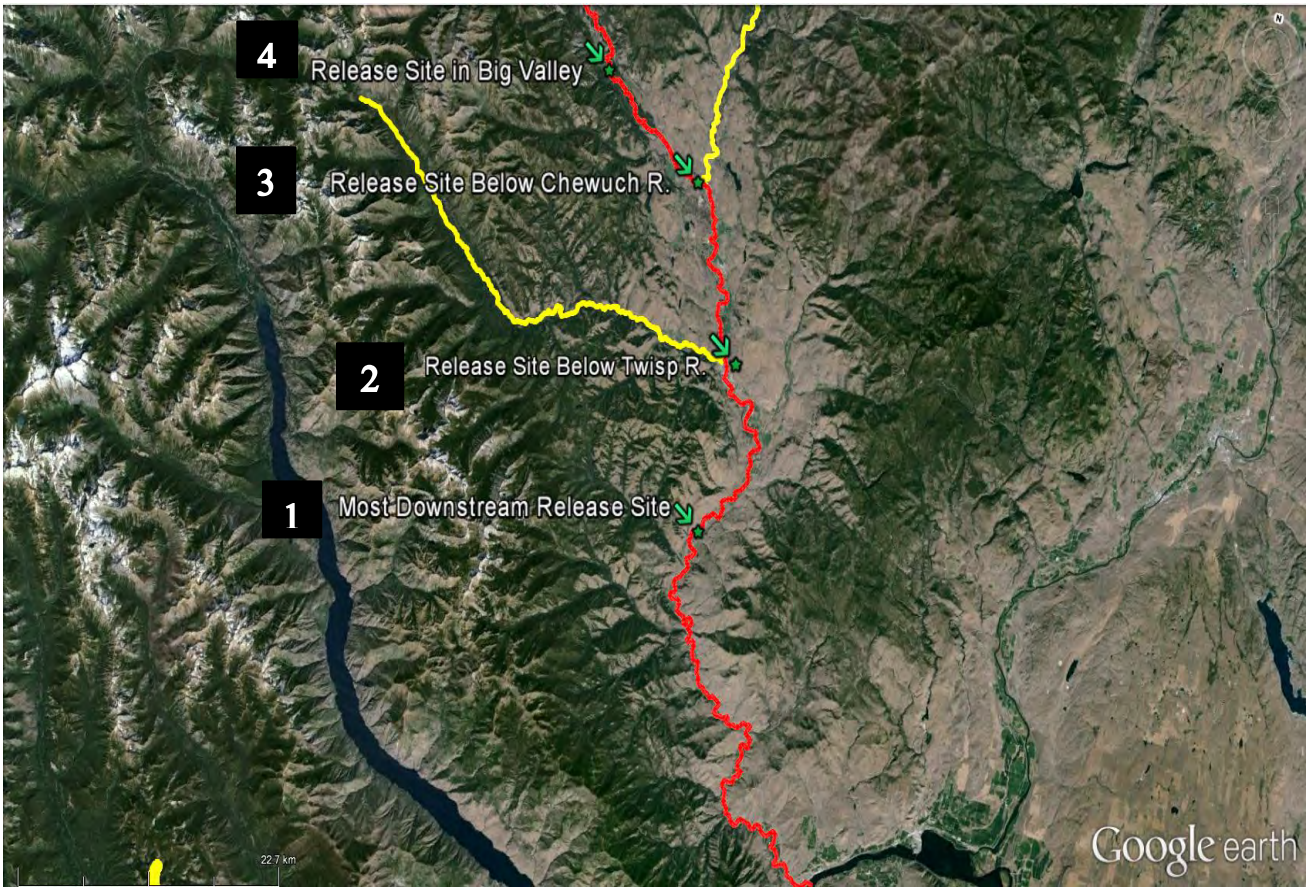

Figure D-4. Overview of the four prospective release sites for adult Pacific Lamprey in the Methow River mainstem; 1) most downstream release site at river km 46.3, 2) release site below the Twisp River confluence at river km 66.4, 3) release site below the Chewuch River confluence at river km 83.8, and 4) release site in the upper Methow River (Big Valley reach) at river km 92.9 (4).

Lower Columbia River Tributaries

The lower Columbia River tributaries provide spawning and rearing habitat for both Pacific Lamprey (*Entosphenus tridentatus*) and Western Brook Lamprey (*Lampetra richardsoni*). The larval stage of Pacific Lamprey (and similarly Western Brook Lamprey) resides in the fine sediment of rivers and streams for up to seven years, making the species highly susceptible to waterborne contaminants. Mercury is a damaging chemical that has been found in high concentrations within the lower Columbia River Basin and connecting tributaries. The railroad that runs along the Columbia River might be a major contributor to the current mercury levels from the abundance of coal that settles in nearby rivers and streams. The primary goal of our 2014 sample of select lower Columbia tributaries was to collect medium to large larval lamprey (either Pacific Lamprey or Western Brook Lamprey) for mercury level analysis, which was later conducted by the Pacific Northwest National Laboratory (Richland, WA). Secondary goals were to briefly assess 1) presence/absence, relative abundance, and distribution of larval Pacific Lamprey and 2) evaluate the relative abundance of larval lamprey habitat. In order to efficiently collect larval lamprey (either Western Brook or Pacific Lamprey), efforts were focused on a

cumulative of 10 sites that had the highest potential of larval lamprey being present (based on existing knowledge) within the mainstem of Rock Creek, Wind River, White Salmon River and Klickitat River (Fig. D-5).

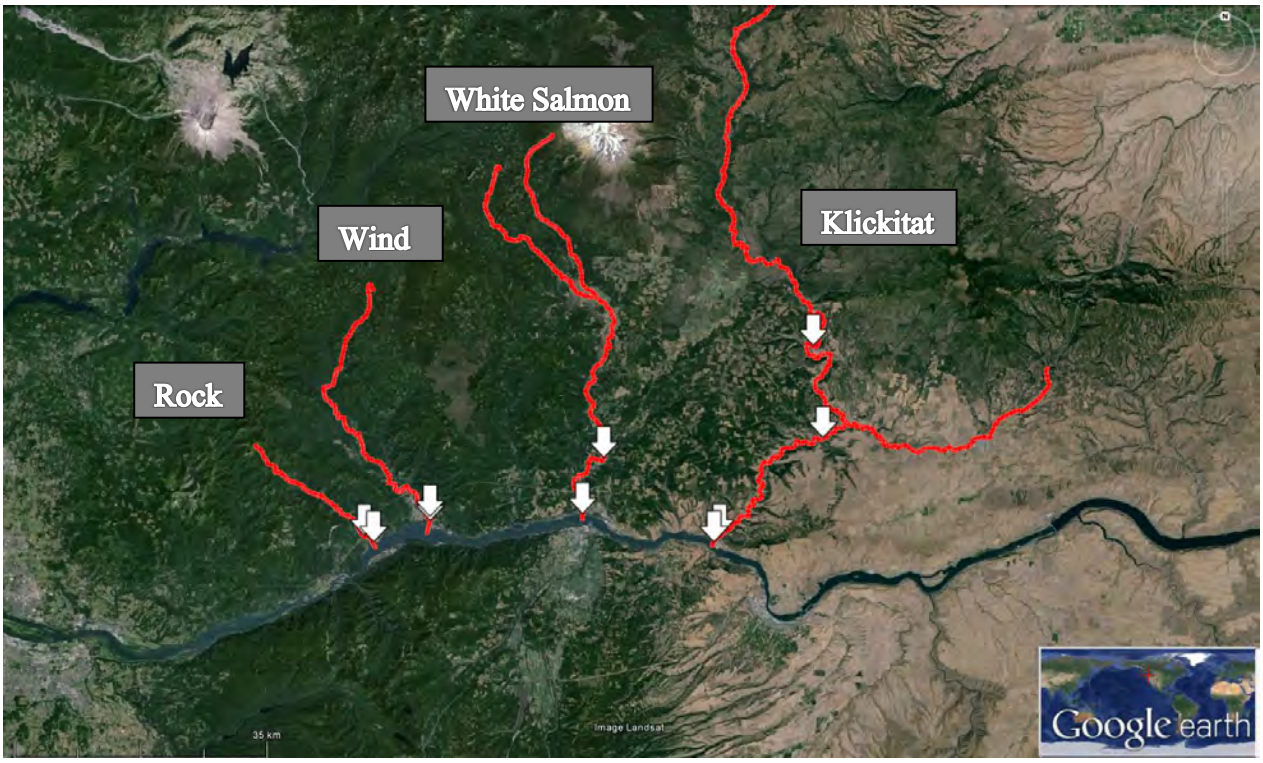

Figure D-5. Overview map of sites where larval lamprey were collected for mercury analysis in Lower Columbia River and tributaries in 2014.

In Rock Creek, the survey date was on September 24, 2014. A total of 11 lamprey were collected at the mouth of the creek (river km 0.0) and 36.4% of the lamprey were confirmed to be Pacific Lamprey. The average total length of the lamprey was 86 mm, with the smallest being 59 mm and the largest at 145 mm. No lamprey observed upstream of Rock Creek Falls (survey site at river km 3.0). The survey date in the Wind River was on September 24, 2014. A total of 5 larval lamprey were collected at the mouth (river km 0.3) and 20% of the lamprey were confirmed to be Pacific Lamprey. Further upstream at river km 2.4 (at the Indian Fish Camp), a total of 10 larval lamprey were collected and 80% were confirmed to be Pacific Lamprey. The average, min and max total length of the captured lamprey was 84 mm, 69 mm and 121 mm respectfully. At the mouth of the White Salmon River (river km 0.0) a total of 11 lamprey were captured and 27.3% of the lamprey were confirmed to be Pacific Lamprey. Upstream at river km 13.0 (behind private property in the town of Husum), a total of 11 lamprey (one transformed lamprey with eyes) were collected and 0% were confirmed to be Pacific Lamprey. All identified lamprey at this site were Western Brook Lamprey. The average, min and max total length of the captured lamprey was 83 mm, 30 mm and 148 mm respectfully. Finally, in the Klickitat River, a cumulative total of 4 individual sites were surveyed on September 23 and October 13, 2014. A

total of 5 larval lamprey were collected at the mouth (river km 0.0 on 9/23/2014) and 40% of the lamprey were confirmed to be Pacific Lamprey. Upstream at river km 1.9 at a public boat launch area, we collected a total of 11 lamprey, but identified 22 lamprey and 20% were confirmed to be Pacific Lamprey. At river km 28.5 and 52.4, Pacific Lamprey were found and we identified 19 and 13 fish, respectfully and 17% and 13%, respectfully, were Pacific Lamprey. The average total length and average min and max total lengths of the captured lamprey was 60mm, 33 mm and 114 mm, respectfully.

E. Work Element 28 –Trap and Haul (Adult Lamprey Collection from Columbia River)

Work Element Associated Appendix Report:
Appendix E1 – 2014 Adult Pacific Lamprey Collection in the Columbia River Basin

The YNPLP collected 904 adult Pacific Lamprey from the lower mainstem Columbia River between May 23 and July 28, 2014, in accordance with the tribal collection allocation guideline (Table E-1, Table E-2, and Fig. E-1). There was a total of 61 mortalities (6.7%), most of which were diagnosed as infected with furunculosis (*Aeromonas salmonicida*). Furunculosis infection appeared to be pervasive in salmonids as well in the lower Columbia River in 2014 (D. Thompson, pers. comm.). Very few adults (7) were collected from the John Day Dam South Ladder this year (Photo E-1). Collection was closely coordinated with the USACE (Portland District) and the Umatilla and Nez Perce tribes. Twenty-two adults collected from John Day Dam were transferred to Grant PUD on July 28 for a passage study at Wanapum Dam. The remainder of the adults will be used for translocation restoration projects in Ahtanum, Satus, and Toppenish creeks and for larval rearing and offspring outplanting within selected sites in the Upper Yakima and Naches subbasins using artificial propagation. See **Appendix E1** for more information on adult collection.

An estimated $30,000 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. 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. The YNPLP is currently planning to undertake a similar collection effort, with the Umatilla Tribes, during the summer of 2015.

Table E-1. Collection allocation of adult Pacific Lamprey based on Tribal Guidelines for 2014

Dam Location	# per Tribe
Bonneville Dam	254
The Dalles	374
John Day	282
Total	**910**

Table E-2. Collection of adult Pacific Lamprey by YNPLP from Lower Columbia River dams in 2014.

	John Day Dam		The Dalles Dam			Bonneville Dam	
Date	North Ladder	South Ladder	East Ladder	North Ladder	Rocky Channel	Cascade Island	AFF
5/23/2014	No Fishing	No Fishing	No Fishing	No Fishing	No Fishing	0	160
6/5/2014	No Fishing	No Fishing	No Fishing	No Fishing	No Fishing	0	56
6/10/2014	No Fishing	No Fishing	No Fishing	No Fishing	No Fishing	0	38
6/18/2014	2	0	22	No Fishing	No Fishing	-	-
6/19/2014	5	0	12	No Fishing	No Fishing	-	-
6/20/2014	0	0	38	No Fishing	No Fishing	-	-
6/21/2014	1	0	5	No Fishing	No Fishing	-	-
6/22/2014	0	0	13	No Fishing	No Fishing	-	-
6/23/2014	6	2	6	No Fishing	No Fishing	-	-
6/24/2014	0	0	30	No Fishing	No Fishing	-	-
6/30/2014	0	0	17	No Fishing	No Fishing	-	-
7/1/2014	0	0	37	No Fishing	No Fishing	-	-
7/2/2014	17	0	14	No Fishing	No Fishing	-	-
7/3/2014	13	1	63	No Fishing	No Fishing	-	-
7/4/2014	30	0	11	No Fishing	No Fishing	-	-
7/5/2014	22	2	36	No Fishing	No Fishing	-	-
7/10/2014	17	0	0	No Fishing	No Fishing	-	-
7/11/2014	16	0	3	No Fishing	No Fishing	-	-
7/12/2014	29	1	30	No Fishing	No Fishing	-	-
7/13/2014	41	1	9	No Fishing	No Fishing	-	-
7/14/2014	2	0	0	-	-	-	-
7/15/2014	28	0	28	-	-	-	-
7/16/2014	18	0	0	-	-	-	-
7/28/2014	22	0	0	-	-	-	-
TOTALS	**269**	**7**	**374**	**0**	**0**	**0**	**254**

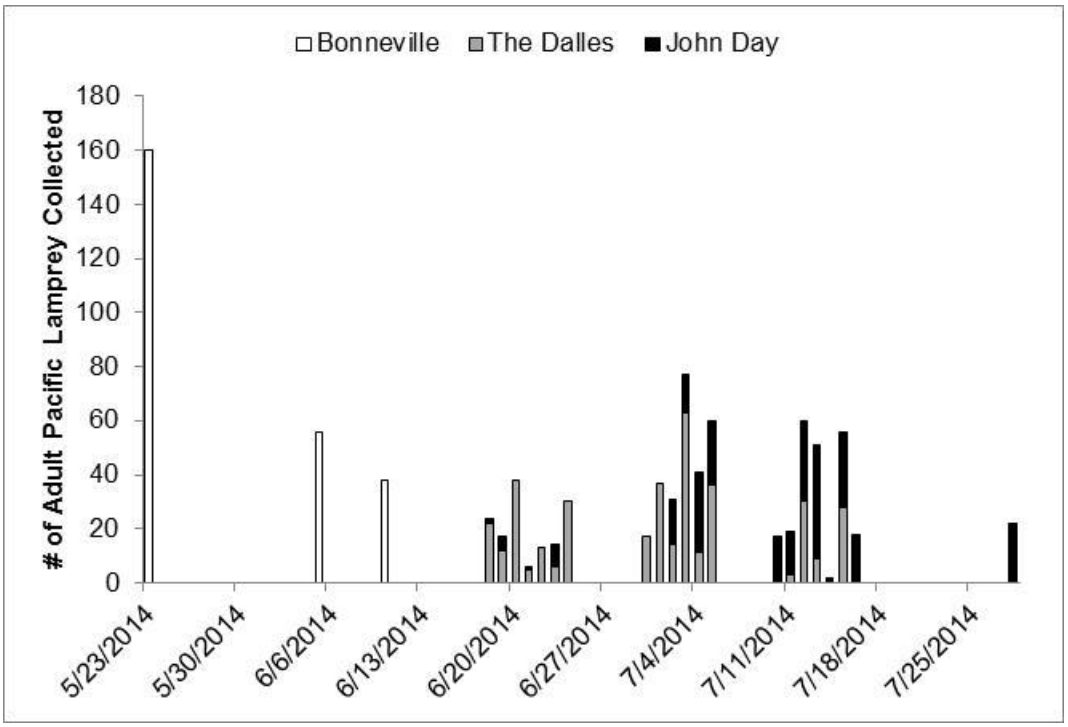

Figure E-1. Yakama Nation adult Pacific Lamprey broodstock collection in 2014

Photo E-1. Upgraded John Day Dam South Ladder crane trap. Unfortunately, not many lamprey were trapped at this location in 2014.

F. Work Element 28 – Trap and Haul (Larval/Juvenile Lamprey Salvage in Diversions)

Work Element Associated Appendix Report:

Appendix F1 – 2014 Summary Assessment of Larval/Juvenile Lamprey Entrainment in Irrigation Diversions within the Yakama Basin, Washington, USA

Appendix F2 – Pilot Assessment of Larval Lamprey Habitat and Occupancy in the Roza Dam Reservoir, Yakima River (Yakima, WA)

Juvenile survey planning and sampling within Yakima Basin irrigation canals were first initiated during the dewatering period in 2010 and are ongoing today. Similar to previous years, planning/coordination meetings between representatives of the YNPLP and Reclamation was held in early October and sampling for the Project Year 4 occurred primarily between mid-October through the end of November, a period of approximately six weeks. More surveys will likely be conducted in Spring 2015 prior to the start of irrigation season to evaluate the status of overwintering lampreys in the canal system.

During 2014, approximately $25,000 dollars were used to fund these activities, including coordination, surveys, equipment, transportation, data analysis and reporting. Starting in Project Year 5, funding from the Natural Resources Conservation Service grant will be available to conduct some of the salvage and monitoring.

A total of 3427 lamprey were observed through electrofishing sampling (1783 fish captured, 1644 fish missed) at 12 of the 15 diversion sites[1] (Fig. F-1). Of these, 2178 lamprey (63.6%) were observed immediately upstream of the fish screens and 864 (36.4%) were observed immediately downstream of the fish screens. Tranformer (juvenile) lamprey were only found in the above screens area. The mean lamprey density where sampled was 1.0 upstream of the fish screens and 0.5 downstream of the fish screens.

The total number of observed (desiccated) lampreys from dry bank surveys was 1087 (Photo F-1). Although desiccated larvae only accounted for 24.1% of the total number of observed lamprey, in reality this number is likely much higher. Finding the desiccated larvae has been very difficult in past surveys and requires a site visit at the precise, right timing. If the site visit is too late, many larvae are likely preyed upon by scavenging predators (as been evidenced by the extensive predator track marks on dry banks). Another thing to consider is that bodies of larvae, without any bony structure, can decompose in a matter of days.

Because the majority of observed desiccated larvae were small size class (84.1%) and no desiccated transformers were found, medium and large sized larvae may potentially be able to adapt to the water level changes better than the small larvae. Increased predation, however, is another possible cause for why less of the larger larvae were detected. We also discovered that even if desiccated larvae are not present, lamprey larval track marks (Photo F-1) can be searched for potential evidence of their presence. In the future, it may be worth excavating the dry banks to assess the duration and extent to which larvae remain hidden under the exposed dry fine

[1] Lamprey numbers described here refer to either of the two species of lamprey present in the basin – Pacific Lamprey or Western Brook Lamprey.

sediment. Reducing the dewatering rates (for example, from 0.2 inch/min to 0.1 inch/min) could possibly reduce the number of desiccated larvae at irrigation diversions. Dewatering rates and associated mortality will be examined further in future studies.

With enhanced larval lamprey identification skills (which was largely due to increased exposure to small larvae from artificial propagation projects), we were able to confirm the exact percentage of Pacific lamprey mixed in within the overall mix of entrained lamprey. There are 12 irrigation diversions that we surveyed within the assumed wild distribution of Pacific Lamprey (below Roza Dam, Yakima River, Rkm 210.7) and at 9 out of the 12 we found larval lamprey. We found Pacific Lamprey in 3 of the 9 diversions. The overall ratio of Pacific lamprey was 7.0% from a combination of electrofishing and dry bank surveys in diversions within the assumed wild distribution range.

The size class proportion of sampled larvae (observed and desiccated) was calculated separately for all diversions by survey location (Fig. F-2). The above screen canal had the highest percentage of large and medium lamprey, but a low percentage of small larvae. We see a gradual decrease in the percentage of large lamprey from upstream to downstream, though a portion of the large and medium larvae are still passing through the fish screens. It is possible these larger larvae are finding small gaps between the fish screens. The percentage of small larvae gradually increases from upstream to downstream, with the highest percentage in the below screen canal. The majority of large sized larvae do not move past the fish screens, but small and medium sized larvae appear to be substantially susceptible to entrainment.

A considerable amount of larval lamprey habitat exists in irrigation diversions (Fig. F-3) - only 17.9% of the area that we observed (3087 m^2) was considered “unusable” by larval lamprey (i.e. classified as Type III habitat). Total amount of Type I (preferred) and II (acceptable) habitat was 7024 m^2 upstream of fish screens (75% was Type I and 25% was Type II) and 7159 m^2 downstream of fish screens (73% was Type I and 27% was Type II). The total amount of larval lamprey habitat, based solely on what we had time to observe, was 14,183 m^2, but we were limited in the number of diversions as well as areas within each diversion we could assess this year. In 2013, we observed a total of 32,102 m^2. Based on diversion facilities surveyed in both years, we also detected an overall decrease in the fine sediment volume in 2014 compared to 2013.

A sharp decrease in the fine sediment volume was observed in some of the diversions that received sediment removal/dredging the previous year (e.g. Congdon and Wapatox diversions). The frequency of sediment removal/dredging in front of the fish screens varies from diversion to diversion, but in many of the smaller diversions, it has taken place once every 2-4 years in the past. After sediment removal, fine sediment does not always fill back up the following year during the irrigation season, lowering the amount and volume of fine sediment available in some

of these diversions. In these diversions with less fine sediment volume, coincidentally, we found that the number of observed lamprey also decreased. However, it is not clear whether the removal of fine sediment actually reduces larval lamprey entrainment by increasing bypass passage or it simply reduces our chances of finding them due to reduced burrowing habitat (while entrainment rates remain the same). In the future, we can test this hypothesis by strategically placing ecology blocks to influence the fine sediment dynamics and monitoring the entrainment ratio. For more information, data, and analysis on diversion entrainment monitoring, see **Appendix F1**.

Dewatering activities can have detrimental impacts on larval lamprey, which burrow in underwater fine sediment and are less likely to move with the water during water withdrawal operations compared to other fishes in the streams and rivers. There is a large area of larval lamprey habitat in the reservoir above Roza Dam on the Yakima River (river km. 210.7). This 34,251 m^2 of wetted larval habitat in the reservoir at full pool, however, decreases dramatically to 12,231 m^2 when the pool is at its lowest level (Photo F-2). Although a total of 21 larvae were found in Roza Diversion from 16 min of electrofishing covering 15 m^2, occupancy and distribution in the reservoir is currently unknown. We used a set of two 2x18" lumber boards (8 feet long) to access the dewatered channel in Roza reservoir through the dewatered, soft and deep fine sediment. Access was limited with this method and we were able to survey only 0.15% of the total available larval habitat (or alternatively, 0.4% of the habitat available on the given sample day) in the reservoir. No larvae were found in the 29 min of electrofishing covering 50 m^2. In the future, we recommend the following methods to evaluate knowledge gaps on lamprey in Roza reservoir: 1) improved method to travel the dewatered fine sediment to access the wetted channel margin, 2) a raft survey for electrofishing channel-margin shallow water habitat, and 3) the use of a deep water electroshocker to access a wider range of habitat. See **Appendix F2** for more information and data on Roza Dam reservoir and diversion monitoring.

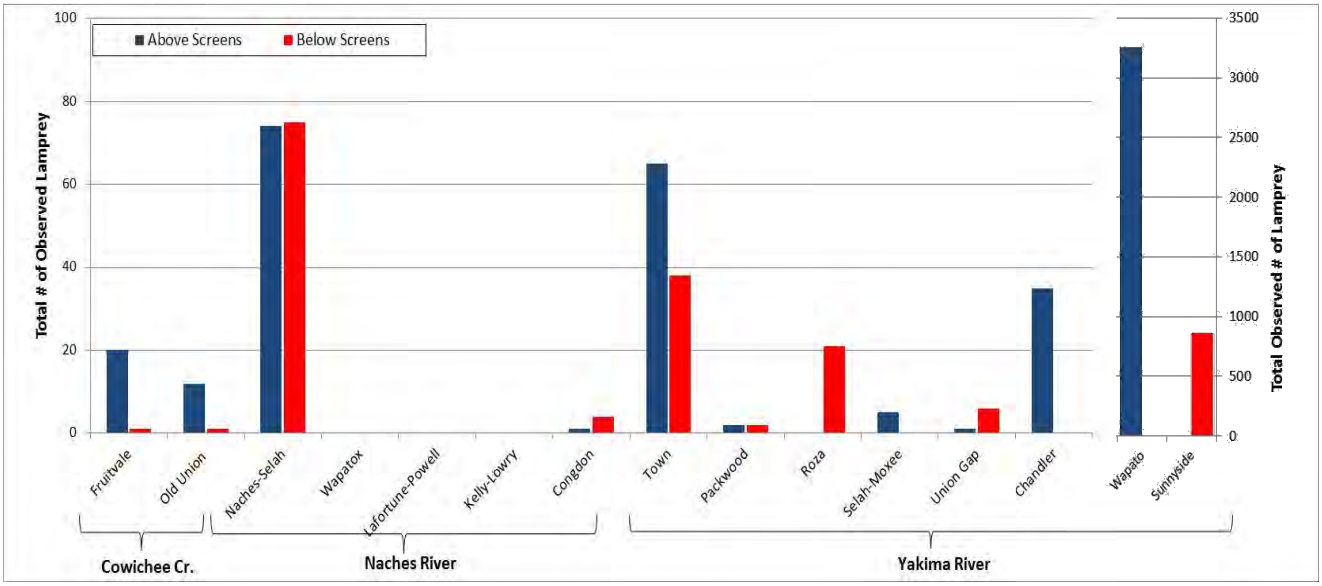

Figure F-1. Total number of observed larval/juvenile lamprey (in water and on dry banks) above and below fish screens, including respective surveyed canals, for each diversion surveyed in the Yakima Basin. The diversions are ordered from upstream to downstream (left to right) within their respective 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.

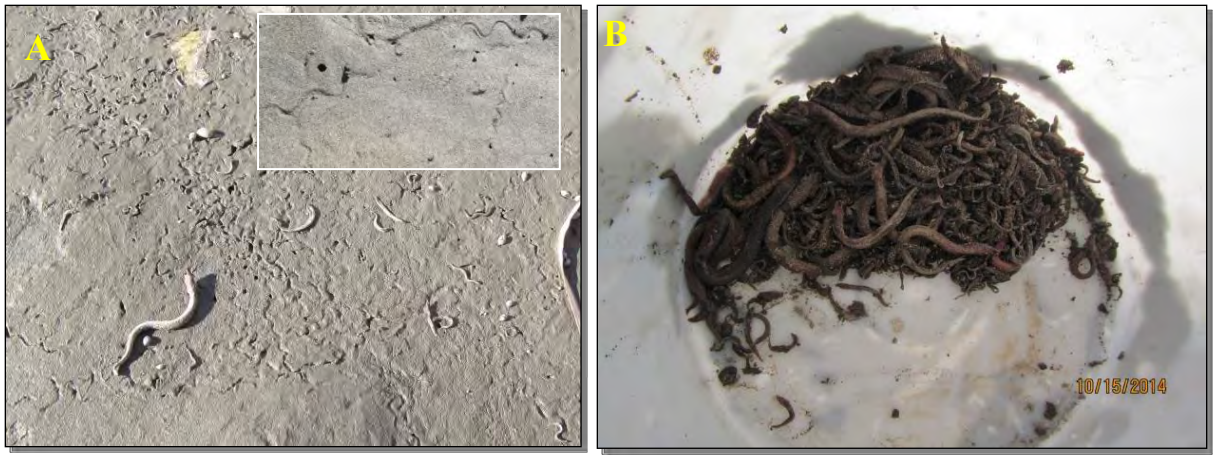

Photo F-1. Larvae found on the dewatered bank Type I habitat, Wapato Diversion, Yakima R., on Oct. 15, 2014, with an inserted photo showing the "S" shaped larvae track marks (A). A total of 897 desiccated larvae were collected from Wapato Diversion on this day (B).

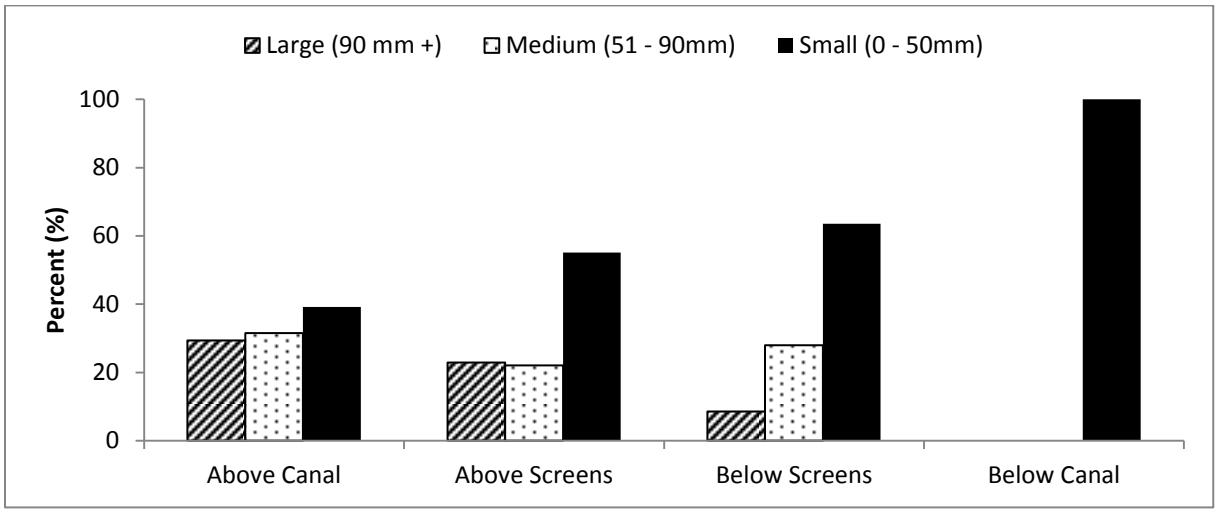

Figure F-2. Size class percentages (small, medium, and large) for all observed lamprey separated by location. Transformers are included in the large size class.

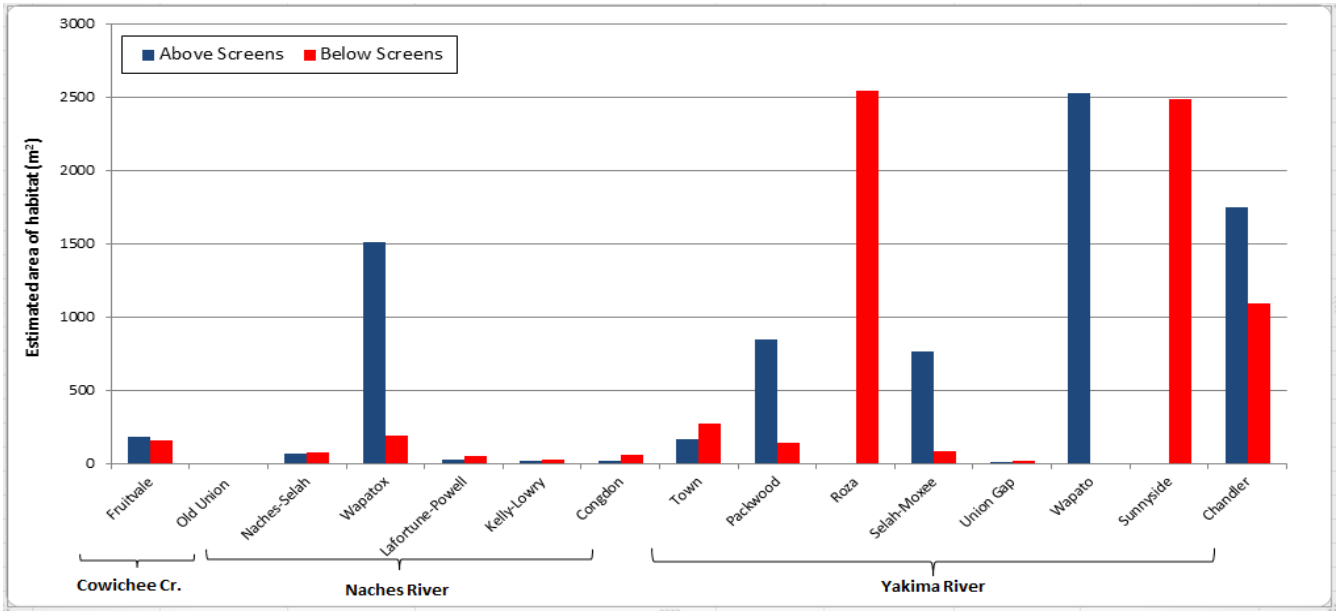

Figure F-3. The total area of observed larval lamprey habitat above and below the fish screens for each surveyed diversion in the Yakima Basin, including their respective canals when habitat was observed and measured. Habitat area was not measured at Old Union Diversion. Observed canal habitat area was not measured at Chandler (Yakima R.), Union Gap (Yakima R.), Sunnyside (Yakima R), and Kelly-Lowry (Naches R.). The diversions are ordered from upstream to downstream (left to right) within their respective watersheds.

Photo F-2. Exposed fine sediment in the Roza reservoir on October 29, 2014 – looking downstream towards the inlet to Roza Diversion (right center) and Roza Dam (left center). Larvae were present in the diversion, but larval occupancy and distribution in the reservoir was unknown. Dewatering of the reservoir not only affects the diversion, but exposes a large area of available larval habitat each year. Considerations for larval lamprey salvage have not begun due to limited existing information on lamprey presence within the reservoir.

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

Work Element Associated Appendix Reports:

Appendix G1 – Pacific Lamprey vs. Western Brook (or River) Lamprey Larvae Identification Guide

Appendix G2 – Medium Size (50-90 mm) Pacific Lamprey & Western Brook Lamprey Larvae Identification Guide and Tips

Appendix G3 – 2012 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands

Appendix G4 – 2013 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands

Appendix G5 – 2014 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands

Appendix G6 – Establishment of Larval Lamprey Index Sites in the Yakama Nation Ceded Lands

Appendix G7 – 2014 Juvenile/Larval Pacific Lamprey Passage Monitoring in Chandler Diversion, Yakima River (Prosser, WA)

Appendix G8 – 2014 Intensive Monitoring of Larval/Juvenile Lamprey Entrainment within the Yakama Basin

Appendix G9 – Mercury Concentrations in Pacific Lamprey (*Entosphenus tridentatus*) and Sediments in the Lower Columbia River Basin – Preliminary Report

Appendix G10 – Preliminary Report of USGS-CRITFC Toxicology Study on Lamprey and Fine Sediment Reconnaissance of Contaminants in Larval Pacific Lamprey (*Entosphenus tridentatus*) tissues and habitats in the Columbia River Basin, Oregon

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.

Lamprey Identification

To accurately monitor Pacific Lamprey status in the wild, there are many unanswered management questions that prevent us from attaining that simple yet challenging goal. Because the Yakima Basin contains both Pacific Lamprey and Western Brook Lamprey, it is crucial that we have the ability to distinguish the two species as accurately and frequently as possible. We have documented many larval Western Brook Lamprey that have features closely resembling Pacific Lamprey features (especially in Naches Watershed). The current 1-page laminated "Lamprey ID Guide" with one tail photo of each species does not accurately capture the subtle variations in their morphological differences, especially as they grow from small to large larvae, and may actually lead some to inaccurately identify species based on the misinterpretation of the identifying features. Therefore, the YNPLP 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, which were confirmed and validated by genetic analyses (see 2013 BPA report). Based on this information, a couple new identification guides were created and were shared widely within the region with various partners (**Appendix G1** and **Appendix G2**). A part of these identification guides was used in the "Pacific Lamprey Instream and Riparian Habitat Restoration Guide" edited by Mr. John Crandall (in press) - see Photo G-1.

A Western river lamprey (*lampetra ayresi*) was captured at Chandler Juvenile Fish Monitoring Facility (Prosser Dam) 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). In addition, we captured what appeared to be larval/juvenile Western Brook Lamprey in Cooper Lake and Cooper River, a tributary to Cle Elum River where lamprey have not been detected to date. Because these lamprey from Cooper Lake were found in the highest elevation in the region (and potentially for the entire species range) and are completely isolated from the

remaining Western Brook Lamprey populations in the Yakima River, it is possible that this population of Western Brook Lamprey in Cooper River may be genetically distinct from other populations.

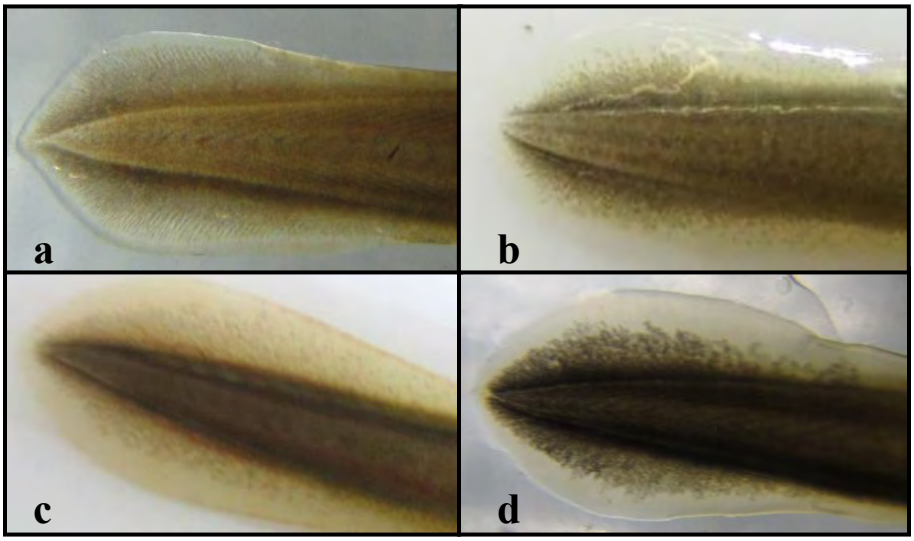

Photo G-1. Caudal (tail) fin morphology is a helpful feature in the identification of ammocoetes and can be used in the field to distinguish Pacific Lamprey from Western Brook and River Lamprey. The caudal fin of Pacific Lamprey have a band of dark pigmentation that extends out from the caudal ridge which is predominantly lighter in color (a and b). The caudal fins of Western Brook and River Lamprey (c and d) are either translucent (c) or peppered (d) with entirely dark pigmentation or dark pigmentation with a narrow band of translucency in the middle on the caudal ridge. Excerpt from "Pacific Lamprey Instream and Riparian Habitat Restoration Guide" (John Crandall, in press).

Adult Passage Monitoring

Radio telemetry is being used to determine approach timing, residence time, fish ladder routes, other passage routes, and migration rates at the diversion dams on the lower Yakima River. This work is being conducted in three phases: Phase 1 evaluated Wanawish and Prosser dams; Phase 2 evaluated Sunnyside and Wapato dams; and Phase 3 is evaluating Roza and Cowiche dams. Each dam and fishway was equipped with multiple antenna telemetry receivers, and seven additional stations were established to monitor tributaries and the boundaries of the study area. The YNPLP supplied the study lampreys and radio transmitters (including 167 nanotags purchased with funding provided by Northern Wasco County PUD Fisheries Mitigation Trust Fund).

In Phase 2, 80 Pacific Lampreys were radio-tagged and released near Sunnyside and Wapato dams. Study lampreys were collected from lower Columbia River dams in summer 2012 and held at the YN fish facility in Prosser prior to tagging. Tagged fish were released in the fall (August 27, 2012, n = 45) and spring (March 20, 2013, n = 35) in order to assess seasonal passage effects. Supplemental mobile tracking has also documented lamprey entrainment in

water conveyance structures (Roza Outfall and Sunnyside Diversion canals) that may also impede passage and migration.

In Phase 3, USFWS released a total of 45 tagged adults below Roza and 44 below Cowiche (Photo G-2). Each site had the standard 2 treatment groups (fall release on September 12, 2013 and spring release on April 4, 2014). Additional radio antennas (n = 12) and receiver stations (n = 2) were installed at the Phase 3 dams in order to improve detection probabilities and passage and route selection monitoring. None of the lamprey were able to pass Roza Dam (0% passage rate). The overall passage rate for Cowiche Dam was 79% (95% from fall release and 41% from spring release). Specific migration and passage metrics will be detailed in the Phase 3 reports, provided by the US Fish and Wildlife Service (in production at this time), which would be available later in 2015.

First record of adult lamprey at Prosser Dam was in 1996 (one adult) and counts have been recorded since then. There is close correlation between adult counts from Prosser Dam and Bonneville Dam, demonstrating that years with larger counts in the lower Columbia River translates to larger counts (relatively speaking) in the Yakima River (Fig. G-1). There have been a peak in counts in 2002 and 2003 and another peak 10 years later in 2012 and 2013, potentially indicating a 10 year life span (or potentially favorable ocean conditions). Adult detection was estimated to be approximately 45% based on radio telemetry, so actual numbers passing Prosser Dam are likely higher (222%).

Photo G-2. Underwater photo of the Pacific Lamprey used for radio telemetry.

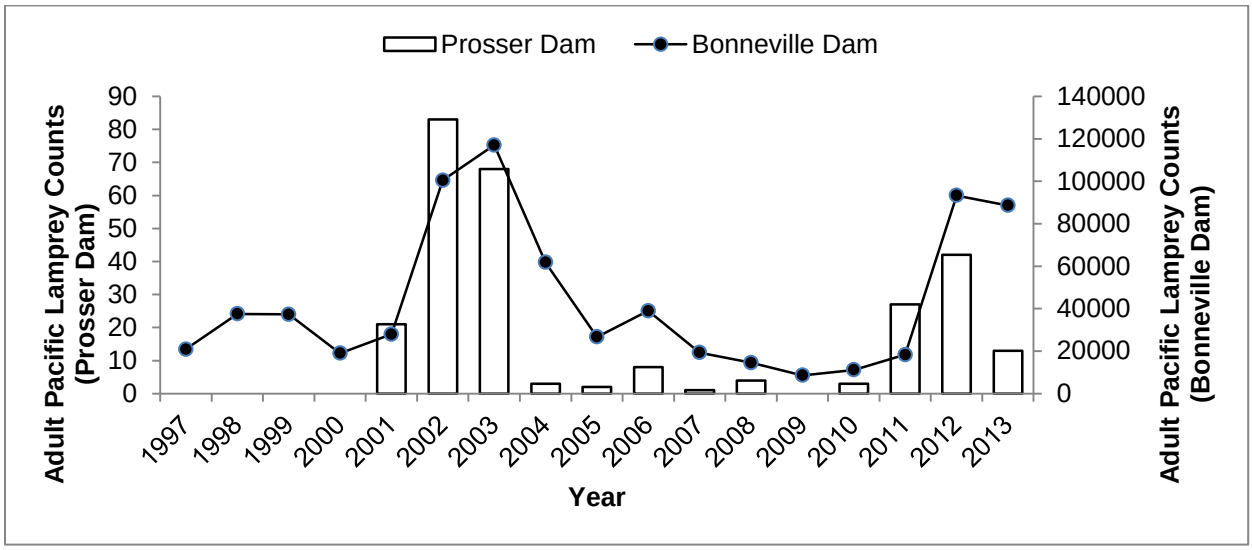

Figure G-1. Adult Pacific Lamprey counts at Prosser Dam vs. Bonneville Dam between 1997 and 2012. Prosser Dam counts were tallied by broodstock year (i.e. 1997 counts include fall migrants from 1997 and spring migrants from 1998).

Adult Passage Improvement

A few conference call meetings were held in winter and spring of 2014 to plan for a Project Alternatives Solutions Study (PASS). Discussion focused on funding sources, framework to guide the process, and roles and assignments for future planning. On May 28 and 29, 2014, many of the participants for the PASS came together at Chandler Diversion in Prosser, WA. Participants included Jim Simonson (Fishhead Technology), Mark Nelson (USFWS), RD Nelle (USFWS), David Child (DC Consulting), Ralph Lampman (YN), Susan Camp (Reclamation), Patrick McGowen (Reclamation), Kevin Yancy (Reclamation), and Joel Hubble (Reclamation). More specifics on the project were discussed, including goals and objectives, existing conceptual designs developed, criteria and sideboards. Installation process and procedure as well as related operation and maintenance considerations were discussed in detail. A PASS is planned to be held on March 3-5, 2015, in Yakima, WA, to evaluate all existing alternatives and make decisions necessary to move forward with needed passage improvement work as determined by the Expert Technical Team[2].

The cost of the standard Lamprey Passage Structures (LPS) for small- to mid-size irrigation dams can range between $15,000 and $50,000. Alternative designs, on the other hand, will cost considerably less; the prototype version of the "Portable LPS" design is estimated to only cost about $5,000 for production, and the deflector design will cost no more than $750. Although these two alternate designs have not been tested previously for effectiveness, if these designs prove to be successful in improving passage, it could be replicated in many other dams across the

[2] The Technical Expert Team will be assembled by the YN and Reclamation technical staff to support development of technical designs for future fish passage structures.

Yakima Basin and Columbia Basin at large. Where we have specific radio telemetry data indicating where the majority of lamprey hold and reside below a dam, it makes sense to build the standard LPS to target and benefit those runs of lamprey. However, implementing and testing these alternate designs in locations where we can also monitor effectiveness (through radio telemetry or automatic counting system) will be extremely beneficial as it will help increase the available tools in the toolbox for future passage improvement work.

Adult Translocation

In 2012, 15 adult Pacific Lamprey were released in Satus Creek (a tributary to Yakima River) on May 10, 2012, at two locations (Fig. G-2). Seven lamprey (4 females and 3 males with a female ratio of 57.1%) were released at river km 19.7, all of which contained pit tags from May 8, 2012. Eight lamprey (5 females and 3 males with a female ratio of 62.5%) were released at river km 33.6, seven of which (87.5%) contained pit tags from May 8, 2012. None of the pit tags were detected at the lower Satus Creek pit tag array (river km 4.3). Water temperature was 10.7 °C at river km 19.7 (11:30 AM) and ~10.0 °C at river km 33.6 (1:30 PM). Both sites contained an abundance of suitable spawning substrate (gravel and cobble) and habitat (glide/riffle, pool tail crest). All lamprey were originally captured from The Dalles Dam or John Day Dam in the Lower Columbia River during the summer of 2011. For more details on 2012 translocation, see **Appendix G3**.

In 2013, a total of 137 adult Pacific Lamprey were released in three lower Yakima River tributaries (Fig. G-3). Overall female ratio was 19.7% and pit tag ratio was 87.6%. All lamprey were originally captured from The Dalles Dam or John Day Dam in the Lower Columbia River during the summer of 2012. Water temperature ranged between 8 and 9.5 °C for the early lower reach release and between 12.6 and 14.0 for the late upper reach release.

Of the 24 lamprey released in lower Satus Creek at river km 4.2, five of them were not detected at all at the lower Satus Creek pit tag array at river km 4.3, approximately 130 m upstream. These lamprey (20.8%) either used spawning habitat downstream of the release site, moved downstream into the Yakima River, or moved upstream but were not detected. Based on the presence of two antenna arrays (upstream and downstream), it is unlikely that they were not detected at both antenna arrays, and we assume they moved downstream. Four of the undetected fish were male lamprey while one was a female lamprey. This female lamprey was the shortest (503 mm) of all lamprey released at this location, but there was no particular trend with the male lamprey in terms of length or weight. For more details on 2013 translocation, including PIT tag data analysis, see **Appendix G4**.

In 2014, a total of 255 adult Pacific Lamprey were released in three lower Yakima River tributaries (Fig. G-4). Overall female ratio was 43.5% and pit tag ratio was 80.0%. All lamprey were originally captured from Bonneville Dam, The Dalles Dam, or John Day Dam in the Lower

Columbia River during the summer of 2013. Water temperature ranged between 12.3 and 13.1°C for the early lower reach release and between 13.9 and 15.0 for the late upper reach release.

Of the 31 lamprey released in lower Satus Creek at river km 3.0, three of them were not detected at all at the lower Satus Creek pit tag array at river km 4.3, approximately 1.3 km upstream. These lamprey (9.7%) either used spawning habitat downstream of the release site, moved downstream into the Yakima River, or moved upstream but were not detected. Based on the presence of two antenna arrays (upstream and downstream), it is unlikely that they were not detected at both antenna arrays, and we assume they moved downstream after release. In 2013, the straying ratio was 20.8%, so the straying have decreased to approximately half in 2014. Two of the undetected fish were female lamprey while one was a male lamprey. These two female lamprey were the shortest females (454 and 478 mm) and the male lamprey was the second shortest male of all lamprey released at this location.

Of the 29 lamprey released in lower Toppenish Creek at river km 1.5, seven of them were not detected at all at the lower Toppenish Creek pit tag array at river km 2.0, approximately 750 m upstream. These lamprey (24.1%) either used spawning habitat downstream of the release site, moved downstream into the Yakima River, or moved upstream but were not detected. Based on the presence of two antenna arrays (upstream and downstream), it is unlikely that they were not detected at both antenna arrays, and we assume they moved downstream after release. Five of the undetected fish were female lamprey while two were male lamprey. Four of the five female lamprey were the second, third, and forth shortest females (482, 516, 528, and 531 mm) of all lamprey released at this location, but there was no particular trend with the two male lamprey in terms of length or weight. For more details on 2014 translocation, including PIT tag data analysis, see **Appendix G5**.

Figure G-2. Overall aerial map of 2012 adult Pacific Lamprey translocation release sites (the number next to the stream name is the stream km and the number in parenthesis is the total number of lamprey released).

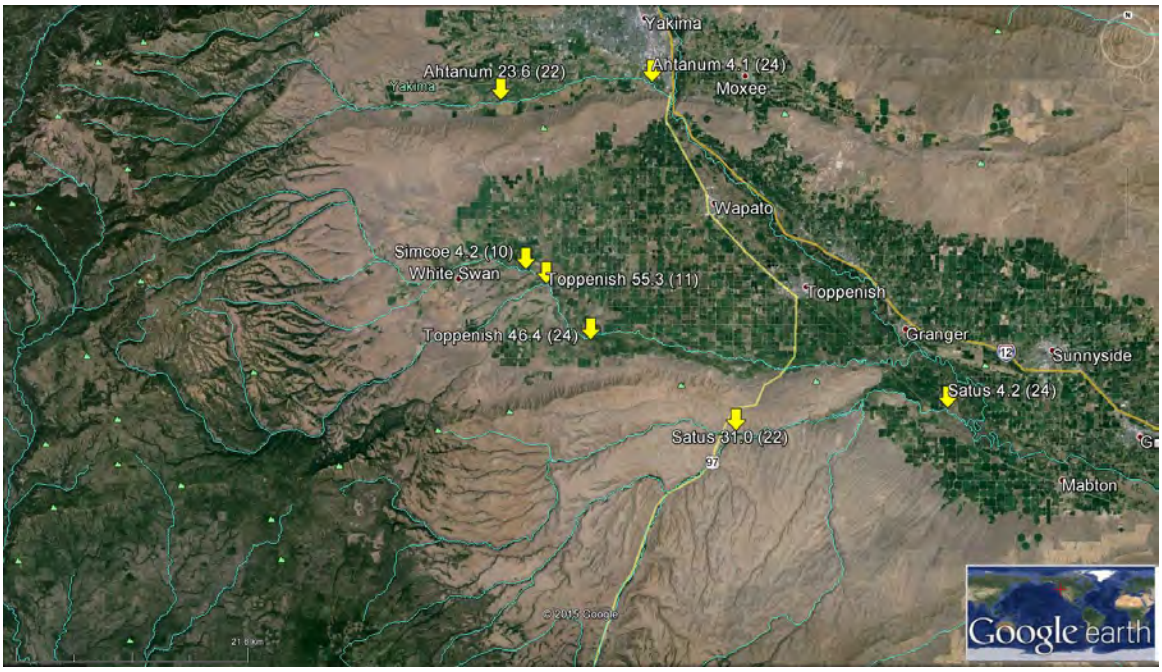

Figure G-3. Overall aerial map of 2013 adult Pacific Lamprey translocation release sites (the number next to the stream name is the stream km and the number in parenthesis is the total number of lamprey released).

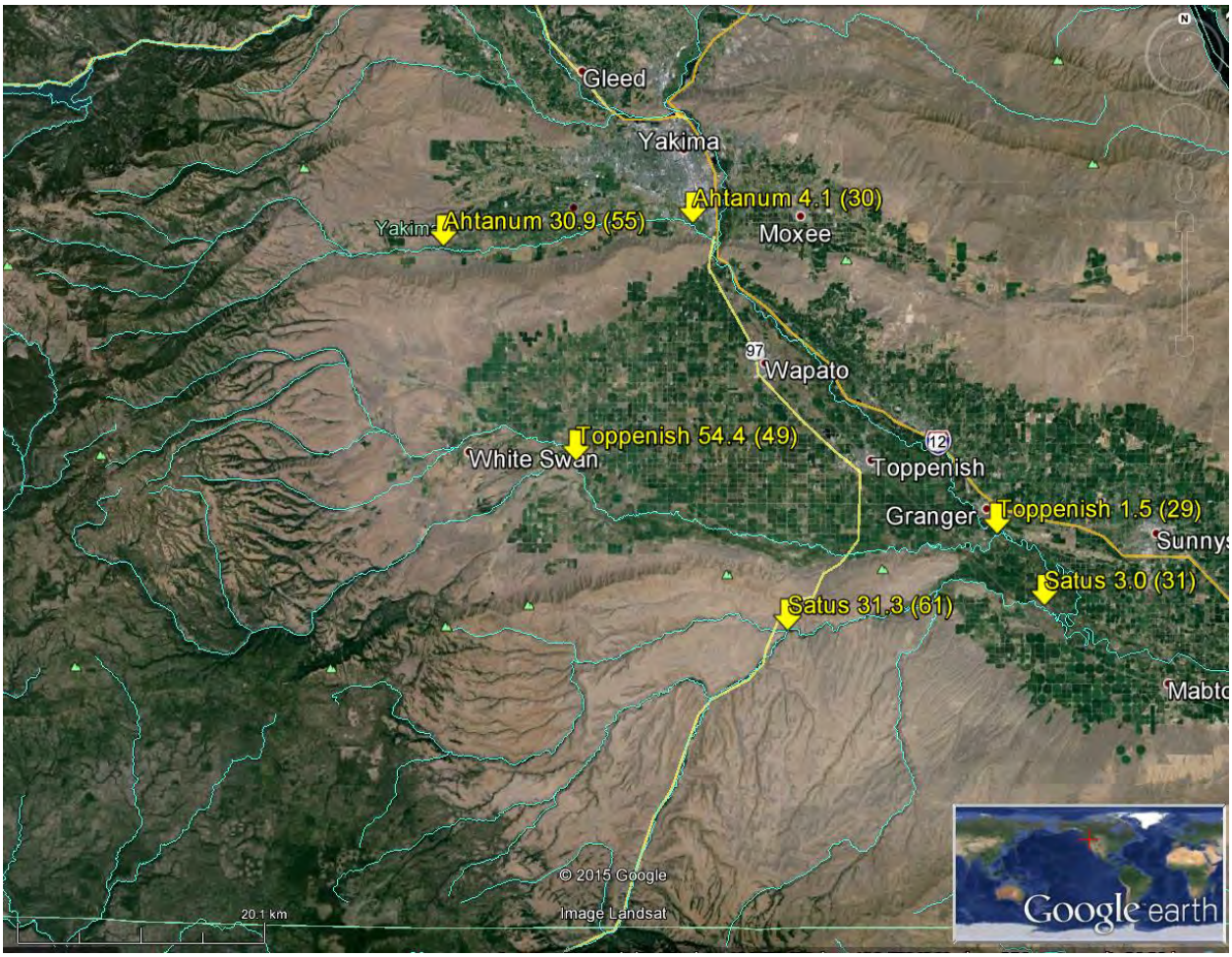

Figure G-4. Overall aerial map of 2014 adult Pacific Lamprey translocation release sites (the number next to the stream name is the stream km and the number in parenthesis is the total number of lamprey released).

Index Sites for Larval Lamprey

A vital step that is crucial to further manage and restore the Pacific Lamprey population throughout the Ceded Lands is to identify key sites of larval lamprey habitat (fine sediments) for long-term status and trend monitoring, otherwise referred to as "Index Sites". Since larval lamprey surveys first began in 2009, the YNPLP has been focusing on identifying ideal locations where index sites could be established throughout the Ceded Lands. Index Sites are established with the following three objectives: 1) to assess the distribution and relative abundance of Pacific Lamprey (primary objective) and Western Brook Lamprey (secondary objective) over time, 2) to evaluate the effects of habitat change on larval lamprey occupancy and 3) monitor the recruitment of adult Pacific Lamprey translocated and/or released into select watersheds.

The YNPLP has identified the prospective locations of 50 index sites spanning the following HUC 4 subbasins (Table G-1 and Fig. G-5): White Salmon, Klickitat, Lower Yakima, Upper Yakima, Naches, Wenatchee and Entiat. Established Index Sites will be visited every 1 to 3 years

depending on needs and time availability. Index sites may be added, removed, or moved within each subbasin in the future based on existing status and future needs.

The Yakima Basin is at the heart and soul of the Yakama Nation Program for Pacific Lamprey restoration. Within the Lower Yakima Subbasin, index sites are established in the mainstem Yakima as well as tributaries, including Satus, Toppenish, Ahtanum watersheds. Within the Naches Subbasin, where Pacific Lamprey are known to exist albeit low numbers, index sites are established in mainstem Naches and Little Naches rivers. Within the Upper Yakima, index sites are established in the mainsteam Yakima as well as Cooper River (tributary to Cle Elum River); however, more sites will be established in association with the larval outplanting in the near future. Index Sites will provide data on long term status and trend as well as continued monitoring of Pacific Lamprey recruitment from adult translocation (Satus, Toppenish, and Ahtanum) and future larval outplanting (Upper Yakima and Naches subbasins) restoration efforts.

The goal of the established Index Sites in the Wenatchee Subbasin is primarily to monitor the distribution of wild Pacific Lamprey population that currently only reside downstream of Tumwater Dam (Wenatchee River, river km 49.6). Tumwater Dam on the mainstem Wenatchee River is a known passage barrier for adult Pacific Lamprey. Adult translocation efforts upstream of the dam will likely be implemented in the near future to reintroduce a population upstream of the dam (and increase the juvenile pheromone attraction for adults). Established index sites upstream of the dam will help monitor reestablished populations moving further upstream within the subbasin.

The goal of the established Index Sites in the White Salmon watershed (Middle Columbia-Hood Subbasin) is to monitor 1) the movement of Pacific Lamprey into the river upstream of the Condit Dam removal site (river km 5.3) and 2) the upstream distribution of larval lamprey (including Western Brook Lamprey). Pacific Lamprey was assumed to be extirpated from the river upstream of the Condit Dam before its removal in October 2011; Pacific Lamprey have only been detected between the dam and the mouth of the mainstem river. Close monitoring of their recolonization further upstream is a vital and exciting step to understand the ecological benefits of the dam's removal. Both Pacific Lamprey and Western Brook Lamprey are found within this watershed.

The Entiat (Upper Columbia-Entiat) Subbasin has been identified as a control subbasin to monitor the long-term status and trend of the Pacific Lamprey population. We are not planning to implement any adult translocation or juvenile outplanting restoration efforts in this subbasin. Index sites are spatially distributed throughout the mainstem (downstream of Entiat Falls) to monitor the natural change in relative abundance and distribution. Entiat Falls is an assumed

passage barrier for Pacific Lamprey. Densities of larval lamprey are relatively high in larval lamprey habitat below the upper distribution all the way to the mouth of the river.

The Klickitat Subbasin has been identified as a control subbasin for the long-term status and trend monitoring of the Pacific Lamprey population, where supplementation actions, such as adult translocation and larval outplanting, will not be implemented. Index sites are spatially distributed throughout the mainstem to monitor the natural change in relative abundance and distribution. This subbasin has a notably high level of mercury and samples collected from these index sites will help monitor its concentration in the system and will likely narrow down its potential source (whether the cause is natural or man-made). Both Pacific Lamprey and Western Brook Lamprey are found throughout this subbasin.

John Crandall (Monitoring Coordinator at Methow Salmon Recover Foundation/Confluence Aquatics) has been conducting larval lamprey surveys throughout the Methow Subbasin since 2008. The YNPLP has assisted Mr. Crandall in his annual surveys since 2013. These past surveys indicate that Pacific Lamprey recruitment has been extremely low (if not absent) for the last few years. The YNPLP will continue to contribute as well as take leadership in the monitoring and restoration activities of Methow Subbasin along with Mr. Crandall in future years.

At this point of time, the YNPLP has not established any index sites in Okanogan Subbasin or Wind River and Rock Creek. We will work closely with partners in future years to help establish index sites in these rivers and streams.

The establishment of index sites is crucial to effectively monitor larval lamprey over time and is an important step for the management of Pacific Lamprey within the Ceded Lands of the Yakima Nation in the Columbia River Basin. The periodic surveys of these sites will provide pertinent information regarding the species distribution, relative abundance, and habitat preference. This information is crucial to increase the effectiveness of conservation and restoration measures. Without the monitoring, it will be difficult to document the natural fluctuation in their abundance or the changes these restoration efforts may be contributing to the species overall. For more details on established Index Sites throughout the YN Ceded Lands, see **Appendix G6**.

Table G-1. Summary of considered index sites identified in eight major HUC 4 subbasins within the Yakama Nation Ceded Lands.

HUC 4	Stream Name	# of Index Sites	Start River km	End River km
Middle Columbia-Hood	White Salmon River	4	0.8	40.5
Middle Columbia-Hood	Trout Lake Creek	1	4.5	4.5
Klickitat	Klickitat River	4	1.9	82.7
Lower Yakima	Yakima River	3	2.9	150.0
Lower Yakima	Satus Creek	4	2.9	42.1
Lower Yakima	Toppenish Creek	5	9.4	73.2
Lower Yakima	Simcoe Creek	1	9.0	9.0
Lower Yakima	Ahtanum Creek	4	4.3	34.3
Upper Yakima	Yakima River	4	191.8	300.9
Upper Yakima	Cooper River	1	9.9	9.9
Lower Naches	Naches River	4	0.6	51.1
Upper Naches	Little Naches River	1	1.7	1.7
Wenatchee	Wenatchee River	6	8.9	84.0
Wenatchee	Icicle Creek	2	5.3	23.4
Wenatchee	Nason Creek	2	6.2	14.7
Upper Columbia-Entitat	Entiat River	4	1.5	40.2
-	-	**50**	-	-

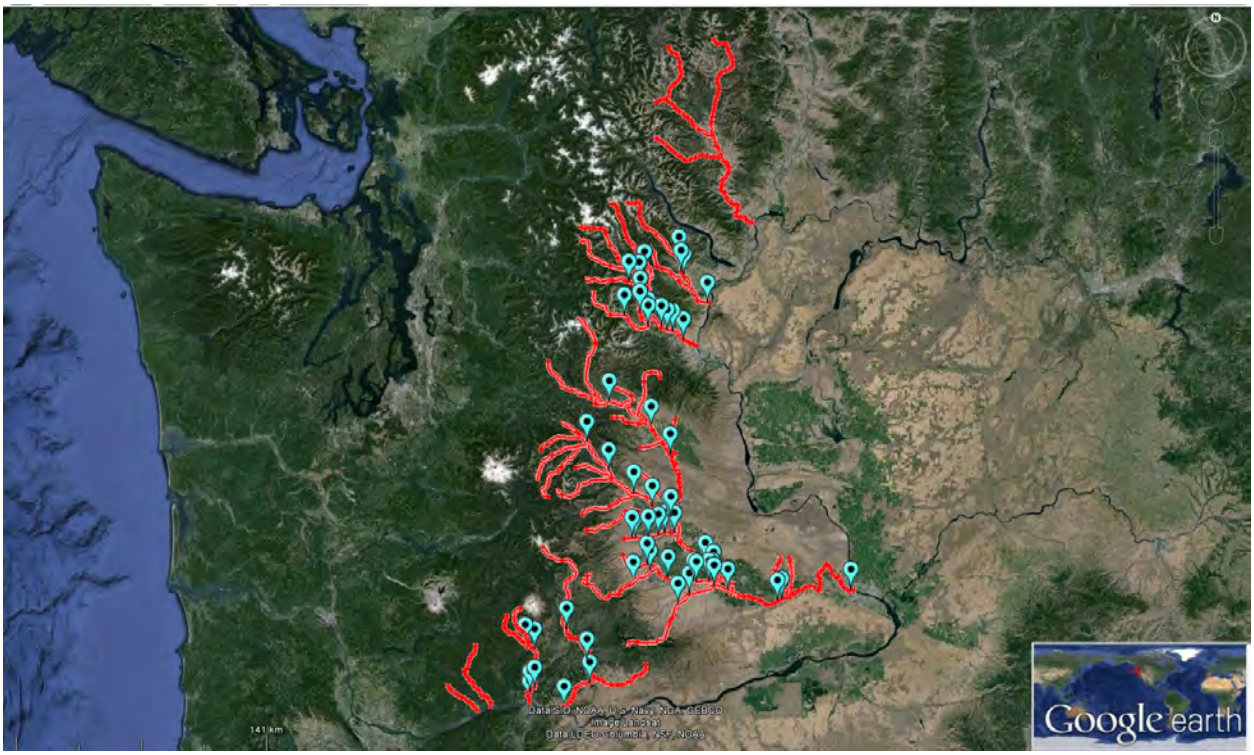

Figure G-5. Overview map of all 50 identified index sites (blue markers) within the Ceded Lands.

Larval/Juvenile Passage Monitoring

Chandler Diversion is a known migration corridor for out-migrating larval/juvenile Pacific Lamprey. Juvenile lamprey have been are counted at Chandler Juvenile Fish Monitoring Facility since 2000 (Fig. G-6). Extrapolated number of juvenile lamprey are calculated based on the subsampling rates at the facility. From monitoring these collected juvenile lamprey over the years, we found that many of the lamprey captured later in the season in May and June were spawning and post-spawned Western Brook Lamprey. More monitoring is needed, but a portion of the early summer migrants may actually be adult Western Brook Lamprey instead of Pacific Lamprey macrophthalmia. A small number of larvae (both Pacific Lamprey and Western Brook Lamprey) were also collected at the facility. Nevertheless, the majority of collected lamprey (>75%) appear to be metamorphosed Pacific Lamprey. On the other hand, not all of the juvenile lamprey population migrating downstream at Prosser Dam will migrate through the diversion bypass as some juvenile may travel directly over Prosser Dam. However, because juvenile lamprey are known to travel near the bottom of the river (because they have no air bladder), the portion that travel through the diversion may be relatively high (potentially >75%) as the head gate for the diversion is placed on the river reservoir bottom. As a result, the extrapolated number may be skewed higher (than the actual number) because it may contain Western Brook Lamprey, but it may also be skewed lower because it does not contain all juvenile travelling downstream, but overall it still should provide a coarse relative abundance value for juvenile Pacific Lamprey.

One interesting trend we see is a strong correlation in extrapolated numbers of adults (by broodstock year) and juvenile when given an 8-year lag time (Fig. G-7 and Fig. G-8). Because the fall migrating adults spend one extra year in freshwater prior to spawning, this means that the juvenile lamprey may be mostly seven-year-old when they travel through Prosser Dam. Although preliminary, the correlation also provides a rough estimate for how many outmigrating juvenile may be produced per spawning adult; average of 21.8 juvenile / adult, excluding extreme values (0, 1, 91). Conversely, if we reverse the relationship between the juvenile and adult numbers, we could make a coarse estimate for marine survival rates, i.e. survival from outmigrating juvenile to returning adult (assuming zero population growth). The mean value was 5.2% excluding extreme values (0.0, 1.1, and 85.6%), which is similar to estimates from anadromous salmonids and sea lamprey. Finally, there is also a strong correlation in extrapolated numbers of adults from Bonneville Dam and juvenile numbers from Prosser Dam again when given an eight year lag time (Fig. G-9 and Fig. G-10).

In the spring of 2014, we pit tagged juvenile (smolts or macrophthalmia) and larval Pacific lamprey to address the following questions: 1) what overall percentage of lamprey will enter the diversion from the Prosser Dam reservoir and 2) what overall percentage of lamprey in the diversion will successfully enter the fish bypass. Because we had a very limited number of samples, we only sought to answer the latter question.

Lengths of released macrophthalmia averaged 163 mm (between 153 and 176 mm). Larvae were smaller, averaging 133 mm (between 115 and 157 mm). Of the 43 tagged Pacific Lamprey that were released upstream of the fish bypass (Fig. G-11), only one macrophthalmia and one larval lamprey (both released on April 4, 2014) were detected in the fish bypass (tag arrays A1, A2, and A3). The macrophthalmia was detected at 10:18 pm on May 5, 2014, 41 days after its release. The larval lamprey was detected at 3:11 am on March 4, 2015, 334 days after its release. As a result, only 12.5% of the macrophthalmia and 2.9% of the larval lamprey were detected. No other tagged lamprey were detected in the fish bypass as of March 11, 2015 (one year after the initial release). Chandler diversion was dewatered on two dates starting on October 29, 2014 (lasting for only a few days) and November 24, 2014 (lasting approximately one month). During the second dewatering event, electrofishing surveys were conducted both upstream and downstream of the fish screens and 29 fish were captured, but none were pit tagged lamprey (all fish >50 mm were Western Brook Lamprey, *Lampetra richardsoni*).

Although all juvenile pit tagged fish migrating back to the river through the bypass channel are supposed to be detected at the pit tag arrays A1, A2, and/or A3, only 12.5% of the macrophthalmia and 2.9% of the larval lamprey were detected. It is uncertain where the rest of the tagged fish ended up. Some could potentially be lost through predation, although for juvenile salmonids (*Oncorhynchus* species), predation rates are typically between 10-30% and usually lower in the spring when water temperature is still cold. There could also be additional screens upstream of the smolt separator, such as at the primary bypass flume, where lamprey may be potentially passing through or getting impinged. There are many factors that may have contributed to the limited percentage of lamprey detected in passing through the fish bypass. A future study with a larger sample size is warranted to further evaluate passage rates for juvenile/larval lamprey, which may have a considerable impact on Pacific Lamprey moving through the lower Yakima River.

Though some portions of larval lamprey actively migrate downstream, they are known to spend multiple years in the freshwater environment prior to outmigration. However, during the two dewatering events on October 29 and November 24, 2014, even these larvae theoretically should have moved out into the bypass channel but were not detected. It is uncertain where the rest of the tagged fish ended up. Some could potentially be lost through predation, although for juvenile salmonids (*Oncorhynchus* species), predation rates are usually somewhere between 10-30% and usually lower in the spring when water temperature is still cold. There could also be additional screens upstream of the smolt separator, such as at the primary bypass flume, where lamprey may be potentially passing through or getting impinged. A future study with a larger sample size is warranted to further evaluate passage rates for juvenile/larval lamprey, which may have a considerable impact on Pacific Lamprey moving through the lower Yakima River. See **Appendix G7** for more information and data on Chandler Diversion pit tag monitoring.

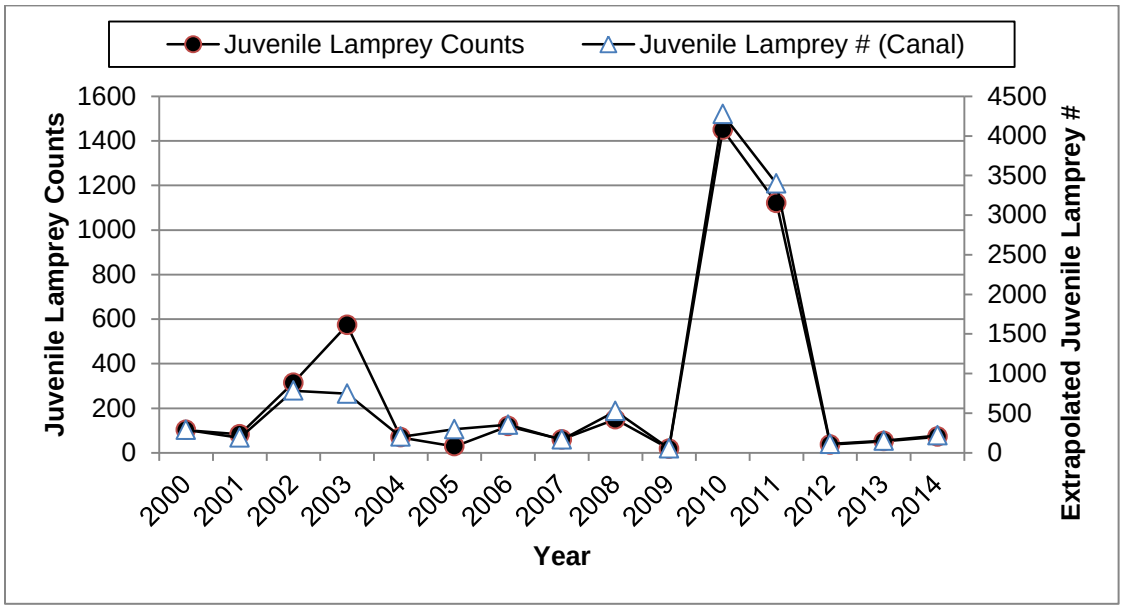

Figure G-6. Juvenile lamprey counts vs. extrapolated juvenile lamprey numbers from Chandler Juvenile Fish Monitoring Facility (Prosser Dam) between 2000 and 2014 based on subsampling rates.

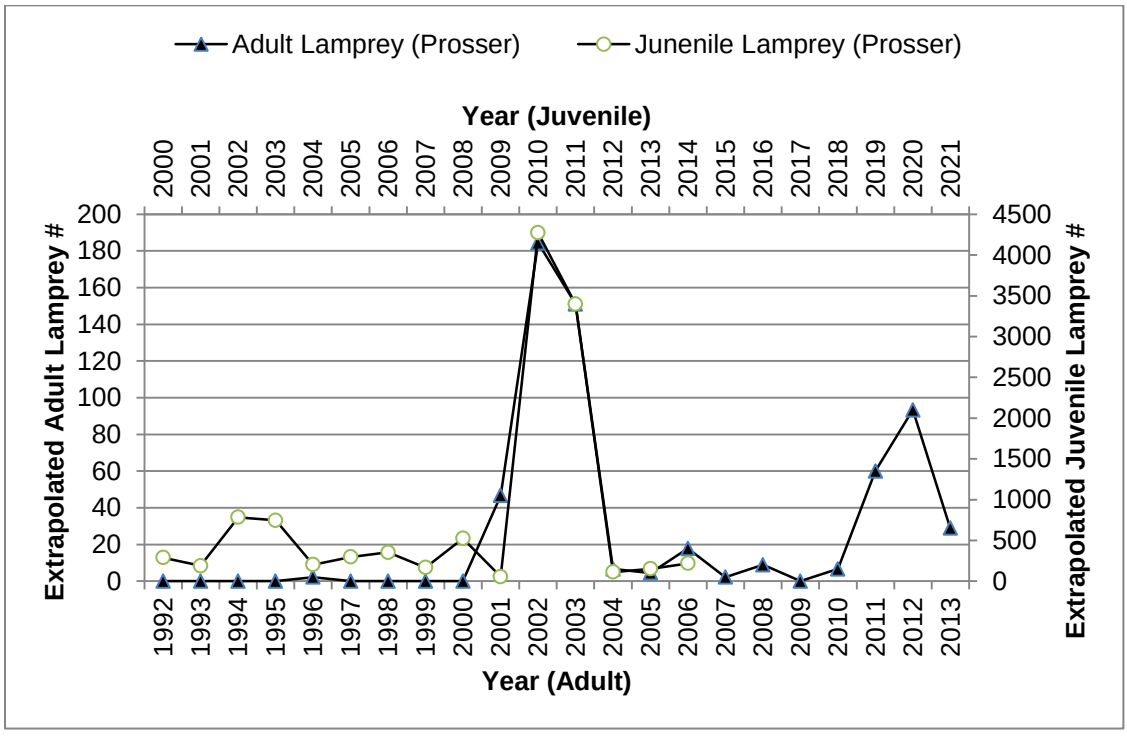

Figure G-7. Extrapolated adult Pacific Lamprey numbers vs. juvenile lamprey numbers from Prosser Dam / Chandler Juvenile Fish Monitoring Facility between 1992 and 2013 for adult lamprey and between 2000 and 2014 for juvenile lamprey.

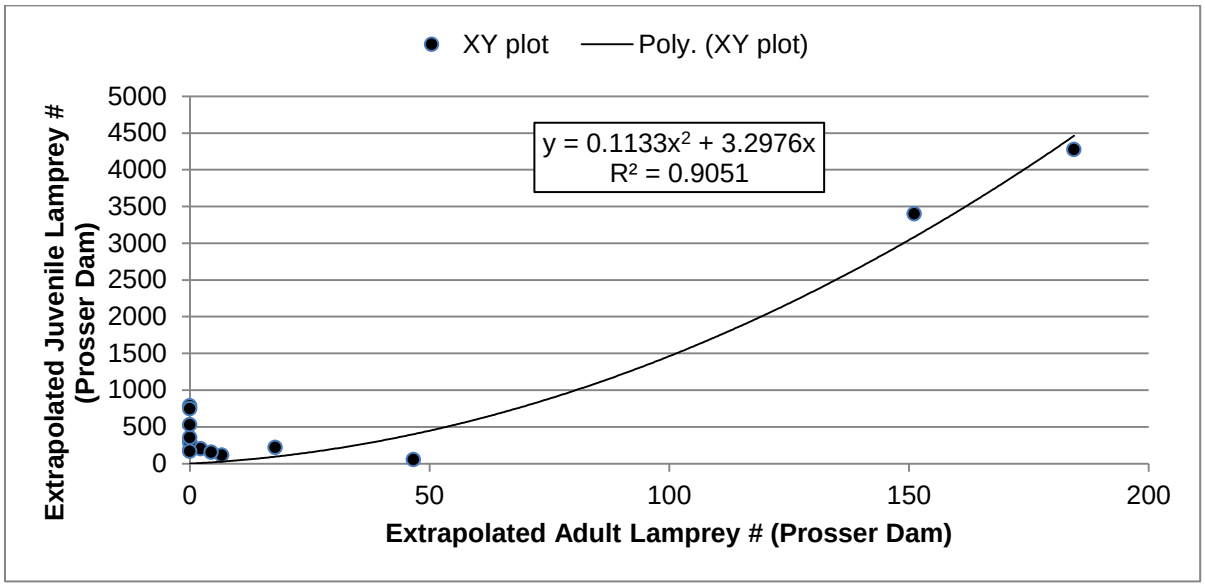

Figure G-8. XY scatter plot of extrapolated adult Pacific Lamprey numbers (between 1992 and 2006) vs. juvenile lamprey numbers from Prosser Dam / Chandler Juvenile Fish Monitoring Facility (between 2000 and 2014). The line graph is a polynomial curve trend line with equation and r^2 value shown in the box.

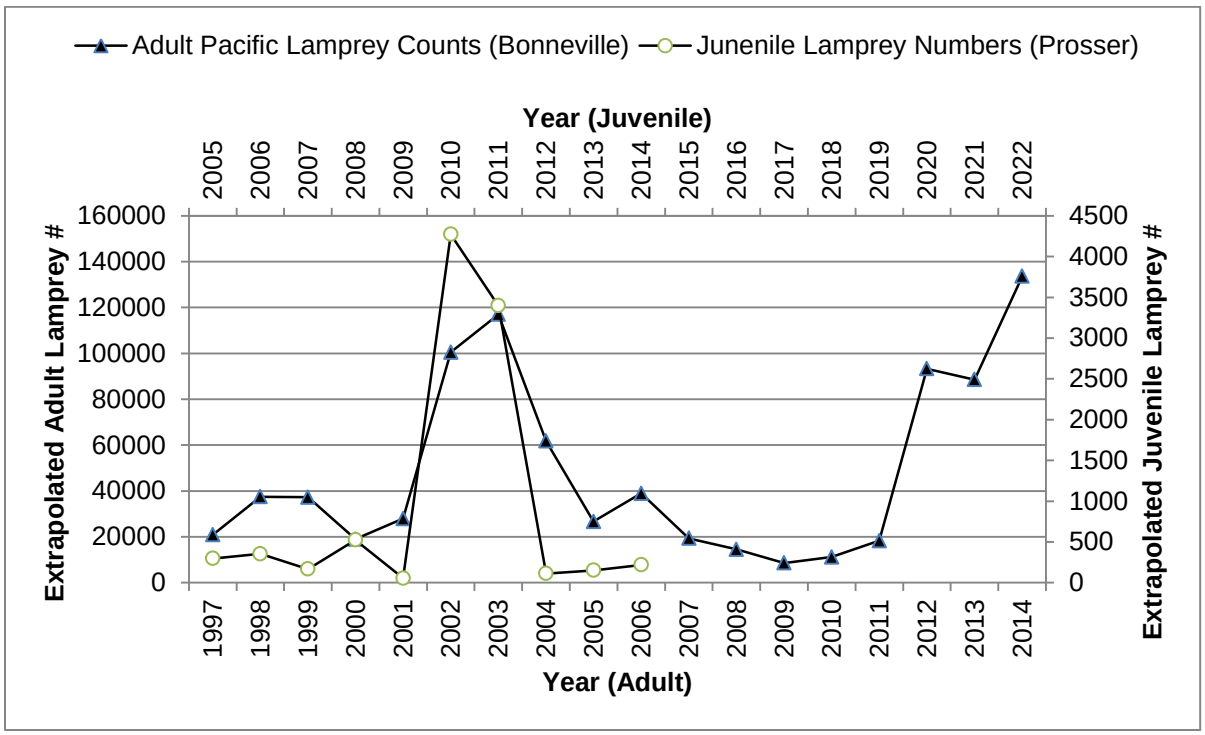

Figure G-9. Adult Pacific Lamprey counts from Bonneville Dam vs. juvenile lamprey numbers from Prosser Dam / Chandler Juvenile Fish Monitoring Facility between 1997 and 2014 for adult lamprey and between 2005 and 2014 for juvenile lamprey. The years for juvenile numbers and adult counts are lagged by eight years, which signifies a seven year residence time in freshwater prior to outmigration (one year of adult overwintering and seven years as larvae).

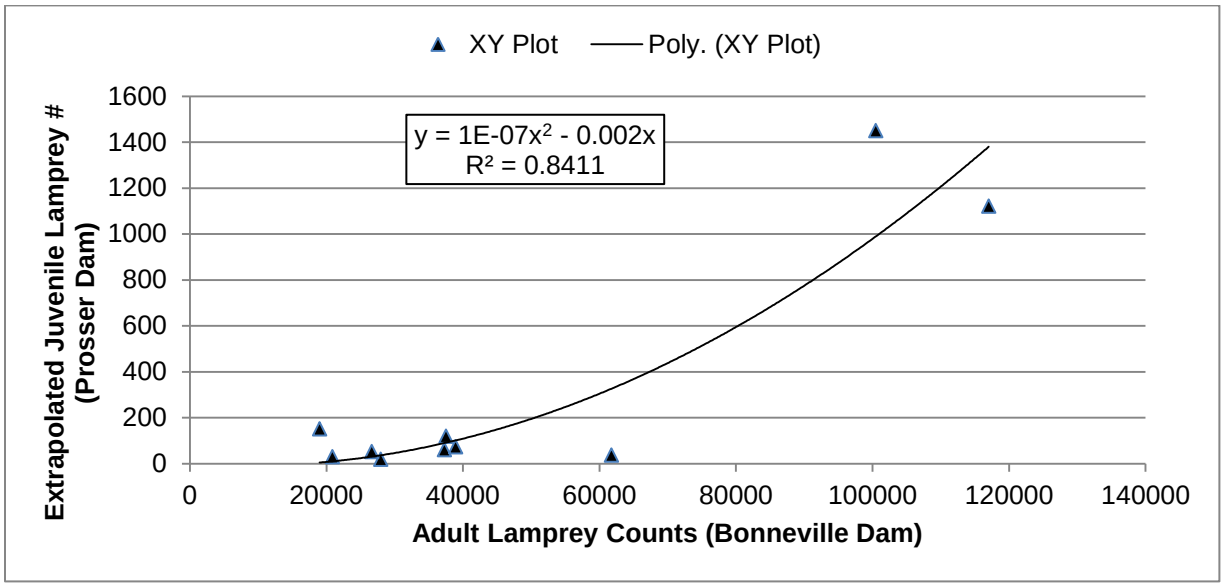

Figure G-10. XY scatter plot of adult Pacific Lamprey counts (between 1997 and 2006) vs. juvenile lamprey numbers from Prosser Dam / Chandler Juvenile Fish Monitoring Facility (between 2005 and 2014). The line graph is a polynomial curve trend line with equation and r^2 value shown in the box.

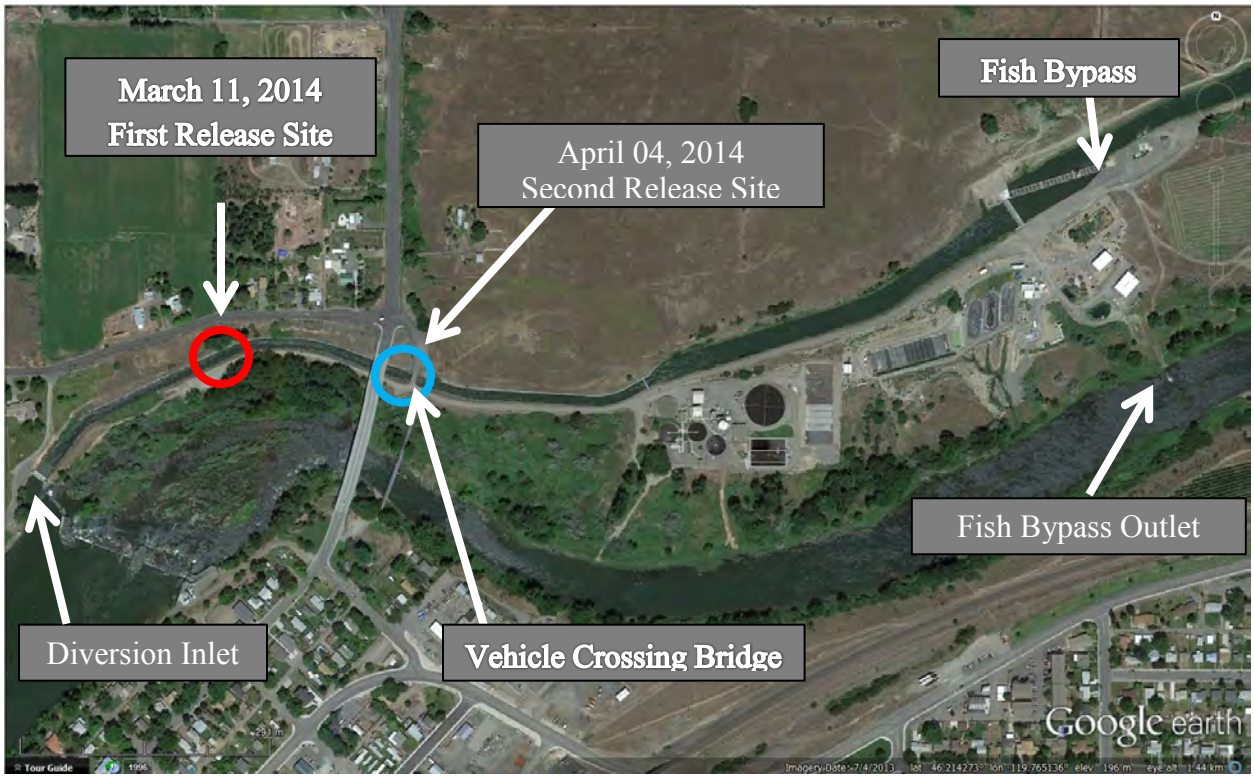

Figure G-11. The two release sites into the canal upstream of the fish screens at Chandler Diversion (March 11, 2014 and April 4, 2014), relative to the diversion inlet, fish bypass, and the fish bypass outlet.

Larval/Juvenile Entrainment Monitoring

There are many biological questions that needs to be answered, including 1) approximately what proportion of the overall population enter these canals, 2) when are lamprey entering the diversion and past the screens and/or the bypass system, 3) what is the mechanism behind screen passage of large lamprey, and 4) how many of the lamprey are able to overwinter and reside over multiple years within these canals?

Each year, irrigation diversions within the Yakima Basin entrain many thousands of larval/juvenile Western Brook Lamprey, with a smaller portion being Pacific Lamprey. The vast majority of lampreys (91.4%) were found in two diversions: Wapato Diversion (upstream of fish screens) and Sunnyside Diversion (downstream of fish screens). 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, 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.

Based on a single pass assessment, the estimated number of lampreys entrained within these areas of interest in Sunnyside Diversion (Yakima River; river km 171.0) and Wapato Diversion (Yakima River; river km 175.5) were estimated to be 3259 and 5249, respectively. Visual implant elastomer (VIE) tags were inserted into larval/juvenile lampreys captured within a high density area above the fish screens at Wapato Diversion. The resulting mark recapture study concluded that potentially only between 19 and 45 percent of the lamprey present in a given area were observed during a single pass survey. If we assume that during our single pass estimate we observed only 45% of the lamprey present (the highest percentage based on our mark recapture study), our estimated totals for Wapato and Sunnyside diversions within the area of interest would increase dramatically to18,907 lampreys (7,423 and 11,664, respectively). In addition to this estimate, over 1,000 desiccated larvae were found in these two diversions; however, this number is likely an underestimate based on the difficulty in finding desiccated larvae from predation and rapid decomposition of larval bodies.

A close examination of the raised fish screens at Sunnyside Diversion showed that lampreys otherwise too large to pass through the fish screens (3.18 mm) might be able to pass through gaps/tears in the rubber seals along the edges of the drum screens, which were 5-14 mm in size. Lamprey that are larger than 150 mm can pass through a 5 mm opening based on hatchery larval lamprey body width measurements).

The orientation of the headgate and channel configuration appears to have a large impact on fine sediment transport and deposition within the irrigation diversion. Diversions with headgates that are positioned parallel to the main river current likely have reduced amount of fine sediment that moves into the diversion compared to those that are positioned perpendicular to the main river current. Channel configuration that directs flow towards the fish screens will also likely transport more fine sediment through the screens compared to those that directs the flow away from the screens. See **Appendix G8** (Part I) for more information and data on the intensive monitoring of larval/juvenile lamprey entrainment in Sunnyside and Wapato diversions.

Lastly, to monitor instream lamprey movement, behavior, and entrainment, 215 VIE tagged larval/juvenile lamprey were released in larval lamprey habitat immediately upstream of major irrigation diversion headgates at Town (Yakima R.), Fruitvale (Cowichee R.), Wapatox (Naches R), and Bachelor-Hatton (Ahtanum Creek) diversions. In lower Ahtanum Creek (river km 4.1), 26 VIE tagged larval lamprey were released above a rotary screw trap. No released lamprey were recaptured in these irrigation diversions in 2014 (Bachelor-Hatton Diversion (Ahtanum Creek) was not revisited due to early dewatering). A limited percentage of tagged lamprey were recaptured (5.6%) at the only revisited release site above Wapatox Diversion. Due to the uncertainty in larval lamprey downstream movement, a larger number of tagged larvae may be needed to fully assess diversion entrainment rates (through both the headgate and fish screens). See **Appendix G8** (Part II) for more information and data on instream monitoring of larval/juvenile lamprey movement, behavior and entrainment.

The YNPLP also assisted with the salvage operations for Dryden Diversion dewatering on October 14 and 15, 2014. Dryden Diversion is a major diversion of the Wenatchee River (river km 27.8; 1.75 mm vertical fish screens) where thousands of larval/juvenile Pacific Lamprey enter each year. Voluminous amounts of fine sand, silt and clay accumulate within the diversion (upstream and downstream of the fish screens), providing ideal larval rearing habitat until dewatering starts in the fall. Our crew captured a total of 591 larval lamprey and 28 macrophthalmia using a backpack electrofisher and provided assistance for the Chelan County PUD crew to net and capture a total of 1783 larval lamprey and 266 macrophthalmia. A total of 2374 larval lamprey and 294 macrophthalmia (12.4% of the total) were salvaged and released back to the Wenatchee River downstream of the diversion dam. While we tried to capture everything we could, a large number of electrofished lamprey were able to escape due to the high density (missed between 2~6 fish for every fish captured). On October 14, 2014, approximately 360 m^2 of the area upstream of the fish screens was surveyed rather quickly at a pace of 2 m^2/min (twice as fast as normal rate of electrofishing surveys) and a total of 1433 lamprey were observed (either captured or missed). The overall wetted area was 1082 m^2 based on Google Earth aerial photos (overall area was 3607 m^2 with about 30% of the area covered in water during dewatering). Based on these statistics, we estimate that there could be approximately

4307 lamprey in this diversion above the fish screens. An estimate based on the numbers observed on October 15, 2014, yielded roughly the same number of lamprey (4539). The total number of lamprey estimated to be downstream of the fish screens was 817 (15.3% of overall fish number) based on density and area observed on October 15, 2014.

Water Quality / Toxicology

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.

During 2011-2012, an initial review of literature and a Water Quality Sampling Strategy has been developed. Larval lamprey tissue and substrate samples from four lower diversion sites (Roza, Union Gap, New Rez, and Sunnyside) were collected in late October and early November, 2012, during the canal dewatering period. These samples were sent in for lab analysis as part of a joint toxicology study in collaboration with the CRITFC and USGS. Additional sediment samples from Chandler and Toppenish-Satus diversion sites, which are located further downstream with more exacerbated water quality problems, were also sent in for lab analysis without the accompanying lamprey tissue sample (due to absence of larval lamprey in these areas). Initially, samples were scheduled to be taken in early summer months, when concentration of agricultural herbicide/insecticide chemicals are most widely used and known to be at the highest concentration within water bodies. However, limited number of larval lamprey available in natural streams/rivers in the lower reaches (where water quality is a known issue) made this plan practically unfeasible.

With the start of adult translocation, we now have more sites where larval lamprey are present, allowing us to expand our investigation on toxicology in lamprey tissue and fine sediment from a wider range of locations within the Yakima Basin. We anticipate expanding this existing project to include additional sites of interest for the re-establishment of lamprey, including but not limited to high quality habitat index sites, potential future supplementation sites, as well as water sources for propagation and juvenile rearing facilities. Our intention is to obtain approximately three years of water quality, substrate and tissue samples, from which to draw conclusions about risk to lamprey from these substances. Sampling strategies will be closely coordinated with the Washington Department of Ecology and Reclamation. The YNPLP intends to use Reclamation facilities and expertise for evaluation of samples whenever possible, and will sub-contract sample analysis to other laboratories as needed.

The results from the 2012 samples were published in the Elsevier Editorial System for Environmental Pollution Journal by the USGS and CRITFC (**Appendix G9**). A wide range of contaminants (115 analytes) was measured in sediments and tissues at 27 sites across a large geographic area of diverse land use, including the YNPLP samples. This is the largest dataset of

contaminants in habitats and tissues of Pacific lamprey in North America and the first study to compare contaminant bioburden during the larval life stage and the anadromous, adult portion of the life cycle. Bioaccumulation of pesticides, flame retardants, and mercury was observed at many sites.

This study identified the individual compounds detected most frequently and at the highest concentrations in both sediments (flame retardants, PAHs, pesticides, Hg, and CECs) and tissues (pesticides, flame retardants, and Hg) at sites across a large geographic area including multiple subbasins and diverse land use. The observed higher concentrations in tissues compared to sediments likely indicate bioaccumulation of pesticides (chlorpyrifos, oxyfluorfen, DDT, chlordane, endosulfan, dieldrin, hexachlorobenzene, and/or their degradation products), flame retardants (BDE 47, 99, and 100), and mercury at many sites. Based on available data, contaminants are accumulating in larval Pacific lamprey at levels that are likely detrimental to organism health and may be contributing to the decline of the species.

In 2014, we collected a total of 69 tissue samples of larvae (36 Pacific Lamprey and 32 Western Brook / River Lamprey samples) from Lower Columbia River tributary confluences and upstream control sites, including Wind, Rock, White Salmon, and Klickitat rivers for a study on mercury contamination in the Lower Columbia River in collaboration with the PNNL and CRITFC. A sediment sample from each site was collected as well to assess the correlation with mercury concentration in lamprey tissue. Based on preliminary results, mercury concentrations in fine sediment were 5~100 times higher than what was previously reported for in river water. Mercury concentration in lamprey tissue showed a clear relationship with that from the associated fine sediment, which appears to be asymptotic as the sediment concentration exceeds ~1.7 ppm, suggesting that mercury concentrations are likely lethal above this value. Mean values for mercury concentration in lamprey tissue ranged between 0.25 and 2.0 ppm (Fig. G-12). Mercury concentration in adult lamprey averaged 0.44 ppm (two samples were $\geq$ 0.7 ppm). Studies on other fish species showed that lethal effects (e.g. mortality, failure to hatch or spawn, developmental abnormalities) increase rapidly once tissue concentration for methyl mercury exceed 0.1 ppm, with 50% lethal injury of early life stage observed at ~0.4 ppm and sub-lethal effects (e.g. altered behavior, development and growth) detected consistently above 0.3 ppm. Concentration of mercury in lamprey tissue was clearly above these values. See **Appendix G10** for more details on the results from this mercury level study.

Additional funding to continue toxicology studies in the Yakima Basin in 2015-2019 is being sought with cost share partnership from the USGS, CRITFC, and Reclamation. Main focus will be 1) to determine the impacts of toxicants on adults and early life stage egg/larvae, 2) the degree to which toxicants are passed vertically from parents to offspring, and 3) to monitor baseline and post stream restoration conditions in translocation streams (Satus, Toppenish, and Ahtanum streams) as well as sites for outlplanting and mainstem Yakima River.

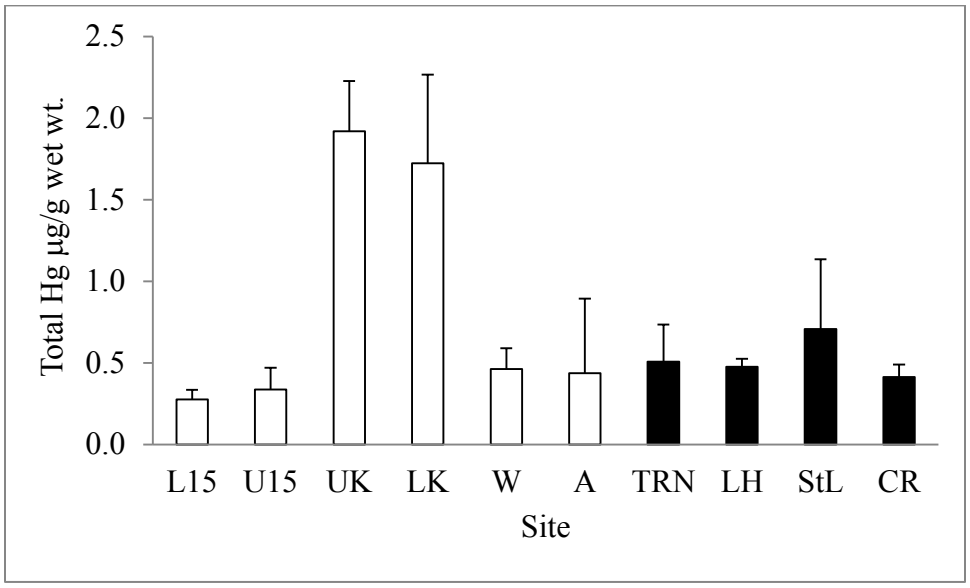

Figure G-12. Total mercury concentrations (mean ± SD) in ammocoetes and adult lamprey from the lower Columbia River (open bars) and other North American locations (closed bars). Site designations are: L15 and U15 (lower and upper 15 Mile River), UK and LK (upper and lower Klickitat), W (Wind River), 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). Excerpt from Appendix 4.1.

Data Depository

All mapping data is currently stored in the Google Earth program and all quantitative data is stored in Microsoft Excel. The YNPLP will 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. We are also in the process of scanning all field data sheets to make all hard copy data available in an electronic form. Data depository options were previously discussed with YN GIS specialists (Leon Ganuelas) and StreamNet staff (Van Hare and Michael Banach), and these options will be pursued further in 2015. The USFWS has also set up a data archival recently 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 range wide and information contributed by an assortment of collaborating agencies. All of this data / information is available upon request.

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

Work Element Associated Appendix Report:

Not Applicable

Throughout Project Year 4, the YNPLP has continued to maintain a strong presence in supporting and guiding Pacific Lamprey recovery in the Yakima Basin and in the Columbia River Basin. The following outlines some of the key activities YNPLP staff is involved with:

Coordination with the Reclamation in the Yakima Basin

Technical representative for both the YNPLP 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) larval/juvenile lamprey salvage/collection in irrigation diversions, and (2) intensive monitoring associated with larval/juvenile entrainment in select diversions. A meeting was also held with the Reclamation discussing logistics for implementing various components of larval/juvenile lamprey salvage and transport in fine sediment using funds from Natural Resources Conservation Service.

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. Initial designs were developed by Jim Simonson (contracted by the YNPLP) and Pat McGowan (Reclamation engineer) in coordination with technical representatives from the YNPLP, Reclamation, USFWS and others. Some feedback was provided from tribal fishermen regarding their fishing sites at Prosser Dam and how structures on the left bank may impact their fishing. More input will be sought in early 2015 to ensure that any of the proposed passage structures will not affect their long-standing rights at the site. This discussion will continue in Project Year 5 with the intent to implement one or more of these structures in 2015-2016 through discussion elaborated and refined as a result of recommendations from the PASS and input from stakeholders, such as tribal fishermen.

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 primary 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

For translocation, a new seasonal temporary technician was hired in July 2015 by CRITFC to assist member tribes collect adult lamprey at the Lower Columbia River dams. The CRITFC also provided crucial funding for lamprey toxicology studies in partnership with the USGS (**Appendix G9**) and PNNL (**Appendix G10**). A considerable amount of planning and coordination occurred with the CRITFC in the development of the "Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin" and "Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research" (**Appendix C1** and **Appendix C2**, respectfully). The YN policy and technical representatives met with the CRITFC Pacific Lamprey Tribal Task Force frequently. Typical agenda items associated with these meetings include the USFWS Conservation Agreement, progress in passage at the FCRPS facilities, progress in adult and juvenile supplementation, and progress among the YNPLP, Confederated Tribes of the Umatilla Indian Reservation, and Reclamation in the Umatilla and Yakima basins. Of primary importance to CRITFC and tribal policy representatives is when we are going to accelerate implementation of solutions (such as passage structures) with a de-emphasis on more and continued research.

Coordination with the USFWS: Conservation Agreement and Lamprey Occupancy Workshop

In June, 2011 the USFWS initiated a Conservation Agreement in which both the Reclamation and YN are signatories. 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 Basin, the YN recognizes that multiple threats exist that limit abundance, productivity and spatial distribution throughout the basin and that multiple agencies, jurisdictions and publics are needed to realize recovery objectives. In Project Year 5, the YN anticipates working closely with the Reclamation to accelerate activities through multiple partnerships at the subbasin scale, within the context of the Conservation Agreement.

The USFWS also held a "Lamprey Occupancy Workshop" on October 27 and 28 in Tualatin, OR, sharing occupancy sampling protocols for larval lamprey. Summarized below is the feedback the YNPLP provided on the workshop: 1) Although occupancy sampling can be valuable in demonstrating confidence in absence, there are other protocols available that can help us detect larval lamprey in a much more efficient manner; 2) there is a need to selectively sample certain habitat preferred by larval lamprey (Type I and II in this case) to enhance our sampling

efficiency; 3) repeated surveys in index sites over the years demonstrate that detection probability for larvae in sites where they are present are very high; 4) small pockets of Type II habitat may exist in predominantly Type III habitat, but a minimum size threshold (such as 0.5 m^2) should be determined to reduce ineffectual survey time searching for every small pockets of Type II habitat; 5) Sampling protocols should be devised in a way so that the results could effectively demonstrate which elements are ineffectual and consequently need to be eliminated (such as sampling in Type III habitat); 6) for inexperienced surveyors, surveyor can choose to sample all habitat until confidence in habitat identification increases; 7) importance of reaching consensus on core elements for larval lamprey surveys, 8) rate of electrofishing can have pivotal impacts on the results and it is essential to at least try to standardize this rate.

Coordination with the Lamprey Technical Work Group (LTWG)

Technical representatives continue to meet periodically with the LTWG, whose meetings are held biannually focusing on regionally important lamprey coordination / conservation projects. With respect to the Yakima Basin, one of the primary considerations brought to the LTWG over the past year has been with the completion of the "Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin" by the YN and Umatilla Tribes and coordinated by the CRITFC. A significant component of this document outlines both adult and juvenile supplementation research which will occur within the Yakima Basin, including elements of future research funded through the YN - Reclamation Agreement of 2011. The importance of standardizing larval/juvenile lamprey sampling methods among the various agencies and entities is another topic that the CRITFC and member tribes have emphasized and proposed through the LTWG, but very little progress has been made consecutively as a team. In 2015, The LTWG will undergo several changes in terms of leadership, oversight, structure, and membership.

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. Each of the three Public Utility Districts (Grant, Chelan and Douglas counties) have Pacific Lamprey Management Plans as a component of 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. Although none of these activities occur directly within the Yakima Basin, some of the mitigation activities (such as artificial propagation) will likely take place within the Yakima Basin. Finally, in collaboration with partners (the Confederated Tribes of the Umatilla Indian Reservation, NOAA Fisheries, and USFWS), we will be conducting a three year (2015-2018) study to investigate the best management practices for rearing larvae/juvenile from artificial propagation, using Chelan County PUD funding allocated for Pacific Lamprey Management.

For activities related to disseminating raw/summary data and results stemming from this project, see Work Element 99 (Outreach and Education). Each of our team members have taken the time to present our latest findings and results in local, state, and regional conferences throughout the year in 2014.

I. Work Element 99 – Outreach and Education

Work Element Associated Appendix Report:
Appendix I1 – 2014 Yakama Nation Lamprey Outreach and Education

Technical representatives of the YNPLP are actively involved with public outreach, providing presentations at professional meetings, local schools, and organizations. 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 important to clear misguided stereotypes and inform audiences of lamprey's true roles in stream ecology and YN culture. We have targeted a wide range of audiences in our outreach activities from early childhood to elders. A show called "Off the Hook" on Animal Planet ran an episode on lamprey harvest at Willamette Falls featuring Patrick Luke and others from our program. We also made an effort to again connect with many of the local schools to expose and familiarize students with lamprey through "Lamprey in the Classroom" (Yakima West Valley Middle School) and restoration activities, such as adult translocation release projects. On World Fish Migration Day (May 24, 2014), a one day global initiative to celebrate the importance of fish migration, we held an event at Ahtanum Mission Church for the public to participate in our adult lamprey translocation release. The event brought together a wide diversity of audiences of all ages and was a huge success. Our ultimate goal is to have strong community involvement in all of our lamprey restoration activities. These events may inspire some of the students to become biologists or natural scientists in the future. More importantly, we simply wish to reconnect the missing ties with lamprey "eels" for the young generation. On a conservative estimate, all these events combined together in 2014 likely reached out to over several thousand people of various background and age groups (Table I-1). For more details on 2014 outreach and education activities, see **Appendix I1**.

Table I-1. Summary of lamprey outreach / educational events in 2014.

Date	Event	Location	Presenter(s)	Audience	# of People Reached
1/17/2014	Hanford Natural Resource Meeting	Yakima, WA	Patrick	Tribal Trustee Council	23
1/27/2014	YN Fisheries Meeting	Toppenish, WA	Patrick	Tribal Fishermen	75
2/11/2014	School Assembly Presentation	Yakama Nation Tribal School	Patrick	Tribal Students	50
2/20/2014	Family Science Night	Garfield Elementary School	Patrick, Ralph, Emily	Students & Family	>300
3/4/2014	Museum Tour (K1-5)	Yakama Nation Museum	Patrick, Emily	Students	30
3/14/2014	Biology Lab Presentation	Heritage University	Bob, Patrick	College Students	20
3/25/2014	American Fisheries Society (WA/BC Chapter)	Vancouver, WA	Ralph	Scientists	70
3/28/2014	Yakima Basin Joint Board Meeting	Yakima, WA	Ralph	Irrigation Districts	25
4/7/2014	YN Fisheries Habitat Workshop	Yakima, WA	Ralph	YN Scientists	75
4/8/2014	Salmon Run Outreach	Central Washington University	Dave'y, Emily	Public	>100
4/14/2014	Yakima Basin Lamprey Conservation Plan Meeting	Yakima, WA	Ralph, Bob	Scientists	15
4/15/2014	Yakama Nation General Council Assembly	Toppenish, WA	Patrick	Tribal General Council	>250
4/23/2014	Lower Ahtanum Creek Lamprey Release	La Salle High School	Patrick, Ralph, Dave'y, Tyler	Students	40
4/24/2014	Tour for Wapato Middle School	Prosser Hatchery	Prosser Staff	Students	42
5/7/2014	Lamprey Release for YN Tribal School	Upper Satus Creek	Patrick, Ed, Emily	Tribal Students	35
5/8/2014	Tour for Sunnyside Christian School	Prosser Hatchery	Prosser Staff	Students	45
5/11/2014	Tour for Visitors	Prosser Hatchery	Prosser Staff	Public	6
5/14/2014	Tour for Outlook Elementary School	Prosser Hatchery	Prosser Staff	Students	120
5/14/2014	Lamprey Release with White Swan Middle School	Upper Toppenish Creek	Tony Washines, Emily, Ralph, Ed	Students	50
5/20/2014	Tour for Zillah Middle School	Prosser Hatchery	Prosser Staff	Students	120
5/22/2014	Update for Facebook / Yakama Nation Website	Agency Website	Emily	Viewers/Subscribers	>600
5/24/2014	World Fish Migration Day / Lamprey Release	Ahtanum Mission Church	Ralph, Tyler, Dave'y, D. Close	Public	75
5/28/2014	Tour for Mabton School	Prosser Hatchery	Prosser Staff	Students	55
5/28/2014	Prosser Dam Passage Improvement Meeting	Prosser Hatchery	Ralph	Scientists	10
6/2/2014	Tour for Grandview School	Prosser Hatchery	Prosser Staff	Students	25
6/2/2014	Willamette River Commemoration Day	Portland, OR	Patrick, Emily	Public	175
6/4/2014	Tour for Chief Kamiakin Middle School	Prosser Hatchery	Prosser Staff	Students	100
6/6/2014	YN Treaty Day	Toppenish, WA	Patrick, Emily	Public	>500
6/18/2014	Tour for Chief Kamiakin High School	Prosser Hatchery	Prosser Staff	Students	23
6/19/2014	Yakima Basin Science & Management Conference	Central Washington University	Patrick, Tyler	Scientists	75
6/30/2014	Tour for Mt. Hood Community College	Prosser Hatchery	Ralph, Tyler, Ed, Prosser Staff	Students	25
7/1/2014	Lamprey Screening Meeting	Cook, WA	Ralph	Scientists	10
7/7/2014	YN Fish Passage Meeting	Toppenish, WA	Ralph	YN Scientists	10
7/10/2014	Summer Camp (YN Tribal High School)	Prosser Hatchery	Ralph, Prosser Staff	Students	70
7/14/2014	Tour for YN Tribal Middle School	Prosser Hatchery	Prosser Staff	Students	20
7/29/2014	YN Production Meeting	Yakima, WA	Ralph	YN Scientists	75
7/30/2014	CRITFC Salmon Camp (K-12)	Camp Chaperall (Klickitat River)	Patrick, Dave'y	Students	50
8/12/2014	"Off the Hook" Lamprey Episode	Animal Planet	Patrick, Dave'y, Jeremy, Emily, JD	Viewers/Subscribers	>1 million
8/13/2014	Yakama Nation Backpack Giveaway	Toppenish, WA	Patrick, Emily	Tribal Students	200
8/15/2014	YN Family Fishing	Marion Drain Hatchery	Patrick, Emily	Tribal Families	50
8/27/2014	Lamprey Travel Bug Geocaching (Yakima Herald Republic)	Yakima River Canyon	Dave'y, Ed, Emily	Viewers/Subscribers	>1,000
9/4/2014	YN Fisheries & Tribal Council	Toppenish, WA	Emily	Public	30
10/23/2014	Presentation to Portland State University	Heritage Museum	Arlen Washines	College Students	30
10/27/2014	USFWS Lamprey Occupancy Workshop	Tualatin, OR	Ralph, Ed, Tyler	Scientists	100
11/13/2014	USFWS Hatchery Mngmnt Training Conference	Richland, WA	Ralph	Scientists	90
12/2/2014	Northwest Fish Culture Conference	Pendleton, OR	Ralph	Scientists	200
				Total	**1005089**

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

Work Element Associated Appendix Report:

Appendix J1 – Developing Techniques for Artificial Propagation and Early Rearing of Pacific Lamprey (*Entosphenus tridentatus*) for Species Recovery and Restoration (Chapter Article within "Jawless Fishes of the World" - AFS Book Publication)

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 YNPLP to embark on the new exciting research. In 2012, the YNPLP succeeded in conducting a pilot project to successfully hold, propagate, incubate, and rear juvenile larvae. Strong partnership with the Umatilla Tribes (especially with Mary Moser) was also extremely valuable. Important investigations and discoveries from Project Year 2 include: 1) variables and elements for fertilization success, 2) best methodology for incubation success, and 3) types of feed and the use of media for feed ready larvae.

Based on the experience from 2012, including countless trials and errors, valuable lessons were learned, and this created a path forward for research in Project Year 3. Over a 10-week period between April 12 and June 14, 2013, 41 adults were propagated successfully at Prosser Fish Hatchery. Highlights from Project Year 3 include investigations in: 1) water source and sexual maturation, 2) fertilization protocols (wait time, gametes mixing, and rinsing), 3) preservation of gametes and use of gametes from freshly dead adults, 4) use of XperCount device for prolarvae counting, and 5) larval rearing tank settings, feed, and substrate media.

In Project Year 4, the following discoveries were made:

- Ratio of the interval between snout and anterior insertion of first dorsal fin to total length for spawn ready Pacific lamprey allowed discrimination of males from females 63% of the time (with a 37% overlap). Ratio for males ranged between 0.435 and 0.490 whereas ratio for females ranged between 0.470 and 0.515.
- The majority of males (87%) and some of the females (16%) could be repeat spawned over the course of 7 days (for females) - 16 days (for males).
- Two anti-adhesion solutions were tested on fertilized eggs to examine their effects on egg de-adhesion and fertilization rates: tannic acid reduced fertilization rates significantly even at low concentrations (500 mg/L), whereas 1% pineapple juice showed no negative impacts on fertilization rates and effectively eliminated egg adhesion.
- Egg fertilization in zip lock bags were equally effective as the bowl and feather method.
- Both formalin and hydrogen peroxide treatment (1667 ppm for 1 hr) on spawn ready adult lamprey reduced fungus growth substantially and appeared to help prolong the duration of spawning season.
- The new XperCount program and software allowed much more accurate estimates of prolarvae counts compared to previous program using the biomass factor in relation to the days post fertilization.
- Prolarvae held in a combination of spawning mat and fine sediment (<500 micron) underneath showed minimum mortality up to densities of 125 g/m^2 (50,000 individuals /m^2). Mortality increased when densities were 250 g/m^2 (100,000 individuals /m^2), yet addition of algae mats were shown to effectively reduce this mortality.

- Flow rate of 3 gallon/min showed minimum impingement of prolarvae on outlet screens, especially with spawning mats as cover (higher rates, such as 5 gallon/min, increased impingement rates).
- Burrowing behavior first began at 26 d post fertilization (~11 d post hatching) and the majority of larvae (>95%) finished burrowing by 33 d post fertilization (~19 days post hatching), corresponding to cumulative degree days of 369 and 469, respectfully.
- Despite low detections of mortality on tank surfaces, survival rates of larvae 3 months post fertilization was variable and mostly low (7.3-68.1%). Evidently, this is the bottle neck life stage for survival in the hatchery environment.
- Survival rates 3 months post fertilization are very high (typically >99% monthly survival).
- Stopping of water during feeding improved growth rates for small larvae (<50 mm), but enhanced growth was not detected for large larvae (>50 mm).
- The additional feed that has shown enhanced growth and/or survival from the 10 gallon aquarium experiments include salmon carcass (added bi- or tri-monthly), wheat straw (added bi- or tri-monthly), alfalfa pellets (added bi- or tri-monthly), and organic wheat flour (added daily with yeast).
- A mixed feed ration of 10-20g / week / fish weight (g), of which ~50% was active dry yeast, resulted in growth rates of 7-12 mm per month between late July and late September for various sizes of larvae, showing the relationship between fish weight and feed requirement (Fig. J-1).
- A mixed feed of 400 – 700 g / m^2 resulted in growth rates ranging between 7.5-12 mm per month between late July and late September for various sizes of larvae, showing the relationship between tank size and feed requirement.
- At start densities of 100 g/m^2, growth rates were limited to roughly half of the maximum growth rates observed under lower densities, showing that growth is also density dependent.
- There was synchrony in growth rates across various tank settings: growth rates increased from summer to early spring whereas a decrease was observed in growth rates from early spring to summer (Fig. J-2).
- Bottleneck life stage in the hatchery environment appears to be the period between first feeding and 3 month old larvae based on results from YNPLP and partners research (Fig. J-3).
- Based on space requirement, survival, and growth calculations, a large scale production of larvae will likely be less efficient for larvae older than 6 months and almost prohibitive for larvae older than one year due to their space requirements (Fig. J-4).

For more information, see **Appendix J1** ("Developing Techniques for Artificial Propagation and Early Rearing of Pacific Lamprey for Species Recovery and Restoration", a chapter article in "Jawless Fishes of the World" – American Fisheries Society Publication). In collaboration with

partners (the Confederated Tribes of the Umatilla Indian Reservation, NOAA Fisheries, and USFWS), we will be conducting a three year (2015-2018) study to investigate the best management practices for rearing larvae/juvenile from artificial propagation using Chelan County PUD funding allocated for Pacific Lamprey Management. The 2015 study will focus on the newly hatched larvae (1-2 months post fertilization), which is considered the life stage bottleneck in the hatchery environment.

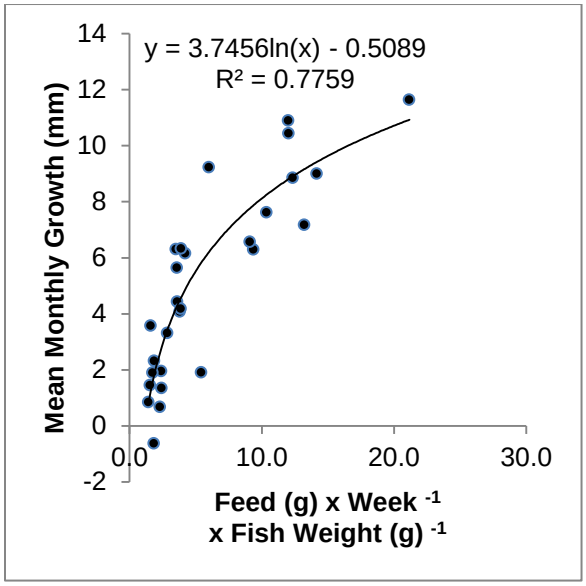

Figure J-1. Mean monthly growth (mm) observed for Pacific lamprey larvae reared in Prosser Fish Hatchery in 2014 in association with the feed (g) per week per overall fish weight (g).

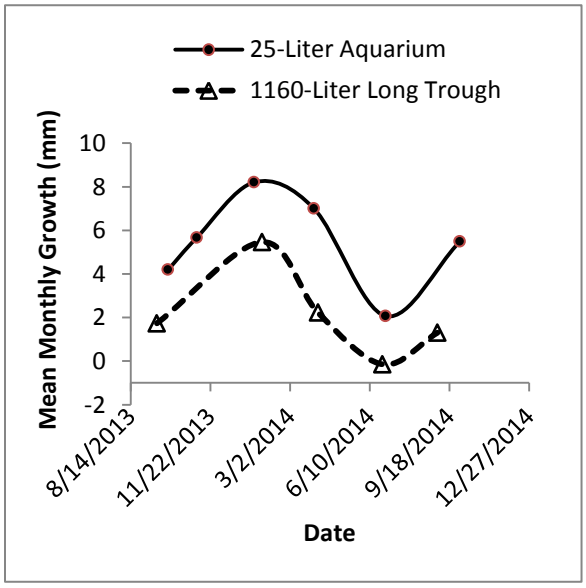

Figure J-2. Mean monthly growth (mm) observed for Pacific lamprey larvae reared in Prosser Fish Hatchery in 2014 in two tank settings.

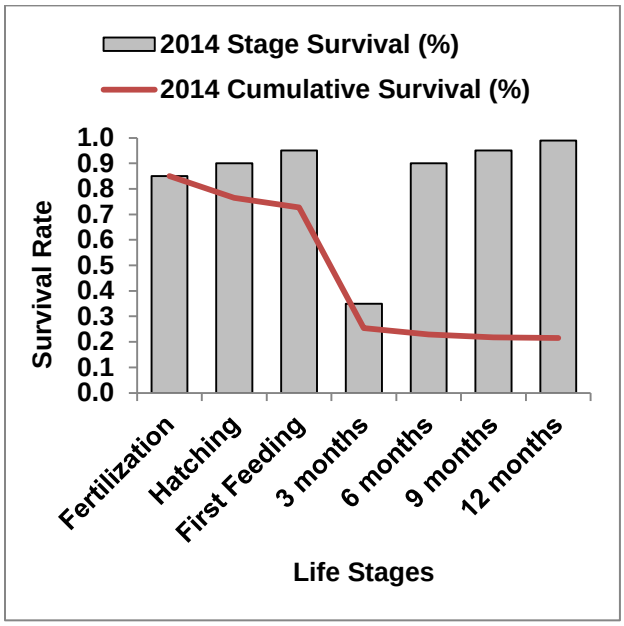

Figure J-3. Approximate life stage specific survival rates as well as cumulative survival rates observed for propagated young of the year Pacific lamprey larvae at Prosser Fish Hatchery.

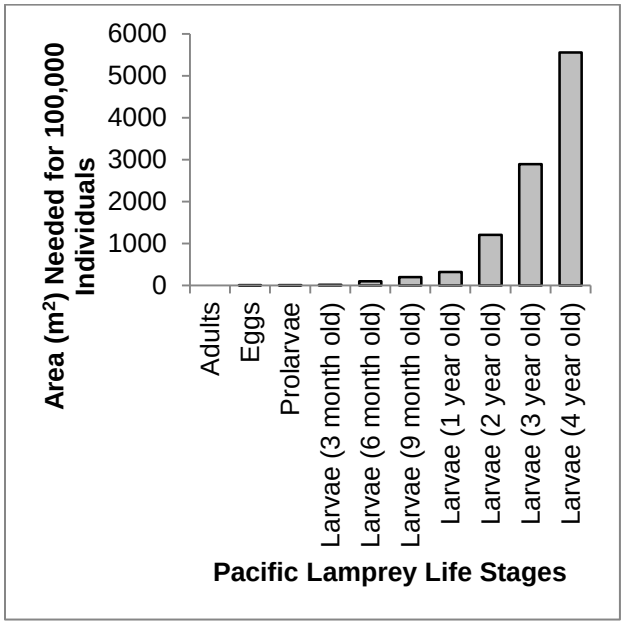

Figure J-4. Conceptual model of space (m^2) needed to adequately rear 100,000 individuals (approximate equivalent of fecundity for one female) of Pacific lamprey for various life stages.

K. Work Element 119 – Manage and Administer Projects

Work Element Associated Appendix Report:
Not Applicable

Since the initiation of this YN - Reclamation Coordination Agreement, the YNPLP has continued to grow in experience and knowledge and has substantially benefited. This is a relatively new project with many technical challenges ahead of us due to a wide variety of critical uncertainties to be addressed. All of the activities and tasks identified in this Cooperative Agreement are important, if not fundamental to the recovery of Pacific Lamprey in the Yakima River. But of priority concern for the YN, at this time, is the need to 1) better understand and address juvenile entrainment into the many irrigation canals within the Yakima Basin and 2) understand and address if irrigation diversion dams provide a significant passage barrier / deterrent to returning adult lamprey.

In order to improve our understanding on juvenile entrainment and overall survival, however, we will need to have access to a much larger sample of larval/juvenile lamprey than what we can readily extract from the already depressed wild populations. Artificial propagation and larval rearing, therefore, are essential components of our overall project to ensure we can thoroughly evaluate the multifaceted potential threats they currently face. These experimental and pilot efforts that the YNPLP is currently leading are also contributing enormously to our knowledge base of adult and larval lamprey biology, especially the early life history stage. Additionally, as a long-term freshwater resident, we are discovering more and more about the potential risk of toxicants in fine sediment and water that may be affecting larval lamprey in the mid to lower part of the Yakima Basin, as well as in the Lower Columbia River at large.

L. Work Element 132 – Annual Progress Report

Work Element Associated Appendix Report:
Not Applicable

The Annual Progress Report for the period January 2014 through December 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 diverables, problems encountered, lessons learned, and the information gathered, synthesized, and updated to assist in long term planning.

M. Work Element 185 – Pisces Status Report

Work Element Associated Appendix Report:
Not Applicable

All quarterly Pisces Status Report for the Year 2014 were completed successfully.

IV. References

Beamish R. J. and T. G. Northcote. 1989. Extinction of a population of anadromous parasitic lamprey, *Lampetra tridentata*, upstream of an impassible dam. Canadian Journal of Fisheries Aquatic Science 46:420-425.

Close, D., M. S. Fitzpatrick, H. W. Li, B. Parker, D. Hatch, and G. James. 1995. Status report of the Pacific Lamprey (*Lampetra tridentata*) in the Columbia River basin. Report to the Bonneville Power Administration, Contract 9SBI39067, Portland, OR.

Close, D. A., A. D. Jackson, B. P. Conner, and H. W. Li. 2004. Traditional ecological knowledge of Pacific Lamprey (*Lampetra tridentata*) in northeastern Oregon and southeastern Washington from indigenous peoples of the Confederated Tribes of the Umatilla Indian Reservation. Journal of Northwest Anthropology 38:141-161.

Columbia River Inter-Tribal Fish Commission (CRITFC). 2011. Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. CRITFC, Portland, OR.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of anadromous fishes in the upper Klamath River watershed prior to hydropower dams – a synthesis of the historical evidence. Fisheries 30:10-20.

Hammond, R. J. 1979. Larval biology of the Pacific Lamprey, *Entosphenus tridentatus* (Gairdner), of the Potlatch River, Idaho. M.S. thesis, University of Idaho, Moscow, ID.

Kan, T. T. 1975. Systematics, variation, distribution, and biology of lampreys of the genus *Lampetra* in Oregon. Doctoral dissertation, Oregon State University, Corvallis, OR.

Murauskas, J. G., A. M. Orlov, and K. A. Siwicke. 2013. Relationships between the abundance of Pacific Lamprey in the Columbia River and their common hosts in the marine environment. Transactions of the American Fisheries Society 142:143-155.

Luzier, C. W., H. A. Schaller, J. K. Brostrom, C. Cook-Tabor, D. H. Goodman, R.D. Nelle, K. Ostrand and B. Streif. 2011. Pacific Lamprey (*Entosphenus tridentatus*) Assessment and Template for Conservation Measures. U.S. Fish and Wildlife Service, Portland, Oregon. 282 pp.

Ward. D. L., B. J. Clemens, D. Clugston, A. D. Jackson, M. L. Moser, C. Peery, and D. P. Statler. 2012. Translocating Adult Pacific Lampreys within the Columbia River Basin: State of the Science. Fisheries 37:351–361.

V. Appendices

Appendix B1 – Consolidated and Summarized Cultural Oral Interviews on Lamprey Eels

Appendix C1 – Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin

Appendix C2 – Assessment of Eschbach Park Site (Naches, WA) for Larval Pacific Lamprey Outplanting

Appendix C3 – Assessment of Lower Wenas Site (Selah, WA) for Larval Pacific Lamprey Outplanting

Appendix C4 – Assessment of Holmes Acclimation Site (Ellensburg, WA) for Larval Pacific Lamprey Outplanting

Appendix C5 – Assessment of Cle Elum Hatchery Site (Cle Elum, WA) for Larval Pacific Lamprey Outplanting

Appendix D1 – 2014 Yakima Basin Larval Lamprey Survey Report

Appendix D2 – 2014 Entiat Subbasin Larval Lamprey Survey Report

Appendix D3 – 2014 Methow Subbasin Larval Lamprey Survey and Identification of Adult Pacific Lamprey Release Sites

Appendix D4 – 2014 Lower Columbia River Tributaries Larval Lamprey Survey Report (for Mercury Concentration Assessment)

Appendix E1 – 2014 Adult Pacific Lamprey Collection in the Columbia River Basin

Appendix F1 – 2014 Summary Assessment of Larval/Juvenile Lamprey Entrainment in Irrigation Diversions within the Yakama Basin, Washington, USA

Appendix F2 – Pilot Assessment of Larval Lamprey Habitat and Occupancy in the Yakima River Roza Dam Reservoir (Yakima, WA)

Appendix G1 – Pacific Lamprey vs. Western Brook (or River) Lamprey Larvae Identification Guide

Appendix G2 – Medium Size (50-90 mm) Pacific Lamprey & Western Brook Lamprey Larvae Identification Guide and Tips

Appendix G3 – 2012 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands

Appendix G4 – 2013 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands

Appendix G5 – 2014 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands

Appendix G6 – Establishment of Larval Lamprey Index Sites in the Yakama Nation Ceded Lands

Appendix G7 – 2014 Juvenile/Larval Pacific Lamprey Passage Monitoring in Chandler Diversion, Yakima River (Prosser, WA)

Appendix G8 – 2014 Intensive Monitoring of Larval/Juvenile Lamprey Entrainment within the Yakama Basin

Appendix G9 – Preliminary Report of USGS-CRITFC Toxicology Study on Lamprey and Fine Sediment Reconnaissance of Contaminants in Larval Pacific Lamprey (*Entosphenus tridentatus*) tissues and habitats in the Columbia River Basin, Oregon and Washington, USA

Appendix G10 – Mercury Concentrations in Pacific Lamprey (*Entosphenus tridentatus*) and Sediments in the Lower Columbia River Basin – Preliminary Report

Appendix I1 – 2014 Yakama Nation Lamprey Outreach and Education

Appendix J1 – Developing Techniques for Artificial Propagation and Early Rearing of Pacific Lamprey (*Entosphenus tridentatus*) for Species Recovery and Restoration

Title	Pages	Authors
Appendix B1 – Consolidated and Summarized Cultural Oral Interviews on Lamprey Eels	18	Patrick Luke
Appendix C1 – Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin	177	Bob Rose, Ralph Lampman and partners
Appendix C2 – Assessment of Eschbach Park Site (Naches, WA) for Larval Pacific Lamprey Outplanting	20	Ralph Lampman
Appendix C3 – Assessment of Lower Wenas Site (Selah, WA) for Larval Pacific Lamprey Outplanting	19	Tyler Beals and Ralph Lampman
Appendix C4 – Assessment of Holmes Acclimation Site (Ellensburg, WA) for Larval Pacific Lamprey Outplanting	18	Tyler Beals and Ralph Lampman
Appendix C5 – Assessment of Cle Elum Hatchery Site (Cle Elum, WA) for Larval Pacific Lamprey Outplanting	19	Tyler Beals and Ralph Lampman
Appendix D1 – 2014 Yakima Basin Larval Lamprey Survey Report	20	Tyler Beals and Ralph Lampman
Appendix D2 – 2014 Entiat Subbasin Larval Lamprey Survey Report	7	Tyler Beals and Ralph Lampman
Appendix D3 – 2014 Methow Subbasin Larval Lamprey Survey and Identification of Adult Pacific Lamprey Release Sites	16	Tyler Beals and Ralph Lampman
Appendix D4 – 2014 Lower Columbia River Tributaries Larval Lamprey Survey Report (for Mercury Concentration Assessment)	9	Tyler Beals and Ralph Lampman
Appendix E1 – 2014 Adult Pacific Lamprey Collection in the Columbia River Basin	21	Patrick Luke
Appendix F1 – 2014 Summary Assessment of Larval/Juvenile Lamprey Entrainment in Irrigation Diversions within the Yakama Basin, Washington, USA	64	Tyler Beals and Ralph Lampman
Appendix F2 – Pilot Assessment of Larval Lamprey Habitat and Occupancy in the Yakima River Roza Dam Reservoir (Yakima, WA)	16	Tyler Beals and Ralph Lampman
Appendix G1 – Pacific Lamprey vs. Western Brook (or River) Lamprey Larvae Identification Guide	2	Ralph Lampman
Appendix G2 – Medium Size (50-90 mm) Pacific Lamprey & Western Brook Lamprey Larvae Identification Guide and Tips	1	Ralph Lampman
Appendix G3 – 2012 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands	5	Ralph Lampman
Appendix G4 – 2013 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands	18	Ralph Lampman
Appendix G5 – 2014 Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands	12	Ralph Lampman and Tyler Beals
Appendix G6 – Establishment of Larval Lamprey Index Sites in the Yakama Nation Ceded Lands		Tyler Beals and Ralph Lampman
Appendix G7 – 2014 Juvenile/Larval Pacific Lamprey Passage Monitoring in Chandler Diversion, Yakima River (Prosser, WA)	7	Ralph Lampman and Tyler Beals
Appendix G8 – 2014 Intensive Monitoring of Larval/Juvenile Lamprey Entrainment within the Yakama Basin	34	Tyler Beals and Ralph Lampman
Appendix G9 – Preliminary Report of USGS-CRITFC Toxicology Study on Lamprey and Fine Sediment Reconnaissance of Contaminants in Larval Pacific Lamprey (*Entosphenus tridentatus*) tissues and habitats in the Columbia River Basin, Oregon	10	Partners
Appendix G10 – Mercury Concentrations in Pacific Lamprey (*Entosphenus tridentatus*) and Sediments in the Lower Columbia River Basin – Preliminary Report	10	Partners
Appendix I1 – 2014 Yakama Nation Lamprey Outreach and Education	14	Patrick Luke
Appendix J1 – Developing Techniques for Artificial Propagation and Early Rearing of Pacific Lamprey (*Entosphenus tridentatus*) for Species Recovery and Restoration	50	Ralph Lampman
Total	587	

Ralph Lampman	20
Patrick Luke	3
Tyler Beals	13