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March 29, 2017

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
Mail Code: DHAC, PJ-12
888 First Street, N.E.
Washington, D.C. 20426

RE: Priest Rapids Hydroelectric Project No. 2114-174
License Compliance Filing – Article 401(a)(12) – 2016 Pacific Lamprey Management Plan Comprehensive Annual Report

Dear Secretary Bose,

Please find enclosed the 2016 Pacific Lamprey Management Plan (PLMP) Comprehensive Annual Report consistent with the requirements of Article 401(a)(12) and the Washington State Department of Ecology 401 Water Quality Water Quality Certification Condition of 6.2(6)(b) (Appendix C) for the Priest Rapids Project.

The 2016 PLMP Comprehensive Annual Report summarizes the on-going activities undertaken at the Priest Rapids Project (Project) in 2015, as identified in the PLMP, for the purpose of identifying and addressing Project impacts on Pacific lamprey. Any variations from the implementation schedule provided in the PLMP have been identified in this document. This report also describes, consistent with the 401 Certification, recent Pacific lamprey passage, behavioral, and survival investigations and measures undertaken in the Columbia River basin, as well as an evaluation to determine if these investigations and measures are: (i) consistent with similar measures taken at other projects; (ii) appropriate to implement at the Priest Rapids Project; and (iii) cost effective to implement at the Priest Rapids Project.

On January 25, 2017, Grant PUD prepared and disseminated the draft 2016 PLMP Comprehensive Annual Report to members of the Priest Rapids Fish Forum including the Washington Department of Ecology (WDOE) U.S. Fish & Wildlife Service, Washington Department of Fish & Wildlife (WDFW), Colville Confederated Tribes, Yakama Nation, the Columbia River Inter-Tribal Fish Commission (CRITFC), Bureau of Indian Affairs, and the Confederated Tribes of the Umatilla Indian Reservation. A request for comments on the draft plan was also distributed to the Wanapum Indians, and other participating stakeholders. WDFW provided comments on February 27, 2017 (Appendix D) and are addressed in Appendix C of the report. On March 14, 2017 WDOE approved the report (Appendix E).

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Federal Energy Regulatory Commission staff with any questions should contact Tom Dresser at 509-754-5088, ext. 2312, or at tdresse@gcpud.org.

Sincerely,

Ross Hendrick
Manager - License & Environmental Compliance

CC: Breean Zimmerman – WDOE
Priest Rapids Fish Forum

2016
Pacific Lamprey Management Plan
Comprehensive Annual Report

Priest Rapids Hydroelectric Project (FERC No. 2114)

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March 2017

Executive Summary

In accordance with the Priest Rapid Hydroelectric Project's (Priest Rapids Project or Project) License Order, issued by the Federal Energy Regulatory Commission (FERC) on April 17, 2008 (FERC 2008), and the 401 Water Quality Certification (WQC), issued by the Washington Department of Ecology (WDOE) on April 3, 2007 (WDOE 2007) and amended March 6, 2008 (FERC 2008), Public Utility District No. 2 of Grant County, Washington (Grant PUD) is required to develop, in consultation with the Priest Rapids Fish Forum (PRFF), a Pacific Lamprey Management Plan Comprehensive Annual Report (PLMP Comprehensive Annual Report) to be filed with FERC on or before March 31 of each year.

The PLMP Comprehensive Annual Report summarizes the on-going activities undertaken at the Priest Rapids Project in 2016, as identified in the PLMP, for the purpose of identifying and addressing project impacts on Pacific lamprey. Any variations from the implementation schedule provided in the PLMP have been identified in this document. This report also describes recent Pacific lamprey passage, behavioral, and survival investigations and measures undertaken in the Columbia River Basin as well as an evaluation to determine if these investigations and measures are: (i) consistent with similar measures taken at other projects; (ii) appropriate to implement at the Project; and (iii) cost-effective to implement at the Project.

During the eighth year of implementation of the PLMP, Grant PUD continued, for a seventh year, its assessment of Pacific lamprey behavior and passage efficiency through fishways at Priest Rapids and Wanapum dams to evaluate the efficacy of design enhancements installed during the 2009-2010 winter fish ladder maintenance outage. For the 2010 through 2016 migrations, Grant PUD monitored a total of 447 and 491 half-duplex passive integrated transponder (HDX-PIT) tagged lamprey at Priest Rapids and Wanapum dams, respectively. Fishway passage efficiency for lamprey was 73% at Priest Rapids Dam over the 2010-2015 period and 72% at Wanapum Dam over the 2010-2013 and 2015 period (2014 intentionally omitted due to anomalous conditions associated with the Wanapum fracture). Fishway passage efficiency for 2016 is not yet available and will be included in the 2017 annual report.

During the 2016 adult Pacific lamprey migration period, two sources of HDX-PIT tagged lamprey were used to evaluate Project passage efficiency; fish from tagging efforts downstream and fish captured at Priest Rapids Dam. In 2016, reduced HDX-PIT tagging effort from downstream sources resulted in a smaller quantity of run-of-river tags detected at Priest Rapids Project than in recent years (n=46). The median passage time at both the Priest Rapids left and right bank fishways was 5.8 hours. Unlike previous years, there was no trend of increased passage time in the Priest Rapids left bank fishway. At Wanapum Dam, median passage times through the left and right bank fishways were 18.5 and 7.0 hours, respectively. These passage times are within the range of previous years.

In 2016, 150 lamprey were captured with mechanical traps in the lower Priest Rapids Dam fishways and implanted with HDX-PIT tags. The tagged fish were released in the lower Priest Rapids left bank fishway to assess passage through the upper fishway and specifically to evaluate passage near the Off Ladder Adult Fish Trap (OLAFT). The median passage time of fish included in this effort from release in the lower fishway to the fishway exit was 15.1 hours. The median passage time through the upper fishway above the count station, past the OLAFT to the exit was 9.1 hours. As such, it appears that the slow passage of the Priest Rapids left bank upper fishway observed in previous years is not a consistent phenomenon.

In addition to the 150 HDX-PIT tagged fish in 2016, 100 adult lamprey captured with mechanical traps from the Priest Rapids Dam lower fishways during the peak migration period in July and August were implanted with both acoustic tags (Vemco V7) and full duplex PIT (FDX-PIT) tags. These fish were released in either the Priest Rapids Forebay at Desert Aire (RM 400.4; n=30) or in the Wanapum Forebay at either RM 415.8 (n=35) or at RM 419.9 (n=35). An array of fixed acoustic receivers deployed throughout the Project area was used to monitor the tagged fish after release. Additionally, mobile tracking was employed to locate tagged individuals in the study area during the remainder of the migration period. As of October 2015, 75 fish were detected in the tailrace of Rock Island Dam (RM 453.0). The median travel time to reach the Rock Island Dam Tailrace was 3.6 days for fish released in the Wanapum Reservoir and 9.9 days for fish released in the Priest Rapids Reservoir. Travel rates to reach the Rock Island Tailrace ranged from 1.4-38.5 km/d for fish released in the Wanapum Reservoir and from 3.9-15.4 km/d for fish released in the Priest Rapids Reservoir. Three fish had not been detected after release and were assumed to have either been mortalities or have failed acoustic tags. Additional results will be provided after the study concludes in August 2017.

As in previous years, Grant PUD continues to participate in regional research and forums in the Columbia Basin to promote coordination and information exchange.

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1.0 Introduction

1.1 General Description of the Priest Rapids Hydroelectric Project

Public Utility District No. 2 of Grant County, Washington (Grant PUD) owns and operates two hydroelectric dams on the Columbia River in the State of Washington; Wanapum and Priest Rapids, known collectively as the Priest Rapids Project (Project), and operated under the terms and conditions of the Federal Energy Regulatory Commission (FERC) Hydroelectric Project License No. 2114.

Wanapum Dam is located at river mile (RM) 415, south of the I-90 bridge at Vantage, Washington; approximately 38 miles downstream of the Rock Island Hydroelectric Project owned and operated by Public Utility District No. 1 of Chelan County, Washington (Chelan PUD) and 18 miles upstream of Priest Rapids Dam. The dam is 8,637 feet long and 186.5 feet high and includes a left and right bank fish passage structure, each with an upstream fish ladder. Wanapum includes ten turbine units with a nameplate capacity of 1,038 megawatts (MW) and a spillway with 12 bays. In April 2008, Grant PUD finished construction of the Wanapum Future Unit Fish Bypass (WFUFB) in the vacant slot of future turbine unit 11 to aid in downstream migration of salmonids. The Wanapum Reservoir is approximately 38 miles long and has a surface area of approximately 14,680 acres. Active storage volume of the Wanapum Reservoir is 160,400 acre-feet and total storage is 693,600 acre-feet. Seven perennial streams (Douglas, Tarpiscan, Johnson, Skookumchuck, Whiskey Dick, Quilomene, Trinidad, and Sand Hollow Wasteway) enter into the Wanapum Reservoir.

Priest Rapids Dam is located at RM 397; approximately 18 miles downstream of Wanapum Dam and the last dam on the Mid-Columbia River before it enters the Hanford Reach. The nearest town is Desert Aire, Washington, which is located approximately two miles upstream on the east-bank from Priest Rapids Dam. The Priest Rapids facility is 10,103 feet long and 179.5 feet high and includes ten turbine units with a generating capacity of 855.0 MW and a spillway with 22 bays. The Priest Rapids Reservoir is approximately 18 miles long and has a surface area of approximately 7,725 acres. Active storage volume of the Priest Rapids Reservoir is 48,600 acre-feet and total storage is 237,100 acre-feet. Two perennial streams (Crab and Hanson) drain into the Priest Rapids Reservoir.

1.2 History of Pacific Lamprey related to Activities at the Priest Rapids Hydroelectric Project

For more than a decade, Grant PUD has actively participated in the research of, protection, and mitigation for Pacific lamprey related to the Columbia River hydro system and the Project area. The development of Grant PUD’s Pacific Lamprey Management Plan (PLMP) has been a formalization of recent research and implementation measures required in the Project’s License Order as issued by the FERC on April 17, 2008 (FERC 2008), but is largely a continuation of prior activities. Grant PUD was the first mid-Columbia River utility to assess the passage of lamprey in and through its Project area (Nass et al. 2003) and to identify potential actions and modifications to improve successful passage (Final License Application, Grant PUD 2003) without compromising adult salmonid passage. Results of the 2001-2002 lamprey telemetry studies in the Project area formed the basis of proposed modifications which are being conducted as part of implementation of the PLMP. These past studies and measures are partly the result of participation at the regional level and cooperating with tribes, agencies, and other hydroelectric operators to address resource challenges and their potential solutions. In particular, Grant PUD's past and present participation in the Columbia River Basin Lamprey Technical Work Group (CRBLTWG) has made them an integral part of the regional research foundation. As a founding participant, Grant PUD assisted in the development of the "Critical Needs and Uncertainties" document and provided information to support the Tribal Recovery Plan (Nez Perce Umatilla, Yakama, and Warm Springs Tribes 2011). More recently, Grant PUD has and continues to participate in and provide support to the U.S. Fish and Wildlife Service (USFWS) Lamprey Conservation Initiative, the Yakama Nation Lamprey Recovery Planning efforts, and the Columbia River Inter-Tribal Fish Commission's (CRITFC) Tribal Restoration Plan.

Past activities and future measures implemented by Grant PUD to mitigate for Project impacts to Pacific lamprey are extensive and on-going. Many of the actions and measures recommended by tribal and agency lamprey experts to address hydroelectric project impacts on lamprey are, in general, a result of actions or fish ladder modifications that are currently or were previously implemented by Grant PUD. These include fish counting facilities that operate 24 hours a day, 7 days a week for the upstream migration period; during fishway dewatering procedures, implementation of fish collection protocols by qualified biologists to ensure safe recovery of all fish species present (Grant PUD 2010); and juvenile lamprey protection as a result of Grant PUD's avian predation and Northern pikeminnow control programs that have been proven to be effective at minimizing impacts to juvenile salmonid outmigrants.

Physical fish ladder and dam modifications include the use of "slotted" (hour-glass style) fishway entrances that provide differential velocity elevations with a range of high and low velocity corridors to suit different species, improved 24-hour video fish counting stations to collect reliable and accurate count data, and downstream migrant bypass systems to meet juvenile salmonid survival criteria. Grant PUD believes measures developed to reduce impacts to juvenile salmonids will benefit juvenile Pacific lamprey as well. The slotted entrances were installed prior to the 2001-2002 lamprey study and have provided effective fishway entrance efficiency. In recent years, the Army Corps of Engineers (ACOE) have experimented with similar entrances at lower Columbia River dams (D. Clugston, ACOE, personal communication). The fish counting stations have undergone several staged modifications starting with the conversion from count board stations (visual) to dual orifice video stations, and in 2010, conversion to engineered crowders which utilize a single orifice video station and picket leads with 11/16 - inch gap spacing to accurately enumerate all adult lamprey. Significant improvements for downstream passage have been achieved by development of the WFUFB and the Priest Rapids top-spill bulkhead for juvenile salmon which presumably provides a high survival alternative passage route for juvenile lamprey.

Grant PUD's continued efforts have contributed to the state-of-the-science for Pacific lamprey including: participation in regional forums and conferences; conducting telemetric passage evaluations and literature research; evaluating turbine intake emergency wheelgate slot exclusion screens; providing upstream and downstream fish passage facilities; support for full-duplex (salmon) and half-duplex (HDX; lamprey) passive integrated transponder (PIT) detection systems for project-specific and basin-wide assessments; trapping and hauling lamprey; and providing educational opportunities for the public to understand the ecological and tribal importance of lamprey in the Columbia River Basin.

As referenced in the FERC Order (Order Modifying and Approving Pacific Lamprey Management Plan, Article 401(a)(12) and Water Quality Certificate Condition 6.2(5)(b)), 127

FERC ¶ 62, 091, Grant PUD is required to develop, in consultation with the Priest Rapids Fish Forum (PRFF), and implement a comprehensive evaluation of adult lamprey passage at the Project. As outlined in its PLMP, Grant PUD implemented measures to improve lamprey passage in 2010. These efforts include conducting inspections of the Project passage facilities by the PRFF members, and the installation of passage-enhancing structures in the fishways at Priest Rapids and Wanapum dams. New structures included diffusion grate aluminum plating, ramps ascending perched orifices, and lamprey-friendly video fish count crowders; all specifically designed to facilitate lamprey passage. To facilitate tagging and fish husbandry research, Grant PUD expanded its fish handling facilities at Priest Rapids Dam by building innovative adult lamprey trapping and holding facilities for the most efficient and non-invasive processing of study fish. Following the installation of these structures, Grant PUD, in consultation with the PRFF, conducted a study of the effectiveness of these modifications during the summers of 2010 to 2012. The extensive HDX-PIT array at Priest Rapids and Wanapum dams was operated to monitor the passage of lamprey originating from tagging activities conducted at dams downstream of Priest Rapids Dam. A total of 20 HDX-PIT arrays were operated each migration season from 2010-2014 to track lamprey through the Project area. All arrays were operational May through December in 2010 through 2012 and from March through December in 2013 and 2014. Further, yearly winter fishway maintenance operations recover adult lamprey during NOAA approved dewatering procedures. These lamprey are scanned for the presence of a PIT tag and released into the forebay of the respective dams. Comprehensive results of this long-term monitoring program are presented in Section 2.1.4 below.

During the winter of 2014-2015 the HDX-PIT arrays at Priest Rapids and Wanapum dams were modified to refine detection resolution in the upper Priest Rapids left bank fishway for the purpose of determining whether a pattern of slower passage through that section in 2010-2013 continued to occur in 2015. Toward this goal, two new stations were installed in the vicinity of the Off Ladder Adult Fish Trap (OLAFT), and one station in each of the lower fishways was removed, reducing the total number of stations to 18. During the peak adult Pacific lamprey migration period in July and August 2015, 133 lamprey were captured with mechanical traps in the lower Priest Rapids Dam fishways and implanted with HDX-PIT tags. The tagged fish were released in the lower Priest Rapids left bank fishway to assess passage through the upper fishway. And additional 150 lamprey implanted with HDX-PIT tags were released in 2016 to continue this assessment. Results of this fishway passage behavior assessment are presented in Section 2.1.4 below.

In addition to the HDX and FDX PIT tagging and monitoring in 2016, 100 adult lamprey were captured and implanted with both active acoustic tags (Vemco V7) and full-duplex PIT (FDX-PIT) tags and released into Priest Rapids (n=30) or Wanapum (n=70) reservoirs for an experimental study (i.e., not required by the PLMP) to assess dam and reservoir passage behavior (Appendix A). Acoustic receivers deployed at fixed locations throughout the Project area were used to monitor the migration behavior of tagged individuals. Additionally, mobile tracking was used to locate tagged individuals in the study area. The objectives of the study were to estimate the proportion of tagged lamprey that 1) migrate upstream out of the Project area to the tailrace of Rock Island Dam, 2) overwinter in the study area and resume migration in spring 2017, 3) experience pre-spawn or predation mortality in the study area, 4) may engage in undetected spawning in reservoir tributaries, and 5) may engage in spawning in the tailrace of Wanapum and/or Rock Island dams. Initial results are presented in Section 2.1.4 below.

In June 2012, monitoring of juvenile lamprey was initiated to assess their presence/absence, habitat use, and relative abundance in areas affected by Project operations. In the Wanapum Reservoir, 36 potential shoreline habit locations were sampled. In the Priest Rapids Reservoir, 12 potential shoreline habitat locations were sampled. One juvenile lamprey was captured in the Priest Rapids Reservoir and another was observed, but not captured, in the Wanapum Reservoir. On November 13-16 and December 11-14, 2012, a field crew continued efforts to assess presence/absence, habitat use, and relative abundance of juvenile Pacific lamprey in areas that may be affected by Project operations. Twenty-seven and 21 shoreline habit locations were sampled in the Wanapum and Priest Rapids reservoirs, respectively. Sampling was conducted at mid-range pool elevations of the FERC-allowed operational range; approximately 570.0 feet (ft) above mean sea level (msl) at the Wanapum Forebay and between 485.3-487.5 ft above msl at the Priest Rapids Forebay. No juvenile lamprey were collected. Additional sampling was completed on May 11 and 12, 2013. Ten potential shoreline habitat locations in the Wanapum Reservoir were sampled resulting in the collection of no juvenile lamprey sampled. The pool elevation at the Wanapum forebay was 569.0 above msl during this sampling event. On October 11 and 12, 2013, a final sampling of eight potential shoreline habit locations in the Priest Rapids Reservoir collected seven juvenile lamprey. An additional 10 lamprey were observed but not captured. The elevation of the Priest Rapids Forebay was 480.2 ft above msl during this effort (near allowable minimum reservoir elevation per the FERC license). On March 4 – 7 and 13-14, 2014 a field crew assessed presence/absence of juvenile Pacific lamprey in areas affected by the abnormal drawdown. Generally, sampling was difficult and at times not feasible due to deep mud exposed by low pool elevation (543.3-544.0 ft above msl at the Wanapum forebay). Three juvenile lamprey were captured and another was observed during sampling on March 4 in the vicinity of Sunland Estates (RM 431). Small numbers of dead juvenile Pacific lamprey were observed in the vicinity of Walling Canyon (RM 449), Crescent Bar (RM 441), and Sunland Estates. Given three years of sampling at varying reservoir elevations (2012-2014) have indicated that juvenile lamprey do not commonly occur within the Project operational zone. A report addressing results from 2012-2013 is included as Appendix B.

During the 2014 migration season, an Interim Fish Passage Operations Plan (IFPOP) was developed by Grant PUD in consultation with PRFF members as a result of the Wanapum spillway fracture. The IFPOP included the installation of Fishway Passage Exit Systems (i.e., weir boxes with lamprey ramps) in each Wanapum fish ladder (Priest Rapids Dam fish ladders were unaffected). The effectiveness of these exit systems was also evaluated (see Section 2.1.4). In addition to facilitating volitional passage, Grant PUD trapped and transported lamprey (n=2,263) collected from Priest Rapids and Wanapum dam fish ladders during the peak of the upstream adult lamprey migration. Captured fish were released to various locations within and upstream of the Project area. Already tagged fish were released immediately upstream of the dam where they were trapped. Untagged fish were released above Rock Island Dam.

Concurrent to evaluation and discussion of fish passage efficiency, Grant PUD and the PRFF (in addition to other regional forums) have engaged in numerous discussions during 2016 regarding the appropriate fish passage efficiency related to NNI (No Net Impact – Grant PUD PLMP, Section 4.1) for Pacific lamprey at Priest Rapids and Wanapum dams. The tribes recommend establishment of an adult dam passage standard of 80% by 2020 (Moser et. al., 2002a; CRITFC 2011). In 2007, a subgroup of the CBFWA (Columbia Basin Fish and Wildlife Authority) Lamprey Technical Working Group was tasked with developing basin-wide adult lamprey passage standards and objectives for measurable and biologically relevant metrics (CRBLTWG

2007). This group had made significant progress on two phases to establish regional passage standards: identifying potential research metrics and determining which metrics were measurable with scientific rigor (CRBLTWG 2010). These include passage efficiency into fishways, passage effectiveness through fishways, passage timing, fallback and fallout through floating powerhouse orifices. A significant proportion of the overall objective remains incomplete and has been complicated by limited passage information at specific facilities, varying data collection methods, and an incomplete understanding of lamprey life history. Despite these limitations, the passage metric subgroup continues to meet regularly to further develop passage metrics and standards for Pacific lamprey. The PRFF discussions have represented a substantial amount of time by all parties in 2016. Although an agreement has not been reached, it is anticipated that discussions will continue in 2017.

Grant PUD continues to be active with respect to investigations related to Pacific lamprey passage research through its historical activities and proactive implementation of research and mitigation measures included in the PLMP. Grant PUD is committed to continue into the future in a similar manner. This report illustrates the continued allocation of effort and resources to achieve the goals and objectives of the PLMP.

1.3 Purpose of the Report

Grant PUD is required to submit the PLMP Comprehensive Annual Report (PLMP Comprehensive Annual Report) in accordance with the Project's License Order, issued by the FERC on April 17, 2008 (FERC 2008), and the 401 Water Quality Certification (WQC), issued by the Washington Department of Ecology (WDOE) on April 3, 2007 and amended March 6, 2008 (WDOE 2007; FERC 2008), which states:

> *License Order:* *The licensee shall file annually with the Commission by March 31, beginning 2010, their Annual Pacific Lamprey Management Report. The report shall include the reporting requirements identified under implementation measure 1 of the Biological Objectives and Implementation Measures under Appendix C of the Washington State Department of Ecology 401 Water Quality Certification. Additionally, the licensee's report shall include an updated implementation schedule and identify any variations from the schedule provided in the licensee's filed plan. The licensee shall prepare their report in consultation with the Priest Rapids Fish Forum and allow the Priest Rapids Fish Forum 30 days to review and comment on the report prior to filing with the Commission. The licensee's report shall include any resource agency and Tribe comments and the licensee's response to any comments. The Commission reserves the right to require changes to their plan based upon review of the report.*

> *401 Water Quality Certification, Appendix C:* *By March 31 following issuance of the New License, and each year thereafter for the term of the New License, [Grant PUD shall] provide an annual report summarizing activities undertaken to identify and address impacts of the Priest Rapids Project on Pacific lamprey, including results of those activities. This report shall include a compilation of information on other Pacific lamprey passage and survival investigations and measures being undertaken in the Columbia River Basin in order to determine if adult and juvenile measures being investigated and/or implemented at the Priest Rapids Project are: (i) consistent with similar measures taken at other projects;*

(ii) appropriate to implement at the Priest Rapids Project; and (iii) cost effective to implement at the Priest Rapids Project.

To fulfill the requirements, the report is structured as follows:

- Section 2.1: Background and existing information (i.e., through October 31, 2016) about Pacific lamprey passage and survival investigations and measures undertaken in the Columbia River Basin.
- Section 2.2: Information from the reporting year (i.e., November 1, 2015 through October 31, 2016) about passage and survival investigations and measures being undertaken throughout the Columbia River Basin.
- Section 3.0: Status report on Pacific lamprey activities underway at the Project, including identification of any variations from the schedule provided in the PLMP (Grant PUD 2009).
- Section 4.0: An evaluation of whether recent activities in the Columbia River Basin should be considered for the Project.
- Section 5.0: A summary of preliminary conclusions regarding Pacific lamprey activities to date, anticipated activities in the Columbia River Basin, and future activities at the Project for the upcoming year.

1.4 Consultation

Pursuant to the reporting requirements, Grant PUD provided a complete draft of the PLMP Comprehensive Annual Report to the PRFF on January 24, 2017. Written comments were received from WDFW on February 27, 2017 and WDOE on March 14, 2017. A summary of comments by the PRFF as received by Grant PUD on the draft PLMP Comprehensive Annual Report have been compiled along with responses from Grant PUD (Appendix C). The summary is based on written comments (Appendix D).

2.0 Pacific Lamprey Activities in the Columbia River Basin

2.1 Background and Existing Information

Pacific lamprey (*Entosphenus tridentatus*) are indigenous to many of the tributaries of the Columbia (Jackson et al. 1997a, Jackson et al. 1997b) and Snake rivers (Close et al. 1995). Wydoski and Whitney (1979) reported that the Pacific lamprey are one of three species of lamprey in the Columbia River Basin where river lamprey (*Lampetra ayresi*) and western brook lamprey (*Lampetra richardsoni*) have been known to exist. Western brook lamprey and river lamprey distributions overlap with the more common Pacific lamprey but populations are concentrated to coastal tributaries and the lower reaches of the Columbia River (Kostow 2002).

The Pacific lamprey is an important fish of cultural, utilitarian, and ecological significance (Close et al. 2002). Close et al. (1995) reported that Native American tribes of the Pacific Coast and interior Columbia Basin harvested Pacific lamprey for subsistence, ceremonial, and medicinal purposes. In addition, a commercial fishery for Pacific lamprey also occurred during the 1940s and was used as food for livestock and cultured fish. Pacific lamprey are important ecologically throughout their life in terms of nutrient cycling, both as predator and prey. As juveniles, lampreys are filter feeders of detritus and algae, and a food source for fish and birds (Close et al 2002). In the past when they were more numerous, downstream migrants were likely an important food source to fish and birds and may have provided a buffer for juvenile salmon migrants. As adults, lamprey are opportunistic feeders and prey on a variety of fish species, thereby minimizing their impact on any particular one species. Adult Pacific lamprey are also a prey item to marine mammals such as sea lions and likely attract predation away from adult salmon (Close et al. 2002). Pacific lamprey carcasses are a food source to sturgeon, and decomposition provides marine-derived nutrients to riverine systems.

Adult lamprey counts have decreased at Columbia River Basin dams as compared with historical estimates, with the greatest declines occurring at the upper Columbia and Snake River projects. Passage counts of adult and juvenile lamprey at Bonneville, the Dalles, John Day, McNary, Ice Harbor, Rock Island, Rocky Reach, and Wells dams indicate a general decreasing trend; large declines occurred in the late 1960s and early 1970s (BioAnalysts 2000).

Based on the decreasing trend of adult Pacific lamprey, conservation groups filed a lawsuit against the USFWS in May 2004 to compel USFWS to act on their January 27, 2003 petition to list four species of lamprey for protection under the Endangered Species Act (ESA), including Pacific lamprey. On October 1, 2004, the USFWS initiated its 90-day finding process as part of a settlement with the conservation groups. On December 22, 2004, the USFWS announced that a petition to list four species of lamprey did not contain sufficient information to warrant further review at that time.

Although Pacific lamprey are currently not ESA-listed, increased regional activity in the Columbia River Basin aimed at developing coordinated conservation and recovery strategies are proceeding. In addition to the ongoing efforts of the CRBLTWG and implementation activities associated with operations of FERC licensed and federal hydroelectric facilities (e.g., ACOE, Grant PUD, Chelan PUD, Douglas PUD, and Portland General Electric [PGE]), the USFWS-led Pacific Lamprey Conservation Initiative, continued its activities by developing a multistate, tribal and Federal Conservation Agreement that will serve as the basis for regional working groups tasked with the development and implementation of conservation actions (USFWS 2012). These initiative activities and recommendations are not regulatory requirements.

2.1.1 General Biology and Ecology

Elongate and snake-like in form, the Pacific lamprey is a relatively poor swimmer in high velocity areas due to its anguilliform swimming motion as contrasted with the more efficient subcarangiform motion used by salmonids (Weihs 1982 as cited in Mesa et al. 2001). The lamprey does not have rigid fins, but rather dorsal and ventral fin-folds with minor cartilaginous ray-like supports. In addition, it lacks a swim bladder and must continue swimming (or attach to substrate), or it will sink.

Pacific lamprey are cartilaginous, jawless, anadromous fish that develop morphologically and physiologically in three primary stages. First, Pacific lamprey begin as larvae that hatch after approximately 19 days at 15°C (Close et al. 2002). After hatching, larvae drift freely downstream until encountering suitable substrate (silt and sand) and flow conditions (low velocities) for a sedentary lifestyle (Pletcher 1963 as cited in Close et al. 2002). Ammocoetes reside burrowed in fine sediment (Close et al. 2002) for a period of 4 to 6 years filter feeding on diatoms, algae, and detritus by pumping water through their branchial chamber (Beamish and Levings 1991). Beamish and Levings (1991) observed peak downstream movement of ammocoetes during May and June (Table 1) and determined ages to range from two to six years (using statolith analysis;

Volk 1986 as cited in Beamish and Levings 1991). In general, downstream movement of juvenile lamprey have been observed to coincide with high flow events.

Table 1 Annual timing of key biological events in the freshwater life history of Pacific lamprey.

Annual Timing of Key Biological Events in the Freshwater Life History of Pacific Lamprey

Event	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Ammocoete downstream migration[1]	Unk	░	░	░	■	■	░	░	░	░	░	Unk
Young adult downstream migration[1]	Unk	░	░	■	■	░			░	░	░	Unk
Metamorphosis / Transition[2]						░	░	░	░			
Parasitic feeding initiated[2]									░	░	░	
Entry into saltwater[2]	░	░	░	░	░	░					░	░

[1] Beamish and Levings (2001)
[2] Beamish (1980)
Peak period = dark shade ■

Pacific lamprey then enter a transformation phase characterized by morphological and physiological changes that begin in the latter period of substrate residence. The young adult stage continues during stream residence and into the period of downstream migration from their parent streams to the ocean. The causal mechanisms which initiate the transformation process, trigger emergence from the substrate, and result in migratory behavior are unknown or undocumented. Young adult lamprey are also termed macrophthalmia following major morphological changes, but prior to parasitic feeding (Hardisty and Potter 1971 as cited in Beamish 1980). Pacific lamprey transform from ammocoetes to macrophthalmia from July to November (Hammond 1979 and Close et al. 2002). During transformation, the shape and angle of the head and mouth changes, and the gut develops to allow consumption of flesh and fluids (Hart 1973). The onset of transformation occurs over a relatively large range in lengths. Beamish (1980) observed characteristics associated with metamorphosis in lamprey ranging from 47 millimeters (mm) to 160 mm in length. As such, there is overlap in the length distribution of larval ammocoetes and macrophthalmia. Macrophthalmia migrate to the ocean between late fall and spring (Table 1).

Beamish and Levings (1991) determined age distributions for macrophthalmia to be 4 to 8 years using statolith analysis (Volk 1986 as cited in Beamish and Levings 1991). Metamorphosing lamprey moved into progressively more rocky and higher flow environments over time (Richards 1980 as cited in Beamish 1980), which may be related to their specific stage of transition. Concurrent downstream migrations of several different lamprey life-stages (including ammocoetes and young adults of many different stages of metamorphosis) has been observed, providing evidence of natural variation in the timing and developmental stage of migrating lamprey (Beamish and Levings 1991).

Juvenile Pacific lamprey have been found to be largely nocturnal, with > 90% of their swimming activity restricted to hours of darkness (Moursund et al. 2000). This is consistent with prior reports that outmigrating individuals were more active at night while settling onto or into the substrate during the day (Hardisty and Potter 1971 as cited in Moursund et al. 2000; Beamish and Levings 1991). However, strict diel movement patterns appear to be restricted to the upper watershed areas, whereas the migration appears more or less continuous (night and day) in the lower parts of the river (Beamish and Levings 1991).

In the mid-Columbia River area, including the Project, juvenile lamprey are collected incidentally during juvenile salmon collection or salvage activities from April through June. At Priest Rapids and Wanapum dams, juvenile lamprey have also been observed during an evaluation of the emergency wheelgate slot exclusion screens (Wright et al. 2010). These results suggested that downstream run timing of juvenile lamprey coincides with spring runoff upstream of the Priest Rapids Project and throughout the Columbia River Basin and supports historical run timing trends of juvenile lamprey (Wright et al. 2010). Juvenile lamprey are also infrequently collected during the fish bypass operation of gatewell dipping (Grant PUD, unpublished data). A portion of these fish are counted and measured for length during juvenile salmonid survival and behavioral evaluations. All fish are subsequently released downstream of the Project. In some years, lamprey have been counted, but not identified beyond the genus level of classification (there are three species of lamprey in the Columbia River). In a separate operation, fyke net sampling at Wells Dam caught lamprey during the period March through August, with the highest catches occurring in May and June (BioAnalysts 2000). It is likely that these lamprey are Pacific lamprey since this is the only species currently known to be distributed upstream of the Yakima River confluence.

Lamprey are considered adults once all transformations are complete and parasitic feeding begins; a process that is likely completed in salt water (Richards and Beamish 1981 as cited in Beamish and Levings 1991). In addition, laboratory research by Beamish (1980) surmised that completely transformed lamprey (i.e., adults) must move into a saline environment within a relatively short period of time, or they will die. Specifically young adults completing the transition to adulthood between June and September need to be in salt water by January. Physiological experiments showed that Pacific lamprey in the Fraser River begin entering saltwater in December and continue through June (Beamish 1980). As an adult (100-700 mm), the animal is fully developed to handle life in salt water, which ranges from 1.5 to 3.5 years (Kan 1975 and Beamish 1980 as cited in Close et al. 2002). In the ocean, Pacific lamprey adults feed as external parasites on marine fish and mammals before returning to freshwater to spawn (Beamish 1980 and Close et al. 2002). Information on Pacific lamprey migration patterns during ocean residency remains a significant data gap for researchers and managers although recent work has been published on the relationship between the abundance of Pacific lamprey in the Columbia River and their common hosts in the marine environment (Murauskas et al. 2013).

Little is known about the ecology of Pacific lamprey in estuarine systems. Weitkamp et al. (2015) conducted the first analysis of Pacific lamprey in the Columbia River estuary, using data from two fish assemblage studies spanning three decades (1980-19801 and 2001-2012) and concluded that juveniles and adults in the estuary clearly were separated by size. Pacific lamprey juveniles and adults were present in the estuary in winter and spring and depth in the water column also differed by lamprey species and age class. During 2008–2012, the study team documented wounds from lampreys on 8 fish species caught in the estuary. The most frequently wounded fishes were non-native American shad (*Alosa sapidissima*), subyearling Chinook salmon (*Oncorhynchus tshawytscha*), shiner perch (*Cymatogaster aggregata*), and Pacific herring (*Clupea pallasii*).

Given the basic understanding of the species biology and ecology (in freshwater), recent work on Pacific lamprey has generally focused on topics such as developing more resolute site-specific information on the distribution and abundance of lamprey "populations", and lamprey physiology. However, in addition to site specific distribution and abundance activities, lamprey biologists and researchers have begun to collect the information and develop the necessary tools to address factors that may limit species persistence and recovery. Throughout the Columbia River Basin, various activities are being implemented. Monitoring activities associated with documenting key habitat related to spawning, rearing, and overwintering are being conducted annually in the Deschutes, Hood, Willamette, and Umatilla rivers. In the Yakima and Umatilla watersheds, tracking adult movement patterns (via radiotelemetry) to overwintering and spawning areas and identifying passage bottlenecks is occurring. In-river and irrigation canal juvenile lamprey distribution and abundance sampling is also occurring in the Yakima basin. Juvenile distribution and abundance sampling, habitat, and/or larval trend and larval occupancy monitoring/sampling is occurring in the White Salmon, Wind, Washougal, Kalama, Wenatchee, Chelan, Okanogan, Klickitat, Entiat, Willamette, and Methow watersheds. On the Chewuch River (Methow watershed), larval trend monitoring associated with salmon-based restoration actions is currently ongoing. Surveys to assess juvenile distribution and relative abundance have also been conducted in several of the mid- and lower Columbia River reservoirs in addition to larval lamprey assessments using deep water sampling methodologies at Bureau of Reclamation (BOR) facilities in the Yakima basin. Past and current activities on the general biology and ecology of Pacific lamprey includes monitoring adult harvest and escapement at Willamette Falls; translocation activities in the Willamette, Umatilla, Yakima, Wenatchee, and Methow watersheds as well as tracking movements of translocated adults using radiotelemetry (Yakima and Umatilla); the development of a larval lamprey identification guide; evaluating re-introduction above Pelton Round Butte Dam; assessing mercury concentrations in Lower Columbia River fine sediment and of adult Pacific lamprey broodstock at the Prosser Holding Facility; continued development of artificial propagation techniques; testing larval lamprey movements and effects on survival in response to dewatering events; DNA sampling and further validation and refinement of the methods for lamprey; and the development of a simple genetic assay to distinguish Pacific lamprey from other lamprey species (see Section 2.2: Updated Information for additional details).

2.1.2 Migration in Rivers

The upstream migration of adult Pacific lamprey in the Project area (RM 397-453) typically occurs from May through November, with peak migration occurring in August (Nass et al. 2003). In the lower Columbia River (Bonneville Dam, RM 146), this timing is shifted earlier by approximately one month (Ocker et al. 2001). Similarly, peak migration past dams upstream of Priest Rapids occur two to four weeks later. As expected, numbers of lamprey observed at successive dams decreases as fish enter tributaries or cease migration to overwinter, however the inherent challenges of counting lamprey is apparent in the years when counts at upstream facilities are higher than downstream facilities. Timing of freshwater entry is closely tied to water temperatures and somewhat with discharge. Keefer et al. (2009a) reported that few lamprey pass Bonneville Dam before water temperatures reach 15°C and half the run, on average, pass by the time water temperatures reach 19°C.

Median upstream migration rates have been estimated at 10 RM/day and 13.7 RM/day on the Columbia River (Jackson et al. 1997b and Vella et al. 2001, respectively), and 6.8 RM/day on the John Day River (Bayer et al. 2001). HDX-PIT tagged lamprey migrated at rates of 7.7 RM/day to 8.5 RM/day between Bonneville and McNary dams (~146 miles). As with timing, migration rates were correlated with water temperatures and inversely related to discharge (Keefer et al. 2009b). At Priest Rapids and Wanapum reservoirs, median upstream migration rates were 3.0 RM/day and 6.8 RM/day, respectively (Nass et al. 2003). Pacific lamprey that are migrating upstream are likely heading to holding and/or spawning areas to overwinter. In general, upstream migration has been documented to cease in mid-September (Beamish 1980 as cited in Close et al. 2002), and resume in mid-March of the following spring if the final spawning destination has not been reached (Bayer et al. 2001). Note however that migration periods may vary by region (e.g., Columbia River, coastal, etc.).

In general, spawning occurs from spring to summer (March to July) following the upstream migration year (Beamish 1980 as cited in Close et al. 2002; Ralph Lampman, Yakama Nation, personal communication). Lamprey prefer low-gradient reaches, with gravel-pebble-sand substrate for spawning (Mattson 1949 and Kan 1975 as cited in Close 1995). Further, spawning typically occurs in lotic habitat with velocities ranging from 3 to 4 feet per second (ft/sec) and in depths ranging from 1 to 3.3 feet (Kan 1975). Both sexes begin moving rocks with their buccal funnel to create nests in excavated depressions (Pletcher 1963). Courting consists of a male approaching a female with a gliding motion to stimulate the female. A male attaches his buccal funnel to a female's head, and then wraps his body around the female to provide mixing of simultaneously released gametes. Each spawning act releases approximately 100 to 500 eggs (Pletcher 1963). Nest dimensions are approximately 12 inches wide, 1 to 2 inches deep, and oval in shape. Pacific lamprey die after spawning (Hart 1973) within 3 to 36 days (Kan 1975).

Pacific lamprey do not appear to have natal homing tendencies (return to a place of origin), but will migrate to other locations (Hatch et al. 2001). Distribution is more uncertain in the mid-Columbia area above Priest Rapids Dam compared to the lower Columbia, but since 1958 the furthest upstream extent on the Columbia River has been Chief Joseph Dam where there are no fish passage facilities.

Recent work on adult lamprey migration in rivers has used active tag technology including radio-telemetry and juvenile salmon acoustic telemetry system (JSAT) tags. These studies have occurred or are occurring in reservoirs of the ACOE projects in the Lower Columbia and Snake rivers and in the Willamette River. In the mid-Columbia, an acoustic telemetry study was implemented in 2016 to evaluate a key assumption of hydroelectric project passage assessments which is that tagged fish (translocated from downstream) will exhibit upstream migratory behavior and are motivated to approach and attempt to pass a dam (in this case, Wells Dam). In past years, assessments have been dependent upon study fish from downstream due to extremely low returns to Wells Dam and previous studies have shown that half or less of tagged, translocated lamprey released downstream of the dam interact with the dam. Additional large-scale monitoring programs have also utilized half duplex (HDX) passive integrated transponder (PIT) tags in combination with multi-entity coordination to take advantage of the individual monitoring programs occurring throughout the mainstem Columbia River. More recently, FDX-PIT tags have also been used in passage and migration assessments for adults; specifically at the Priest Rapids Project in 2015 (see Section 2.2: Updated Information for additional details).

Information regarding juvenile migration in rivers is relatively limited. Much of the information available has been collected anecdotally during tributary operations targeting juvenile salmonid outmigrants and is consistent with previous information regarding timing and the environmental variables associated with such movements. Juvenile lamprey have been observed using dual frequency identification sonar (DIDSON) during an evaluation of the emergency wheelgate slot exclusion screens at Priest Rapids and Wanapum dams (Wright et. al. 2010). These results suggested that downstream run timing of juvenile lamprey coincides with spring runoff upstream of the Priest Rapids Project and throughout the Columbia Basin and supports historical run timing trends of juvenile lamprey (Wright et. al. 2010).

Over the past decade the lack of available tag technology has limited researchers and fish managers' ability to collect more detailed information to better understand and address challenges of juvenile lamprey movement. BioAnalysts (2000) summarized anecdotal information on the distribution of juvenile lamprey in tributaries of the mid-Columbia, which include the Wenatchee, Entiat, Chelan, and Methow rivers. Recent evidence indicates the presence of lamprey in the Similkameen River, a tributary of the Okanogan River (T. Holder, Washington Department of Fish and Wildlife, personal communication) previously thought unused by Pacific lamprey. Further, juvenile Pacific lamprey have been captured in rotary trapping operations on the Okanogan River near Malott (M. Rayton, Colville Tribes Fish & Wildlife, personal communication). Juvenile lamprey outmigration monitoring via rotary screw trapping is also occurring at RM 2.5 of the Umatilla River from November to May to support translocation activities. Regional entities such as the Fish Passage Center have evaluated available juvenile lamprey PIT tag data in the Columbia River Basin toward improving understanding of this life stage and regularly collect data of lamprey incidentally collected at juvenile salmonid collection/bypass facilities at mainstem dams. A recent juvenile lamprey data synthesis (Mesa et al. 2015) summarized data and research related to the presence, numbers and migration timing characteristics of juvenile (eyed macropthalmia) and larval (ammocoetes) Pacific lamprey Entosphenus tridentatus, in the Columbia River basin. Included were data from various screw trap collections, data from historic fyke net studies, catch records of lampreys at JBS facilities, turbine cooling water strainer collections, and information on the occurrence of lampreys in the diets of avian and piscine predators. Key data gaps and uncertainties that should be addressed in a juvenile lamprey passage research program were identified. The goal of the work was to summarize information from disparate sources so that managers can use it to prioritize and guide future research and monitoring efforts related to the downstream migration of juvenile Pacific lamprey within the Columbia River basin.

Given the high number of irrigation diversions in the Columbia River Basin and the recognition that poorly designed or unscreened diversions can result in fish mortality, researchers continue to evaluate the efficacy of different irrigation diversion screen panels and the effectiveness of fish screen materials to prevent juvenile lamprey impingement and entrainment at these locations. Furthermore, to begin understanding the potential impacts of irrigation diversions on juvenile lamprey, researchers have begun conducting surveys in irrigation canals in the Yakima and Wenatchee watersheds (see Section 2.2: Updated Information for additional details).

2.1.3 Population Status

2.1.3.1 Distribution

Pacific lamprey are native to the Columbia River Basin and their spawning migration extends into many inland rivers draining Oregon, Washington and Idaho (Kan 1975; Hammond 1979; and Simpson and Wallace 1982). Collections and historic observations of Pacific lamprey are common in the Columbia River below the mouth of the Deschutes River. Areas include numerous small tributaries such as Fifteenmile Creek, Gnat Creek, Elochoman River, and larger tributaries such as the Lewis, Willamette, and Klickitat rivers. Lamprey probably used all accessible watersheds in the Lower Columbia, including mainstem and slough habitats. A comparison of counts at Bonneville Dam to harvest at Willamette Falls during the 1940s indicates that Pacific lamprey were probably more abundant in the Willamette subbasin at that time than they were anywhere upriver of the Columbia River Gorge (Kostow 2002).

Watersheds upstream of the Columbia River Gorge, specifically noted in historic collections and observations, include the Deschutes extending into the Crooked River above Pelton/Round Butte Dam, John Day, Umatilla, Walla Walla, Yakima, Entiat, Okanogan and Kootenay Lake. In the Snake River Basin, collections and historic observations have been made in the lower Palouse, Clearwater, Salmon, Grand Ronde, Imnaha, and upstream to at least the Powder River. Historic records are too sparse to determine the full extent of historic occupation of these basins; however recent work has focused on collecting more current distribution information and a report documenting the current status of Pacific lamprey in some of these river basins was published in 2011 (IDFG 2011). A study conducted by Idaho Fish and Game from 2000 to 2006 determined that Pacific lamprey currently occupy only about 25% of their historic distribution in the Snake River Basin (Hyatt et al. 2006). In the upper Columbia River Basin, distribution information is being collected in the Wenatchee, Entiat, Chelan, Okanogan and Methow rivers while past adult translocation activities by the Nez Perce Tribe indicated that juvenile lamprey in Asotin, Lolo, Newsome and Orofino creeks in the Snake River were primarily the progeny of translocated adults (Chris Peery, USFWS, personal communication).

The current distribution of Pacific lamprey is substantially reduced from the historic distribution. Lamprey have been lost from all areas that are blocked by impassible barriers. These barriers include the Willamette subbasin dams, and other high dams such as the Pelton/Round Butte complex (Deschutes), Dworshak (Clearwater), Hells Canyon complex (Snake), and Chief Joseph Dam (Columbia) that block upstream passage by all migratory fish. Lesser barriers that may pass salmonids also block upstream passage by lamprey, including smaller dams, small water diversion dams, culverts, tide gates and numerous other barriers. Adult Pacific lamprey are known to pass through the Project, but no radio-tagged lamprey were observed to use tributaries in the Project area (Nass et al. 2003).

2.1.3.2 Abundance

Pacific lamprey populations of the Columbia River have significantly declined in abundance in recent years as evidenced by counts at dams on the lower Columbia and Snake rivers (Close et al. 1995; Vella et al. 1999; Close et al. 2002). Starke and Dalen (1995) reported that adult lamprey counts at Bonneville Dam that regularly exceeded 100,000 fish in the 1960s were estimated at approximately 22,000 in 1993. Specific reasons for this decline are not fully understood, but have been related to similar factors contributing to the decline of Pacific salmon. Close et al. (1995, 2002) identified several factors that may account for the decline in lamprey counts in the Columbia River Basin. This includes reduction in suitable spawning and rearing habitat from flow regulation and channelization, pollution and chemical eradication, reductions of prey in the ocean, and juvenile and adult passage problems at dams. Comparison of counts between dams and between years is complicated by variable and inconsistent sampling protocols (BioAnalysts 2000), potential over-wintering between dams, changes in personnel, and counting station passage efficiency (the ability of count station equipment to force individuals through a counting area for observation). Annual counts of adult Pacific lamprey passing select mainstem dams in the Columbia River Basin are summarized below in Table 2.

Efforts are underway to improve estimates of the number of adult lamprey passing dams using nighttime video at count stations (Clabough et al. 2009). Adding nighttime passage through count windows increased estimated escapements at Bonneville Dam by 42% in 2007, but decreased the estimated escapement to a negative value in 2008. The net downstream movement observed at Bonneville Dam in 2008 indicates that fish were passing by unmonitored routes such as through picketed leads at count stations. At The Dalles, adding nighttime counts increased estimated escapement by 42% in 2007 and by 70% in 2008. Douglas PUD has recently begun addressing accuracy of lamprey counts through structural improvements at the Wells Dam counting windows.

In addition to adult dam counts, the lack of ammocoetes in surveys in the Snake River basin and in Upper Columbia River tributaries may be an indication of the decline of Pacific lamprey.

Table 2 Annual counts (via Columbia River Data Access in Real Time [DART]) of adult Pacific lamprey at select Columbia and Snake basin dams.

Year	McNary	Priest Rapids	Wells	Ice Harbor	Lower Granite
2006	2,456	4,383	21	277	35
2007	3,454	6,593	35 [2]	290	34
2008	1,530	5,083	7 [2]	264	61
2009	676	2,713	9	57	12
2010	825	1,114	2	114	15
2011	868	3,868	1	269	48
2012	971	4,025	3	494	48
2013	1,570	5,968	21	328	19
2014	1,783	7,579	7	721	82
2015	1,748	6,749	0	764	50
2016[3]	1,612	8,139	7	875	106

Notes:

1 Ice Harbor and McNary day counts only. 24-hour counts at Wells (since 1998) and Priest Rapids (since 2008). Lower Granite counts have been conducted 24 hours a day since 2009.

2 The Pacific lamprey adult passage counts at Wells Dam are not reflective of actual run size during 2007-2008. Trapping, monitoring, and research efforts at Wells Dam artificially lowered the passage numbers for Pacific lamprey; i.e., more fish would have passed without tagging and trapping efforts.

3 Counts through December 5, 2016.

2.1.3.3 Population Structure

Genetic stock information suggests there is uncertainty among different Pacific lamprey stocks regionally. Powell and Faler (2001) determined that Pacific lamprey do not appear to have genetically different stocks, at least between some lower and mid-Columbia basins. These observations are similar to results by Goodman (2006) that found no evidence of mitochondrial DNA divergence in 81 collections of Pacific lamprey from two of the geographical regions common to the Columbia River and Klamath Mountain Province. Conversely, Lin et al. (2007; 2008) found significant differences among collections within those regions using approximately 180 amplified fragment length polymorphisms (AFLP) loci. These results detected significant genetic differences among adult Pacific lamprey returning to streams separated by as little as 54 miles (between the Deschutes River and John Day Dam). The differences between these studies may reflect the increased power of using approximately 180 AFLP loci versus a single mitochondrial DNA locus or differences in polymorphisms due to sampling of adult migrants versus ammocoetes. The geographical scale over which genetically meaningful management units (e.g., stocks, populations, or evolutionarily significant units) occur in this species could not be identified based on the results of Lin et al. Work based upon microsatellite analysis of 21 sites along the west coast of North America found low levels of genetic differentiation, providing support for a lack of natal homing in Pacific lamprey. The report noted that Pacific lamprey from most of the sites examined in this study can be managed as one unit but recommended future investigations to confirm whether this conclusion is applicable to all sites (Docker 2010). The most recent genetic analyses have continued to add uncertainty to Pacific lamprey population structure. Spice et al. (2012) evaluated the hypothesis of natal homing in Pacific lamprey and had results that were inconsistent with philopatry, suggesting that anadromous lampreys are unusual among species with long migrations, but suggest that limited dispersal at sea precludes panmixia. Work done by Hess et al. (2012) may provide context for observed genetic divergence among collections and thus, could reconcile previous findings of population genetic heterogeneity within a species that displays extensive gene flow.

One recovery strategy for Pacific lamprey is the translocation of pre-spawn adults from downstream Columbia River locations and supplementation with hatchery spawned ammocoetes into suitable habitat upstream. Cummings (2007) found that trapping and translocating adult lamprey did not appear to affect their migration success but the implications to population structure are currently unknown. Since the late 1990's and 2006, the Umatilla and Nez Perce tribes, respectively, have been implementing Pacific lamprey translocation programs as a conservation measure to maintain some level of lamprey production in target spawning streams. In 2012, the Yakama Nation began implementing translocation programs in mid-Columbia River tributaries (see Section 2.2: Updated Information for additional details about active efforts).

In 2009, the CRBLTWG was asked to develop a review paper on lamprey translocation and artificial propagation. Due to the uncertainty surrounding the potential implications related to unknown genetic stock structure related to translocation and differing opinions by CRBLTWG members, the CRBLTWG concluded that it would not be able endorse a position or shared opinion at that time and instead completed a literature review paper outlining the potential benefits and risks of translocation (CRBLTWG 2010).

2.1.4 Adult Passage at Hydroelectric Facilities

Radio-telemetry studies of adult lamprey migration patterns past dams and through reservoirs in the lower Columbia River during 1997 to 2002 provided the earliest data sets on lamprey passage timing, travel times, and passage success at hydroelectric projects (Vella et al. 2001; Ocker et al. 2001; Moser et al. 2003a; Moser et al. 2003b). While these studies have shown that 87 to 96% of the radio-tagged lamprey released migrate upstream and are detected at Bonneville Dam, less than 50% of the lamprey which encounter an entrance actually pass the dam. Passage times at lower Columbia River dams (2 to 4 days) were considerably longer compared to salmonids (1 day). Similarly, during 2005 to 2008, at McNary and Ice Harbor dams overall passage efficiencies ranged 58 to 89% and 50 to 59.1%, respectively. Median passage time from the first approach until exit into the forebay for adult lamprey ranged from 1 day to 2 days for both dams (Cummings et al. 2008). Despite different estimation techniques, HDX-PIT tag results of Daigle (2008) were generally consistent with previous study results for Bonneville, McNary and Ice Harbor dams. Recent evaluations (Keefer et al. 2009c; 2009d) indicated significantly lower passage success from release to passage of John Day Dam for radio-tagged lamprey compared to HDX-PIT-tagged lamprey (2.3 to 4.5% versus 17 to 18%), suggesting previously reported passage estimates were conservative.

Recent radio-telemetry studies at Bonneville Dam have expanded our understanding of adult lamprey behavior and passage performance in the lower Columbia River (Johnson et al. 2009a; Keefer et al 2009c; 2009d). For 2007 and 2008, 68 and 74%, respectively, of lamprey released to the tailrace were known to have returned to the dam. Of these, 32% successfully passed in both years (Johnson et al 2009a; 2009b; Keefer et al. 2009d). Entrance efficiencies (ranged 51 to 76%) were generally poorer than previous years although passage times (around 3.0 d median) was relatively good in 2007and 2008. Researchers speculated performance may have been related to smaller lamprey returning in 2007 and 2008 compared to earlier years.

In recent years passage efficiency has been estimated for radio and HDX-PIT tagged individual adult Pacific lamprey at Columbia and Snake River dams (Stevens et al. 2015; Keefer et al.

2015; LGL and Douglas County 2014; Keefer et al. 2011). Sample sizes for these studies has varied widely based on availability of lamprey in different regions of the Columbia River basin (CRB). Passage efficiency estimates (Table 3) were also highly variable by year and dam (i.e. 69% in 2010 and 89% in 2009 at McNary Dam; 60-82% for studies in 1997-2002 and 2005-2010 at Ice Harbor Dam) but it is important to note that passage metrics were not necessarily standardized between studies.

Table 3 Passage efficiency estimates for tagged individual adult Pacific lamprey at Columbia and Snake River dams.

River	Site	Year	Passage Efficiency	Technology employed	Reference
Columbia	Wells	2013	9.5%[1]	Radio	LGL and Douglas County PUD (2014)
		2007-2008	33.0%	Radio	LGL and Douglas County PUD (2008)
		2004	25.0%	Radio	Nass et al. (2005)
	Rocky Reach	2014	66.0%	HDX PIT	Blue Leaf Environmental (2015)
		2004	55.5%	Radio	Stevenson et al. (2005)
	Wanapum	2014	Not included due to spillway fracture and resulting abnormal fishway operations		
		2013	79.0%	HDX PIT	Blue Leaf Environmental (2014)
		2010-2012	67.0%	HDX PIT	Blue Leaf Environmental (2013)
	Priest Rapids	2014	80.0%	HDX PIT	Blue Leaf Environmental (2015)
		2013	77.0%	HDX PIT	Blue Leaf Environmental (2014)
		2010-2012	66.5%	HDX PIT	Blue Leaf Environmental (2013)
	McNary	2010	69.0%	Radio	Keefer et al. (2011)
		2009	89.0%	Radio	Keefer et al. (2011)
		2008	74.0%	Radio	Keefer et al. (2011)
		2007	70.0%	Radio	Keefer et al. (2011)
		2006	80.0%	Radio	Keefer et al. (2011)
		2005	72.0%	Radio	Keefer et al. (2011)
	John Day	2014	73.0%	HDX PIT	Keefer et al. (2015)
	The Dalles	2014	58.0%	HDX PIT	Keefer et al. (2015)
	Bonneville	2014	56-60.0%	HDX PIT	Keefer et al. (2015)
Snake	Ice Harbor	2014	22.0%	Radio + HDX PIT	Stevens et al. (2015)
	Lower Monumental	1997-2002; 2005-2010	60-82.0%	Radio	Keefer et al. (2012)
		2014	50.0%	Radio + HDX PIT	Stevens et al. (2015)
	Little Goose	2014	56.0%	Radio + HDX PIT	Stevens et al. (2015)

River	Site	Year	Passage Efficiency	Technology employed	Reference
	Lower Granite	2014	62.0%	Radio + HDX PIT	Stevens et al. (2015)

Notes:

1 Given extremely low counts at Wells Dam in recent years, this assessment utilized adults captured at Bonneville and Priest Rapids dams and held at Prosser Hatchery for an extended period of time prior to transport, tagging and release at Wells Dam. Active upstream migration of these study fish appeared to be low and the protracted holding period at Prosser Hatchery remains a potential explanation for low encounter rates at Wells Dam.

In the mid-Columbia at Wanapum, Priest Rapids, Rocky Reach, and Wells dams, the results have been more varied, in part due to the use of slightly different metrics (Table 3; Nass et al. 2003; Stevenson et al. 2005; LGL Limited and Douglas PUD 2008).

During a 2008 study at Wells Dam, 18 lamprey were released into the Wells Project tailrace. Twelve of the 18 lamprey yielded sufficient data for analysis. Over the study period, 11 of 12 (91.7%) lamprey approached a fishway entrance with several lamprey making multiple approaches. Only two tailrace-released lamprey successfully entered a fishway and both failed to ascend into the forebay. Overall, 2008 study results indicate that any potential areas of impediment at Wells Dam are restricted entirely to the entrance and lower fishway, as upper fishway passage efficiency (releases in the fishway) was 100% for the two consecutive study years (LGL Limited and Douglas PUD 2008). In 2013, another fishway passage study was conducted at Wells Dam with adult lamprey translocated from Bonneville and Priest Rapids dams (due to low numbers at the dam). Results of the assessment are summarized in Table 3 above however; translocated study fish may have impacted the encounter rate of study fish at Wells Dam.

At Priest Rapids and Wanapum dams, the proportion of fish that approached the fishway that exited the ladders was 70% at Priest Rapids, and 51% at Wanapum Dam in 2002 (Nass et al. 2003). Fishway passage efficiencies (entrance to exit) were substantially higher at 87% and 82% for the same study despite substantial delays or termination of active migration near the first weir walls and old style counting stations which have subsequently been modified to include lamprey-specific crowder structures at both Priest and Wanapum dams. Design enhancements (plating and ramps at Priest Rapids Dam) installed during the 2009-2010 winter fish ladder maintenance outage, are also anticipated to address these areas and improve volitional passage efficiency. To test these design enhancements, Grant PUD, in consultation with the PRFF, has been evaluating lamprey passage behavior at the Project using an extensive HDX-PIT array (originally 20 receivers, reduced to 16 total receivers in 2015) at Priest Rapids and Wanapum dams since 2010. For the 2010 through 2016 migrations, Grant PUD monitored a total of 447 and 491 HDX-PIT tagged lamprey at Priest Rapids and Wanapum dams, respectively. Fishway passage efficiency for lamprey was 73% at Priest Rapids Dam over the 2010-2015 period and 72% at Wanapum Dam over the 2010-2013 and 2015 period (2014 intentionally omitted due to anomalous conditions associated with the Wanapum fracture).

Passage times of HDX-PIT tagged adult lamprey at Priest Rapids and Wanapum dams were relatively consistent during the 2010-2013 period. Median passage times at Priest Rapids and Wanapum right bank were less than 10 hours while passage times through the left bank fishways were greater; 76.6 hours and 24 hours at Priest Rapids left bank and Wanapum left bank fishways, respectively. This apparent delay at Priest Rapids left bank was associated with the upper fishway as fish ascended beyond the count station and past the OLAFT. To gain a better understanding of this phenomenon and provide increased detection resolution, two additional HDX-PIT detection stations were installed in the Priest Rapids upper left fishway in the vicinity of the OLAFT in early 2015. However, passage times of HDX-PIT tagged adult lamprey that volitionally ascended fishways in 2014 were different than previous years, possibly due to modified operations (lamprey trapping activities related to the trap-and-haul effort). At Priest Rapids Dam the median passage time in the left bank fishway improved to 17 hours, while median passage time through the right bank remained consistent with previous years at 5 hours. Fallback of HDX-PIT tagged adult lamprey was relatively uncommon during the 2010-2015 period. Only one fish at each dam was detected falling back and failing to re-ascend the fishway.

Median reservoir passage time through Priest Rapids reservoir for HDX-PIT tagged adult lamprey with detections at the Priest Rapids Dam exits and Wanapum Dam entrances ranged from 4.4 to 5.9 days during the 2010-2016 period. Finally, fish tagged in a previous study year were occasionally detected during the migration period the following year (i.e. fish tagged at Bonneville Dam in 2012 but detected at Priest Rapids Dam in 2013). These fish were assumed to have overwintered in the Columbia River then resumed migration behavior the following year. These fish have generally made up between 2% to 5% of detected tags, annually. The presence of these fish suggests that estimating passage efficiency for adult lamprey requires a nuanced approach.

Table 4 Passage metrics of HDX-PIT tagged adult lamprey including quantity of fish detected, median fishway passage time, net fallback, median Priest Rapids reservoir passage time, and overwintering fish at Priest Rapids (PR) and Wanapum (WA) dams during 2010-2016.

Year	Qty Detected		Median fishway passage time (h)			
	PR	WA	PR Left	PR Right	WA Left*	WA Right [1]
2010-2015	447	491	70.3	5.2	19.9	18.3

Notes:
1 2014 Wanapum passage data omitted due to abnormal Project operations resulting from the Wanapum Dam spillway fracture

Year	Qty Net Fallback		Median PR Reservoir passage time (d)[1]	Qty tags from previous year (overwintering fish)
	PR	WA		
2010-2015	TBD	TBD	4.9	27

Notes:
1 2014 Priest Rapids reservoir passage data omitted due to abnormal Project operations resulting from the Wanapum Dam spillway fracture

During the 2010 migration, an additional assessment of lamprey passage was conducted using underwater video. In this study, cameras were placed to view newly installed aluminum plating on the diffusion grating, the floor through weir orifices, and on the fish count station. This monitoring activity produced observations that the plating at weir wall orifices was extensively used by lamprey and was a benefit to lamprey passage. For 19 complete passage events through an orifice, 95% of lamprey used the plating and 100% of the events demonstrated successful passage. The fish count crowder was also observed to promote guidance of lamprey through the counting chute. Of 123 events, 79% of lamprey were successfully guided by the structure to the chute and 40% of these used the plated ramp to stage below the chute.

On February 27, 2014, a horizontal fracture was discovered in the spillway monolith No. 4 at Wanapum Dam. The fracture opened a crack on the upstream face of the structure approximately

2 inches high by 65 feet long on the spillway monolith. Grant PUD immediately initiated its EAP (level B) and began to draw the Wanapum Reservoir down in a steady controlled state. As of March 4, 2014, the Wanapum Reservoir was lowered to a safe operating elevation range between 545 feet and 541 feet. As a result of the drawdown, the fish ladder exits at Wanapum Dam were dewatered, preventing upstream migrating fish from passing Wanapum Dam. The fish ladder entrances at Wanapum remained operational, due to the tailwater elevation. At an elevation of 560-562 feet, the Wanapum Dam fish ladders exits would be able to be operated within criteria and without modifications. Fishway Exit Passage Systems were installed at Wanapum Dam on April 15 (on left-bank) and April 26 (right-bank) and were operated throughout the fish passage season. The Wanapum Fishway Exit Passage Systems (WFEPS) successfully passed adult salmonids (spring Chinook), steelhead and other species (mountain white fish). To facilitate adult lamprey passage at the both the left and right bank fishways at Wanapum Dam, lamprey ramps were designed and incorporated into the WFEPS.

In order to assess the WFEPS, 28 adult lamprey were tagged with HDX PIT tags and released at dusk on July 25, 2014 into the upper Wanapum Dam left bank fishway. Within six days, 26 of the tagged fish were last detected at the left bank exit PIT reader, 1 fish moved downstream within the fishway, and 1 fish was not detected after release.

In addition to volitional passage, Grant PUD trapped and transported 2,263 adult Pacific lamprey collected from Priest Rapids and Wanapum dam fishways via 36 tube style traps distributed between the two dams and four mechanical weir traps at Priest Rapids. All trapped lamprey were scanned for a PIT tag, and previously tagged lamprey (n=45) were transported and released immediately upstream of the dam where they were trapped. Untagged lamprey were then held in a circular holding tank at Wanapum Dam until there were sufficient numbers to haul them upstream to the Kirby Billingsley Hydro Park (RM 461), approximately eight miles upstream from Rock Island Dam. Trap and transport activities occurred from July 17 to September 30, 2014, through the peak of the upstream adult lamprey migration.

Reduced HDX-PIT tagging effort from downstream sources in 2015 and 2016 resulted in a smaller quantity of run-of-river tags detected at Priest Rapids Dam than in 2010-2014 (n=46). The median passage time at the Priest Rapids through both the left and right bank fishways was 5.8 hours, which represents faster passage than previous years through the left bank and no change from previous years through the right bank. At Wanapum Dam, median passage times through the left and right bank fishways were 18.5 and 7.0 hours respectively. Compared with earlier study years, this represents somewhat increased passage time through the left bank but decreased passage time through the right bank. However, as in previous years, the quantity of lamprey passing the Wanapum right bank fishway is small compared to the left bank (approximately 15% ascend the right bank and 85% ascend the left bank).

In addition to monitoring run-of-river tagged adults, 133 adult lamprey were captured with mechanical traps from the Priest Rapids Dam lower left and right bank fishways during the peak migration period in July and August 2015 and implanted with HDX-PIT tags. The fish were released in the lower Priest Rapids left bank fishway to assess passage through the upper fishway, and specifically to evaluate passage near the OLAFT. This effort was undertaken to assess whether the apparent delay noted in results from 2010-2013 persisted in 2015 after operations returned to normal following the events surrounding the Wanapum Dam spillway fracture in 2014. The median passage time of fish included in this effort from release in the lower fishway to the fishway exit was 13.9 hours. The median passage time through the upper fishway above the count station, past the OLAFT to the exit was 6.0 hours.

In 2016, another 150 adult lamprey were captured with mechanical traps from the Priest Rapids Dam lower left and right bank fishways during the peak migration period in July and August and implanted with HDX-PIT tags for the same purpose. The median passage time of fish included in this effort from release in the lower fishway to the fishway exit was 15.1 hours which was similar to that observed in 2015. As such, there did not appear to be a passage delay for adult lamprey in the Priest Rapids upper left bank fishway in 2016 and no further evaluations are planned.

Additionally in 2015, 100 adult lamprey captured with mechanical traps from the Priest Rapids Dam lower fishways during the peak migration period in July and August were implanted with both acoustic tags (Vemco V7) and FDX-PIT tags. These fish were released in either the Priest Rapids Forebay at Desert Aire (RM 400.4; n=30) or in the Wanapum Forebay at RM 415.8 (n=35) or RM 419.9 (n=35). An array of fixed acoustic receivers deployed throughout the Project area was used to monitor the tagged fish after release. Additionally, mobile tracking was employed to located tagged individuals in the study area during the migration period. A total of 83 fish were detected in the tailrace of Rock Island Dam (RM 453.0). The median travel time to reach the Rock Island Dam tailrace was 3.6 days for fish released in the Wanapum Reservoir and 16.8 days for fish released in the Priest Rapids Reservoir. Travel rates to reach the Rock Island Tailrace ranged from 0.2-28.2 km/d for fish released in the Wanapum Reservoir and from 0.9-12.7 km/d for fish released in the Priest Rapids Reservoir. Three fish were never detected after release and were assumed to have either been mortalities or have failed acoustic tags. Additional results are provided in Appendix A.

In 2016, another 100 adult lamprey were captured during the peak migration and implanted with both acoustic tags (Vemco V7) and FDX-PIT tags. Release numbers and locations and monitoring were similar to 2015. The median travel time to reach the Rock Island Dam tailrace was 3.6 days for fish released in the Wanapum Reservoir and 9.9 days for fish released in the Priest Rapids Reservoir. Travel rates to reach the Rock Island Tailrace ranged from 1.4-38.5 km/d for fish released in the Wanapum Reservoir and from 3.9-15.4 km/d for fish released in the Priest Rapids Reservoir. Three fish had not been detected after release and were assumed to have either been mortalities or have failed acoustic tags. Complete results will be provided after the study concludes in June 2017.

In 2016, Grant PUD also coordinated with other PUDs to provide adult lamprey for ongoing regional studies. In total, 211 and 50 fish were collected at Priest Rapids Dam to support lamprey assessments at Chelan PUD and Douglas PUD, respectively. Grant PUD has provided fish to support other adult lamprey studies for three consecutive years.

Other regional studies and experiments included an experimental fishway at Bonneville Dam in 2004-2006 evaluated lamprey response to: 1) a fishway ramp and the effects of ramp flow volume, ramp angle, and attraction flow at the ramp entrance; 2) a divided fishway with differing flow velocities at each channel entrance; 3) two styles of mid-ramp lamprey “rest boxes”; and 4) three methods of attracting lampreys to the ramp entrance (water jets, air bubble streams, and waterfalls [Keefer 2008]). In the ramp tests, the majority of tagged fish ascended the ramp under all treatment conditions but lamprey passage times differed significantly in response to flow levels. When the fishway was divided, lamprey preferentially used channels adjacent to the flume walls, and this preference increased as flow through the outside channels decreased. Lamprey passage times also increased with concentrated flow through the center channel. With the differing types of “rest boxes”, there was little difference in lamprey behavior between rest boxes under various flow treatments, and fish that ascended the ramp appeared to be unaffected by either rest box type. Finally, regarding the various methods of attraction to the ramp entrance, lamprey passage efficiency was highest during the water jet treatment, but differences among tests were not statistically significant.

A potential physiological problem facing successful passage of Pacific lamprey at dams may be related to their unique method of movement as it relates to specific areas within fish ladders. Typically, lamprey move through an adult fishway in a repeated series of motions consisting of attaching to the ladder floor with their mouths, surging forward, and re-attaching. Adult lamprey have an estimated critical swimming speed of about 2.8 feet per second at 15°C (Mesa et al. 2003) and a burst swimming speed calculated at 6.9 feet per second (Bell 1990). Fishway operational criteria at Wanapum and Priest Rapids dams include average velocities over submerged weirs that are approximately 2 to 4 feet per second and 4 to 6 feet per second through the slotted entrance gates near the surface. The design of the slotted entrance gates is such that the velocity gradient will be near zero at the bottom while maintaining average water velocities to the surface of the water column (M. Nicholls, Grant PUD, personal communication). Average velocity through the orifices is approximately 6 to 7 feet per second. The physiological response of adult Pacific lamprey to exhaustive exercise may be immediate, sometimes severe, but short-lived (Mesa et al. 2003). These data suggest that lamprey may have difficulty negotiating fishways that operate according to criteria established for salmonids.

In an effort to improve monitoring of Pacific lamprey in the basin, HDX-PIT tag monitoring sites were deployed at dams beginning in 2005. HDX-PIT tags were selected for Pacific lamprey passage evaluations to avoid potential tag collisions with the FDX PIT tags used to monitor salmonids in the basin. In 2005, HDX detectors were installed at Bonneville Dam to evaluate lamprey passage systems (LPS) in the Bradford Island makeup water channel and at the entrance to the Washington-shore main ladder. Detectors were also installed at McNary and Ice Harbor dams to monitor lamprey in a parallel study (Cummings 2007). In 2006, additional detectors were installed at the tops of ladders at The Dalles and John Day dams. Daigle (2008) concluded that the prototype HDX detectors used in 2005-2006 appeared to be reasonably efficient (e.g., 20-100%) at detecting tagged lamprey passing antennas. Studies comparing the use of radio-telemetry and the HDX-PIT tags were conducted in 2007-2009. Study results indicated higher escapement rates for HDX-PIT tagged fish versus radio-telemetry tagged fish at and between dams. Larger fish of both tag types were significantly more likely than smaller fish to pass through most monitored dam-to-dam reaches. The results suggest a tradeoff between tagging effects and the collection of high resolution, fine-scale data provided by the active radio telemetry system (Keefer et al. 2009a, 2009b and 2010).

Since the cumulative evidence on adult lamprey passage at dams has indicated that fishway entrances may be a major passage bottleneck, a significant effort was undertaken by the ACOE to develop and evaluate new entrance designs and operations. In 2007, a study was undertaken at Bonneville Dam to evaluate the use of reduced water velocities at entrances at night to improve entrance rates for lamprey (Johnson et al. 2009a). Lowering entrance head levels to 0.5 ft (4 feet per second target velocity level) from 2200 to 0400 hrs at PH2 improved entrance efficiencies from 2% at normal velocity to 26% at the lowered velocity at the north-shore entrance, although the number of lamprey attracted to the entrance appeared lower during reduced velocities (i.e., net entrances may not have been different. There was also evidence that the time to enter during the lower velocity was improved. In 2008, when PH2 entrances were placed in standby mode (0 feet per second velocity) at night, entrance efficiencies were 2 and 12% at the north and south-shore entrances versus 9 and 30% during normal conditions, respectively (Johnson et al. 2009b). Lamprey were also more likely to drop out of the fishways during the standby operations. In 2009, the telescoping weir bulkheads at the Cascade Island fishway entrance at Bonneville Dam were replaced with a variable-width entrance bulkhead. Bollard structures were also added out- and inside the fishway to provide an area of low velocity along the floor as a potential route for lampreys to enter. Preliminary results from radio- and HDX-PIT tag monitoring indicated that lamprey entrance use was improved in 2009 at the Cascades Island entrance but further analyses are planned. In 2009 and 2010, Douglas PUD utilized DIDSON to evaluate lamprey entrance efficiency at the Wells Dam fishways in response to three alternative entrance flow velocities. Although number of observations were low, the data indicated that adult lamprey were able to volitionally enter fishways under reduced nighttime flows (P.N. Johnson et al. 2011). The Wells Dam 2013 passage study conducted by Douglas PUD also included a treatment with alternative entrance flow velocities.

In recent years, Columbia River Basin hydroelectric facilities have begun modifying fishways and fishway operations to facilitate the upstream passage of adult lamprey. ACOE and utilities with hydroelectric facilities or dams in the basin are in various phases of design and implementation of passage improvements that include variable width weirs, bollard arrays, ¾ inch diffuser grating, LPS in various fishway locations, lamprey entrance flume systems, lamprey orifices in control section weir walls, diffuser grating plating, ramps at perched orifices, rounded edges of fishway walls, temporary velocity reductions at fishway entrances, and lifting picket leads at count stations. In particular, given their adaptability, the use (and evaluation) of LPS have been implemented to facilitate adult lamprey passage on dams and diversions on the Umatilla and Yakama rivers. Operational changes that continue to be implemented at some mainstem hydroelectric facilities include reduced water velocities at entrances, lifting picketed leads, improving collection and counting accuracy, and compliance with established fishway operations criteria. Researchers have also begun testing passage efficiency of an experimental vertical climbing wall, implementing passage evaluations on the Clackamas River, Yakama (see Section 2.2: Updated Information for additional details).

2.1.5 Juvenile Passage at Hydroelectric Facilities

Juvenile lamprey moving downstream may pass through a hydroelectric structure using several different routes, including the powerhouse (turbines), spillway (bottom or top discharge tainter gates), powerhouse gatewell slots (fish bypass collection area), and adult fishways. Potentially high juvenile lamprey turbine entrainment rates are likely given the tendency of juveniles to swim low in the water column (Long 1968 as cited in Moursund et al. 2000). Fyke net capture data from Wells (Douglas PUD) and Rocky Reach (Chelan PUD) further confirm that juvenile lamprey tend to pass via turbines in the lower half of the water column (BioAnalysts 2000). At the Project, turbine intake emergency wheelgate slot exclusion screen evaluations also observed small numbers of juvenile lamprey in the vicinity of turbine intake areas (Mike Clement, Grant PUD, personal communication).

The lamprey's ability to survive turbine passage, including response to changes in pressure, turbulent flow, and shear stress are not clearly understood. Another concern is how juvenile lamprey respond to diversion screens which are designed to bypass or divert fish into or toward preferred fish passage routes. For example, investigators reported large numbers of juvenile lamprey impinged between individual bars of fixed bar screens at The Dalles and McNary dams (Hatch and Parker 1998). The effects of blade strike or sub-lethal effects, such as increased vulnerability to predation following turbine passage, are not known (Becker et. al. 2003). Although the necessary tag technology to evaluate the potential impacts to juvenile lamprey passage through hydroelectric facilities is currently unavailable (see Section 2.1.5.3), increased efforts that include synthesis of available information (e.g., juvenile bypass facilities, screw trap operations, existing reports/studies, etc.) have been implemented to provide a basin-wide perspective on juvenile lamprey passage and movements and to identify information gaps. Operational and structural modifications being implemented at hydroelectric facilities include delayed deployment of extended length screens during juvenile outmigration, JBS modifications, and salvage operations during ladder outages, and compliance with fish bypass criteria. Monitoring passage timing, numbers, and mortalities of juvenile lamprey and predation control measures continue to be implemented at some Columbia and Snake river hydroelectric facilities to protect outmigrants (see Section 2.2: Updated Information for additional details).

2.1.5.1 Effects of Hydrologic Pressures on Juvenile Lampry

Moursund et al. (2000 and 2001) subjected lamprey to an abrupt pressure spike (using a hyperbaric chamber) in order to simulate turbine passage. Lamprey were examined for injuries immediately after the trial, and then again after 48 hours. Test lamprey showed no immediate or latent injuries. Juvenile lamprey hardiness likely results from their lack of swim bladder, the flexibility associated with an anguilliform body type and cartilaginous skeleton, and the reduced size of vulnerable structures, such as eyes.

To further evaluate Pacific lamprey's ability to survive turbine passage, Pacific Northwest National Laboratory (PNNL) scientists conducted laboratory tests designed to measure a juvenile Pacific lamprey's response to the absolute change in pressure or "pressure drop" during passage through a Kaplan turbine simulation (Neitzel et al. 2000). Tests conducted by PNNL used a hyperbaric chamber to test a single worst-case scenario for lamprey: bottom-acclimated with a surface return. Juvenile lamprey were acclimated to an equivalent pressure of 60-foot depth for 24 hours prior to passage. The entire pressure sequence lasted about 90 seconds (Becker et al. 2003). Results from the simulated turbine passage tests showed no immediate external injuries or mortalities for lamprey exposed to rapid changes in pressure, i.e., ~400 kPa to ~5 kPa in 0.1 second. That juvenile lamprey lack a swim bladder may be one reason for their resistance relative to bluegill sunfish (Becker et al. 2003). In 2011, continued testing by PNNL on the effects of rapid and prolonged decompression simulating hydroturbine passage were conducted on juvenile Pacific lamprey. Generally, no mortalities or barotrauma were observed for lamprey exposed to these decompression scenarios (Colotelo et al. 2012).

2.1.5.2 Effects of Bar Screens on Juvenile Lamprey

Swim trials in a laboratory flume showed that juvenile Pacific lamprey are fair to weak swimmers as compared to salmonids, with an average burst speed of 2.3 feet per second (Moursund et al. 2000). Sustained juvenile lamprey swim speeds averaged 0.75 feet per second over a five-minute interval and 0.5 feet per second over a 15-minute interval (Moursund et al. 2000).

In laboratory conditions at PNNL in 2000, lamprey interactions with bar screens using an oval flume fitted with 1/8-inch spaced wedge-wire screen were examined. Lamprey were exposed to the screen at water velocities ranging from 0 to 2 feet per second. Observations were recorded using video cameras and infrared illuminators. At all water velocities greater than zero, the lamprey made contact with the bar screen within one minute of their entry into the water column upstream of the screen. At water velocities up to 1 foot per second, they were able to push off the screen and disperse throughout the test flume. At water velocities greater than 1.5 feet per second, all lamprey made immediate contact with the screen. Seventy percent became impinged within one minute of the exposure. After 12 hours of exposure, 97% of the lamprey were impinged on the screen (Moursund et al. 2000).

Physical model data obtained by the U.S. Army Engineer Research and Development Center suggest that the average perpendicular flow velocity at a typical turbine bypass screen is 2.4 feet per second. Field measurements directly on a screen face at John Day support the model data (Weiland and Escher 2001). They also suggest this velocity exceeds the velocities that caused impingement of juvenile lamprey during laboratory tests and was also higher than the average burst speed of the test population. On an extended-length submerged bar screen, local velocities was as high as 10 feet per second and occurred at the upper end of the screen (Weiland and Escher 2001).

As part of the series of laboratory studies conducted by PNNL in 2000, the effects of screen alignment and angles on lamprey impingement were evaluated. 1999 laboratory flume tests utilized 1/8-inch wedge-wire screen oriented perpendicular to the flow and having vertical bars. Testing in 2000 included having vertical and horizontal bars and screen orientations at 10 degrees from vertical. The angled screen provided upward sweeping velocities that were not present in the previous perpendicular tests. Trials were conducted at velocities from 2 to 5 feet per second. The findings showed lamprey were far more susceptible to become impinged on horizontal bars than on vertical ones. At water velocities of 4 feet per second, 50% of lamprey became impinged on the horizontal bars but none were stuck on the vertical bars. At 5 feet per second, 55% of the lamprey were impinged on the horizontal bars but just 25 became impinged on the vertical bars (Moursund et al. 2002). General findings showed that an increase in either water velocity or the duration of conditions favoring impingement increases the lamprey's chances of permanently becoming stuck on the screens.

Alternative screening material was also tested by PNNL. Previous testing of 1/8-inch square nylon mesh was tested against 2/29-inch bar screen. The narrower spacing was expected to reduce the amount of space for lamprey to work their tails in and become impinged. Testing results showed that while 70% of the juvenile lamprey were permanently impinged on the 1/8-inch bar screen at velocities up to 4 feet per second, none remained stuck on the bars having the smaller 2/29-inch spacing, and just 15% were permanently impinged on the 1/8-inch square mesh (Moursund et al. 2002).

2.1.5.3 Need for Active Tag Technology

A review of the most recent research addressing juvenile lamprey at hydroelectric facilities concludes that there is a current lack of methods and technology to effectively quantify survival of juvenile lamprey migrating through hydroelectric facilities (Douglas PUD and LGL 2008). Furthermore, no studies exist that determine a level of mortality attributed to a project's operations. This is due to the lack of miniaturized active tag technologies to overcome two study limitations: 1) macrophthalmia are relatively small in size and unique in body shape; and 2) migrate low in the water column resulting in the rapid attenuation of active tag signal strength. In 1999, the ACOE funded Oregon State University to assess the applicability of available tag technology to monitor juvenile lamprey macrophthalmia outmigration (Schreck et al. 2000). Results from this effort indicated that the smallest currently available radio-tag is still too large for implantation in the body cavity of a juvenile lamprey (Schreck et al. 2000). Additionally, external application was not effective as animals removed tags within the first week and fish performance and behavior were affected (Schreck et al. 2000). Internal implantation of PIT tags is currently the most viable option for tagging juvenile lamprey; however this methodology presents severe limitations due to the limited range of detection systems, and the ability to tag only the largest outmigrating juvenile lamprey (Schreck et al. 2000). Since the 1999 assessment, there have been some improvements in tag technology with several studies associated with developing biological criteria for active tags and standard protocols for PIT-tagging juvenile lamprey. With 8mm Pico tags, lamprey ammocoetes greater than 70mm have recently been tagged (R. Lampman, Yakama Nation, personal communication).

Recent funding from the ACOE and Department of Energy has been made available to design, prototype and evaluate an acoustic microtransmitter that can be used to study the behavior and survival of juvenile lamprey. In 2016, PNNL completed the design of a juvenile lamprey acoustic micro-transmitter that is 2 mm in diameter and 12 mm in length and weighs 0.08 g in air. The prototype tag lasts 20 to 30 days at 5-s ping rate interval. The biological tagging results from implanting juvenile Pacific lamprey showed that implantation is not likely to have an adverse impact on fish survival over a 28-day holding period. Additionally, there was minimal tag loss due to shedding for fish greater than 130 mm in length. The surgical procedure was effective at placing tags within the body cavity without causing significant hemorrhaging or fungal infections at the tagging site. Sustained swimming tests showed no significant differences in swimming ability when comparing implanted fish to control fish for all size classes (120–160 mm) tested (see Section 2.2: Updated Information for additional details).

2.1.5.4 Gatewell Exclusion Screen Evaluation

During the spring and early summer months of 2010, turbine intake emergency gatewell exclusion screens were monitored at Priest Rapids and Wanapum dams (Grant PUD 2011). Prior to the juvenile salmonid outmigration, a DIDSON camera was installed on the end of the screen that allowed 69% of the screen surface to be effectively imaged. Fishes were enumerated as they passed within the insonified area near the screen, and interactions with the screen were classified by type (contact or non-contact). A total of 18 days of data collection throughout the spring and summer salmonid migration periods were analyzed at each dam. These results showed that fishes observed had a low level of interaction with the screens and a very low level of multiple or extended contact. At Wanapum Dam, 10,632 fishes were observed near the exclusion screen with 784 (7.4%) coming in contact with the screen and at Priest Rapids Dam, 29,340 fishes were observed with 360 (1.2%) contacts with the screen (Wright et. al., 2010). Although the study was originally developed to evaluate juvenile salmonid outmigrants, small numbers of lamprey were also observed at monitored locations at both Wanapum (n=31) and Priest Rapids (n=161) dams (Wright et. al., 2010). During the study period (May 12 to July 15, 2010) no negative impacts or screen impingement events were observed at these locations (Mike Clement, Grant PUD, personal communication).

2.2 Updated Information

Pursuant to the requirements of Grant PUD's PLMP (Grant PUD 2009) and specifically for this comprehensive annual report (as described in Section 1.2 above), recent Pacific lamprey passage and survival investigations and measures undertaken in the Columbia River Basin are summarized in Table 5. For the purposes of this comprehensive annual report, the "updated" information includes activities that are either occurring or are being reported on during the current reporting period of November 1, 2015 through October 31, 2016. Worth noting is that the table only includes activities that have been implemented through the end of the reporting period. Efforts that are proposed or planned for future implementation or are proposed as a potential measure are not identified in this section. Proposed and planned efforts are, however, addressed in Section 4.0 which contains a comprehensive evaluation of all regional activities (implemented, planned and proposed) and assesses their applicability to the Project.

Information contained in the table includes the activity, project and river in which the activity occurred, results or status of activity, lead entity and information source.

Table 5 Pacific lamprey activities in the Columbia River basin in 2016.

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
	General Biology, Ecology, and Population Status					
1.	Monitoring entrance timing, escapement, and movement patterns	No associated hydro project	Fifteenmile Creek	In 2014, adult Pacific lamprey abundance in Fifteenmile Creek was estimated at 3,238 (2,646 – 3,962). From February through October, 256 PIT tagged lamprey were detected at interrogation sites in the Fifteenmile Creek Subbasin. Of those 256 detections, 64 were PIT tagged in 2013 (25%) and six were PIT tagged in 2012 (2%). From the total fish marked by CTWSRO (198), 110 were considered to have backed out of Fifteenmile Creek and fates unknown since going undetected. Eightmile Creek had a total of seven detections, three adults tagged by UI and 4 tagged by CTWSRO. Mill Creek detected one UI fish, on August 4, 2014; in 2013 this antenna detected only two CTWSRO fish tagged. The life-history pattern of lamprey spending two winters before spawning was again documented in 2014 in Fifteenmile Creek. In 2014, distribution of ammocoetes in Fifteenmile, Eightmile, and Mill creeks was similar to 2013. Ammocoete density surveys in Reservation streams indicated a wide range, as in previous years. Due to low water levels and warm temperatures in Fifteenmile Creek in 2015, no abundance estimate at Cushing Falls was made. Only 53 lamprey were tagged at Cushing Falls in 2015. None were detected as recaptured fish. Estimated harvest at Cushing Falls in 2015 was 14 on t9 (95% CI 115-183)	CTWSR	Evaluate Status and Limiting Factors of Pacific Lamprey in the lower Deschutes River, Fifteenmile Creek and Hood River Subbasins. Confederated Tribes of Warm Springs Reservation of Oregon, Warm Springs. (CTWSR 2014) Evaluate Status and Evaluate status and limiting factors of Pacific lamprey in the Deschutes River, Fifteen Mile Creek, and Hood River (Baker 2016a).
2.	Adult lamprey monitoring and juvenile lamprey density and distribution surveys	No associated hydro project	Deschutes and tributaries	Due to low water levels and warm temperatures in Fifteenmile Creek in 2015, no abundance estimate at Cushing Falls was made. Only 53 lamprey were tagged at Cushing Falls in 2015. None were detected as	CTWSR	Evaluate status and limiting factors of Pacific lamprey in the Deschutes

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				recaptured fish. Estimated harvest at Cushing Falls in 2015 was 149 (95% CI 115-183). In 2015, an occupancy sampling approach was used to verify end of distribution of lamprey in the Deschutes River and tributaries. Larval lamprey were detected up to the mouth of Shitike Creek (rkm 157) but none upstream of the Pelton Re-regulating Dam (rkm 161). Densities of larval lamprey in the Deschutes River in 2015 were about half that found in Reservation streams in 2014 (30 fish/m2 and 14.8 fish/m2). Distribution of lamprey in Shitike, Beaver, and Badger creeks were within the range found previous years. No larval lamprey were found in Trout Creek, a tributary of the Deschutes River (rkm 141).		River, Fifteen Mile Creek, and Hood River (Baker 2016a).
3.	Larval Lamprey Assessment	BOR projects in Yakima (Roza Dam)	Yakima	In 2015, PNNL and staff from the Yakama Nation conducted deep water larval lamprey surveys near the Roza Dam Diversion Fish Screening Facility and at the Yakima River delta region to determine lamprey occurrence and provide a general assessment of substrate composition. At the Yakima River delta, larval lamprey searches were conducted at three general areas consisting of the main river channel and delta regions to the north of the mouth. A total of three larval lamprey were observed in a relatively small region along the north section of the delta region in water depths of approximately 6 m in Type I and II substrates. At the Roza Dam forebay, a total of four larval lamprey were observed in Type I and II substrates. Three of the four lamprey were found near the trash racks upstream from Screening Bay 5 at a water depth of 5.3 m, and the other was found ~515 m upstream from the facility at a water depth of 2.9 m.	PNNL	Larval Lamprey Assessment at the Roza Dam Forebay and Yakima River Delta Region, 2015 Annual report to BPA (Mueller 2016).
4.	Larval Lamprey Assessment	BOR projects in Yakima (Wapato and Sunnyside	Yakima	In 2015 PNNL utilized a portable deepwater shocking system to conduct larval lamprey surveys in conjunction with screening facility dewatering to assess density and substrate composition. At Sunnyside	PNNL and Yakama Nation	Larval Lamprey Assessment at Wapato and Sunnyside Fish

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
		Fish Screening Facilities)		diversion, At the headgate region, The suitable habitat was estimated to be 93.4 sq/m with a density of 2.5 lamprey per sq/m. The total estimated within the suitable region was estimated at 232 larval lamprey. Macrophyte growth and larger substrates were the predominate features. At the screening region, a total of 75 lamprey ammocoetes were observed across all size ranges. The total survey area polygon was 2,870 sq/m and the total estimated survey area was 10.82 sq/m. Within the suitable region, the total area was estimated to be 1,410 sq/m and 8.5 sq/m was surveyed. The estimated density was 8.8 fish per sq/m and the total estimated lamprey that may be inhabiting this region was 12,408. At the Wapato headgate region The majority of the substrate was comprised of larger sized rocks, large woody debris or sand over concrete. The only suitable region was a relatively small patch (3.3 sq/m) which was found in the upper portion adjacent to the log boom walkway (Figure 9). A total of 4 lamprey were observed in this region. Based on the surveyed area and a density of 4.2 fish per sq/m, a total of 14 lamprey was estimated. At the Wapato forebay region, A total of 50 lamprey ammocoetes were observed across all size ranges. The total survey area polygon was 2,220 sq/m and the total estimated survey area was 10.41 sq/m. The suitable region with Type I and II substrates encompassed 1,452 sq/m and an estimated 7.7 sq/m of this was surveyed. The estimated density within the suitable region was 6.5 fish per sq/m and the total estimated lamprey that may be inhabiting this region was 9,404.		Screening Facilities (DC Consulting LLC. And RP Mueller 2016).
5.	Conduct adult lamprey movement study using radio telemetry	BOR projects in Yakima	Yakima	In 2016, the Annual Report for Phase 3 of the USFWS adult Pacific lamprey passage study in the Yakima River was completed and released. Lamprey passage efficiency at Cowiche Dam was relatively high (79%), whereas at Roza Dam (0%) no tagged lamprey detected passing the complete fishway (including the	USFWS	Personal communication with Ann Grote, USFWS (10/11/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Adult Fish Facility). Work on a final synthesis report is ongoing.		Passage of Radio-tagged Adult Pacific Lamprey at Yakima River Diversion Dams 2014 Annual Report Phase 3: Roza and Cowiche Dams (Grote et al. 2016).
6.	Determining adult escapement and adult harvest monitoring	Willamette Falls	Willamette	In 2015, an estimated 32,112 Pacific lamprey passed through the fish ladder at Willamette Falls (95% CI 21,697 – 47,231). The number of lamprey in the horseshoe area of the falls was estimated at 136,286 based on the multiplier of tagged lamprey that failed to return to the ladder and escapement through the ladder. In 2015, there was a larger proportion of the total abundance that failed to return to the ladder. This may have been related to the low water year and discharge is known to affect whether lamprey are attracted to the horseshoe area or ladder. In 2015, there were 270 lamprey counted ascending lamprey ramps on the east side of the falls between June 4 and 16, 2015. Estimated harvest of lamprey at Willamette Falls in 2015 was 2,143.	CTWSR	Willamette Falls Lamprey Study. 2014 Annual Report to BPA (Baker 2016b)
7.	Evaluation of larval Pacific lamprey mainstem rearing	Bonneville	Columbia River	Larval Pacific lamprey occupancy was evaluated in tributary delta/mouth habitats in the mainstem Columbia River above and below Bonneville Dam. Tributary mouths sampled were the Klickitat, Hood, and Wind rivers in Bonneville Pool, as well as the Sandy, Washougal, and Kalama rivers below Bonneville Dam. A generalized random tessellation-stratified approach was used to delineate sample quadrats (30 m X 30 m) in a random, spatially-balanced order. Larval Pacific lampreys were detected in the mouths of the Wind, Washougal and Kalama	USFWS	Personal communication with Greg Silver, USFWS (10/6/16) Evaluation of Larval Pacific Lamprey Rearing in Mainstem Aras of the Columbia and Snake Rivers

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				rivers. Larvae too small to identify visually were collected in the Klickitat, Hood, and Sandy river mouths in addition to larval Western brook lamprey. Tissue clips were collected from unidentified larvae for genetic assignment of species. Genetic analyses of these specimens are pending.		Impacted by Dams (Jolly et al. 2016)
8.	Portland Harbor Superfund Restoration Monitoring: Larval Pacific Lamprey	No associated hydro project	Willamette River	Larval Pacific lamprey occupancy was evaluated at the Alder Point restoration area as well as six reference areas in the lower Willamette River. A generalized random tessellation-stratified approach was used to delineate sample quadrats (30 m X 30 m) in a random, spatially-balanced order from Willamette Falls downstream to the confluence with the Columbia, and including the Multnomah Channel. Larval Pacific lampreys were found to occupy the Oswego Creek mouth, Ross Island shoreline, and Cemetery Creek mouth reference areas. Larvae too small to identify visually were detected in the Alder Point restoration area, as well as the McCarthy Creek mouth and Multnomah Channel reference areas. Tissue clips were collected from unidentified larvae for genetic assignment of species. Genetic analyses of these specimens are pending.	USFWS	Personal communication with Greg Silver, USFWS (10/6/16)
9.	Evaluating Pacific lamprey occupancy	No associated hydro project	White Salmon, Wind, Washougal, Kalama rivers	Larval Pacific lamprey occupancy was evaluated in the White Salmon River basin above the former site of Condit Dam. Backpack electrofishing sampling was conducted for larvae in wade-able depth portions of the mainstem White Salmon River between BZ and Husum falls, Buck Creek, and Rattlesnake Creek. No larval Pacific lamprey were detected in any of the areas sampled. However, small, larvae too small to identify visually, as well as Western Brook larvae were collected in the mainstem White Salmon River above Husum Falls. Tissue clips were collected from unidentified larvae for genetic assignment of species. Genetic analyses of these specimens are pending. Pacific lamprey occupancy was also evaluated in the	USFWS	Personal communication with Greg Silver, USFWS (10/6/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Wind River, Washougal River, and Kalama River basins through backpack electrofishing. Larval Pacific lamprey were detected in 0 of 10, 50 m long reaches sampled in the Wind River basin, 2 of 10 reaches in the Washougal River basin, and 3 of 6 reaches in the Kalama River basin.		
10.	Lamprey monitoring	No associated hydro project	Hood River	In 2013, 11 sites in Hood River were sampled, including two in the mainstem, two in the Middle and West forks of the Hood River, and three in the East Fork Hood River. Sites sampled in tributaries included two in Neal Creek and one in Odell and Indian creeks. Ammocoetes were present in the Hood River up to the confluence with the East and West Fork Hood River (rkm 0 – 19.3). Ammocoete distribution extended 5.6 km up into East Fork Hood River. Total distribution in the Hood River Subbasin for larval Pacific lamprey was 24.9 rkm. Out of six sites sampled in Hood River and two in East Fork Hood River with ammocoetes present, four sites had ammocoetes large enough to sample. Lamprey captured upstream of the former Powerdale dam site (rkm 6.5) in 2013 were the first large enough to measure, which averaged 53.3 mm (range 39 – 82, n=18). There was no significant difference in mean lengths of ammocoetes upstream or downstream of the former dam site (t=-1.17, p- value=0.26, α=0.05), 50.9 and 57.1 mm, respectively. Densities in the four sites ranged from 2.1 to 17.8 ammocoetes/m^2. About 100 small (< 20 mm) ammocoetes were observed at every sample site throughout the mainstem and East Fork Hood River. Range expanded for Pacific lamprey recolonizing Hood River in 2014, where ammocoetes were detected 5.8 km further upstream in East Fork Hood River compared with 2013. In the Hood River sub-basin, there were no fish present in Middle or West forks.	CTWSR	Evaluate Status and Limiting Factors of Pacific Lamprey in the lower Evaluate Status and Limiting Factors of Pacific Lamprey in the lower Deschutes River, Fifteenmile Creek and Hood River, 2015 (Baker 2016b).

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Surveys in Odell, Neal and Indian Creek also had no presents of larval lamprey. In 2015, end of lamprey distribution in the Hood River was not completed.		
11.	Re-introduction evaluation	Pelton Round Butte	Deschutes	As part of relicensing the Pelton Round Butte Hydroelectric Project (PRB), the licensees, Portland General Electric and CTWSR, developed a Fish Passage Plan approved by the Federal Energy Regulatory Commission. A component of the Fish Passage Plan is the Pacific Lamprey Passage Evaluation and Mitigation Plan (PLEMP). To re-establish lamprey upstream of PRB, a series of assessments is called for in the PLEMP. The first step was to study habitats currently occupied downstream of PRB, then identify potential habitat upstream of PRB. Both juvenile and adult lamprey downstream of PRB were studied to ascertain: 1) timing and locations of spawning and overwintering, 2) spawning and rearing distribution, and 3) habitat associations. The culmination of this assessment was a theoretical abundance estimate of Pacific lamprey ammocoetes (larval lamprey) in habitat that may be re-colonized upstream of PRB. The extent of potential ammocoete rearing habitat upstream of PRB includes the Metolius River from the mouth to Camp Creek (rkm 13.8), the Deschutes River from the head of Lake Billy Chinook (rkm 193) to Big Falls (rkm 213), Whychus Creek from the confluence with the Deschutes River to Alder Springs (rkm 2.4) and the Crooked River from the head of Lake Billy Chinook to Opal Springs (rkm 6.9). Two models; a capture efficiency (CE) model and an ammocoete abundance model (AAM) were developed and used in conjunction with water temperature and habitat data upstream of PRB, which resulted in an estimate of 4.8 million ammocoetes (95% prediction	CTWSR	Personal communication with Cyndi Baker, CTWSR (10/13/16) Synthesis of Pacific lamprey studies conducted by the Confederated Tribes of Warm Springs Reservation of Oregon, 2003 to 2013 (Baker 2016c)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				interval = 3.7 to 7.5 million ammocoetes) for the identified habitat. The evaluation to determine whether lamprey can be re-established upstream of the PRB Hydrologic Complex (rkm 161) in the Deschutes River is complete, however a management decision on reintroduction is still pending. No new work on this topic was completed in 2014. A synthesis of lamprey studies undertaken by CTWSRO from 2003 to 2013, which addresses possible avenues for mitigation given the unlikely re-establishment of lamprey upstream of PRB, has been completed and will be available in 2016. The lamprey synthesis was completed in January 2016. No further lamprey re-introduction or evaluation work was done upstream of Pelton Round Butte Hydrologic Complex. Pacific lamprey end of distribution in the Deschutes River was confirmed with occupancy sampling in 2015; end of distribution was near the mouth of Shitike Creek (rkm 157).		
12.	Larval lamprey surveys for status and trend, distribution, relative abundance, and habitat availability	No associated hydro project	Yakima, Wenatchee, Entiat, Methow, White Salmon, and Klickitat	Sampling in 2016 for all subbasins focused on index sites (for long-term status and trend) with a mix of new sites to examine various questions, such as distribution, occupancy, habitat availability, entrainment rates into irrigation diversion, genetic analysis, and translocation potential or success. In the Yakima Subbasin, many larval Pacific Lamprey are found in the mid reaches of Yakima River and translocation tributary streams, and albeit small numbers, we have found larval Pacific Lamprey (>50mm) in Upper Yakima above Roza Dam for the first time this year since monitoring began in 2011. In the Wenatchee Subbasin, upper distribution of larval Pacific lamprey was pursued as well as relative abundance and habitat availability throughout the	Yakama Nation	Personal communication with Ralph Lampman, Yakama Nation (12/4/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				subbasin (Pacific Lamprey were documented for the first time upstream of Tumwater Dam since adult translocation the same year). In the Methow Subbasin, most time was spent assisting the Methow sampling lead by John Crandall (see Activity #14), but additional sites were covered to document translocation success. In the White Salmon Subbasin, Trout Lake Creek and White Salmon River was sampled to document distribution and abundance of lamprey (no Pacific Lamprey >50mm were found above the old Condit Dam site). In the Entiat Subbasin, key sites in lower, mid, and upper reaches were surveyed to monitor index sites (some larvae resembling Western Brook Lamprey were captured in the upper reach). 2015 Reports are available upon request (2016 Reports available in 2017).		
13.	Mercury study on adult lamprey in Lower Columbia River	No associated hydro project	Lower Columbia River and Prosser Holding Facility	PNNL analyzed total and methyl mercury in adult Pacific lamprey collected from the ocean, fresh migrants collected at Bonneville, The Dalles and John Day dams, and those held for broodstock at the Prosser Juvenile Fish Facility. The fish were collected in 2103, 2014, 2105 by the Yakama Nation Fisheries Program. There was a wide variation in THg concentrations in adult lamprey, particularly in mature females, which ranged from 0.26 – 7.98 ug/g wet weight. The mean ± SD for the fresh migrants was significantly lower (0.34 ± 0.25 ug/g wet) than those held up to 322 days until spawning at the Prosser Hatchery (2.14 ± 2.75 ug/g wet). Females generally had higher THg concentrations (0.43 ± 0.27 ug/g wet) than males (0.26 ± 0.22 ug/g wet) for the fresh migrants, as did mature females (2.35 ± 3.47 ug/g wet) compared to mature males (1.8 ± 1.17 ug/g wet), but there was no significant difference between sexes for either fresh migrants or mature fish Total Hg concentrations from two females and their eggs collected at Bonneville and John Day dams and held at the Prosser Hatchery until	PNNL, CRITFC and Yakama Nation	Personal communication with Robert Mueller, PNNL (10/12/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				ripe also showed evidence of generational Hg transmission. An adult female (530 mm) THg tissue concentration was 7.91 ug/g wet, whereas the concentration in the eggs was 1.02 ug/g wet, or a 12.8% transmission and a smaller female (456 mm), collected at John Day Dam, the tissue THg concentration was 1.13ug/g wet compared to 0.053 ug/g wet, or a 4.7% transmission.		
14.	Habitat restoration and effectiveness monitoring	No associated hydro project	Methow (Chewuch River)	A salmonid-based habitat restoration action on the Chewuch River at RM 10 is being assessed to determine its effects on 1) the distribution of larval lamprey rearing habitat, 2) the distribution and relative abundance of ammocoetes. The restoration project was initiated by the Yakama Nation and the monitoring component is being coordinated by John Crandall. Pre-treatment data was collected in 2010 and post-treatment data has been collected in subsequent years including 2013-2016. MSRF continues with larval status and trend monitoring at six sites (3 in Methow and 3 in Chewuch) with field assistance from Yakama Nation. Significant changes to larval habitat monitoring sites following spring runoff in 2016 will lead to changes in status and trend sites for 2017 sampling. First young of the year larvae (since lamprey sampling began in the Methow watershed in 2008) were observed in 2016 samples YN released several hundred adult lamprey into Methow River in fall 2015. Additional monitoring revealed larval use of several instream habitat restoration areas on the Methow River. Interim report to be completed spring 2017.	Methow Salmon Recovery Foundation, and Yakama Nation	Personal communication with John Crandall, Methow Salmon Recovery Foundation (10/10/16)
15.	Distribution and relative abundance monitoring of spawning and larval lamprey	No associated hydro project	Willamette	Spawning surveys of adult lamprey and backpack electrofishing for larval lamprey were conducted throughout the Willamette River Basin, 2011-2013. Lamprey redds were detected in all survey segments visited, including reaches on Ritner Creek (~4m average channel width) and the Santiam River (~70-100m average channel width), but more redds were	Oregon Cooperative Fish and Wildlife Research Unit at OSU	Personal communication with Luke Schultz, OSU (10/12/16) Using Spatial Resampling to Assess Redd Count

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				detected in reaches composed of alluvial underlying sediments. Spawning habitat was similar to that used by salmonids and results suggest that ongoing habitat restoration will be mutually beneficial for these species of concern. The attached manuscript details our findings related to developing monitoring plans for lamprey spawning. Larval lamprey were also collected throughout the Basin, but appeared to be limited by small anthropogenic barriers. In areas with adult access, we did not detect any differences in relative abundance across the basin, but larvae were strongly associated with low velocity burrowing habitats and, in particular, off channel areas (backwaters, side channels). Similar to adults, findings suggest habitat restoration strategies that increase the complexity of stream channels will be beneficial to Pacific lamprey juveniles. In addition, we developed length-based mortality estimation techniques and applied them to Pacific and brook lampreys from the Willamette River Basin. Results indicated that survival was fairly high (21% annual mortality) during the larval portion of the life cycle. These findings have immediate utility in the development of life cycle models to understand Pacific lamprey population dynamics and may be used in other fishes. Lastly, we used statistical resampling to evaluate sample sizes need to accurately describe length frequency distribution of larval Pacific lamprey populations with field sampling. Results suggested that sample sizes of 40-130 individuals were needed to describe length frequency, depending on the length interval used for performing the analyses. We recommend collecting 100 individuals and using 5 mm length intervals.		Survey Length Requirements for Pacific Lamprey (Mayfield et al. 2014) The distribution and relative abundance of spawning and larval Pacific lamprey in the Willamette River Basin (Schultz et al. 2014)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
16.	Spawning ecology	No associated hydro project	Willamette	We sampled embryos from redds of Pacific lamprey and used genetic parentage analysis to examine their spawning biology including the number of redds constructed per adult, the spatial distribution of spawning, and the number of different mating pairs that individual spawners parent. Embryos were found in only 20 of the 48 redds sampled (suggesting 58% false redds), however multiple sets of parents were detected in 44% of the true redds. Estimates from pedigree reconstruction suggested that there were 0.48 (95% C.I. 0.29-0.88) effective spawners per redd and revealed that individual lamprey contributed gametes to a minimum of between one and six redds, and, in one case, spawned in patches that were separated by over 800 m. These findings may provide useful information for refining lamprey redd survey methodologies.	Oregon Cooperative Fish and Wildlife Research Unit at OSU	Personal communication with Luke Schultz, OSU (10/12/16)
17.	Lamprey artificial propagation	N/A	N/A	Pacific lamprey artificial propagation research in 2016 focused on improving early survival of larvae and continued assessment of incubation timing. The work was conducted in close coordination with the Yakama Nation (Ralph Lampman) and the USFWS (Abernathy Fish Technology Center). Data indicated that food particle size is critical to early larval growth, as is culture density. Incubation timing was not affected by water supply, but differed between years of study (2015 and 2016). In 2015, we completed a review of pathogen prevalence in Pacific lamprey with data provided by state and federal fish pathologists which is still in review. Final assessment of PIT-tagging effects on larval lamprey was also completed and lamprey tagged as ammocoetes with 8.5 mm PITs were starting to metamorphose 2 years later. A manuscript detailing tag effects is in review.	NOAA Fisheries, CTUIR, Yakama Nation	Personal communication with Mary Moser, NOAA Fisheries (11/2/16)
18.	Lamprey artificial propagation	N/A	N/A	Since 2012, the Yakama Nation Fisheries in partnership with Confederated Tribes of the Umatilla	Yakama Nation,	Personal communication

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Indian Reservation, NOAA Fisheries, and U.S. Fish & Wildlife Service, have been refining best management practices for rearing newly hatched larval lamprey (1-3 months post fertilization), which appears to be the "bottleneck" life stage in the hatchery settings. In 2016, the Yakama Nation Fisheries focused on answering questions related to the effects of 1) density (with commensurate feeding rates), 2) supplemental feed types (Otohime vs. mixed leaves vs. mixed leaves / lamprey carcass), 3) spawning mat, 4) frequency of feeding (twice vs. three times a week), 5) turning off water during feeding, and 6) feeding schedule (constant vs. gradual). Feeding experiments using 20 aquarium tanks started on July 1, 2016, and lasted for 60-63 days. Preliminary results indicate that overall survival was high (80.4%) and average growth ranged from 8.2 mm to 13.1 mm per month (in length) and 0.017g to 0.052 g per month (in weight). Lamprey in the medium density (1500 fish per m2) treatment tank (with commensurate medium feeding rate) was able to maintain high survival and high rate of growth compared to lamprey in the high (3000 fish per m2) and low density (750 fish per m2) treatment tanks. Otohime A1 had the highest survival (>15% higher than others) and growth rates compared to the other supplemental feeds that were tested this year. These results indicate that newly hatched larvae can be reared successfully in relatively high density with high survival and growth rates given the refined best management practices demonstrated by this study.	CTUIR, NOAA Fisheries, USFWS	with Ralph Lampman, Yakama Nation (12/4/16)
19.	Lamprey translocation project including juvenile surveys and radio-telemetry studies.	No associated hydro project	Willamette	In 2016, the CTGR collected 240 adult pacific lamprey from Willamette Falls and translocated them to Fall Creek above the Fall Creek Dam. Electrofishing is also being conducted to determine the presence and distribution of juvenile lamprey both above and below the Fall Creek Dam. The study is ongoing with no formal reports available at this time.	CTGR	Personal communication with Torey Wakeland, CTGR (11/21/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
20.	Collection of adult lamprey for translocation, artificial propagation and radio-telemetry studies	No associated hydro project	Umatilla	In 2016, the CTUIR collected adult lamprey from lower Columbia River mainstem dams. In total, 1,003 adults were captured and transported to the South Fork Walla Walla lamprey holding facility throughout the fall and then moved to Minthorn Springs to over-winter. These fish will be used for translocation programs in the Umatilla and Grande Ronde basins; to support radio-telemetry assessments (releases in the lower Umatilla River); and to support artificial propagation research occurring at the Walla Walla Community College, Water Environmental Center lab.	CTUIR	Personal communication with Aaron Jackson, CTUIR (11/17/16)
21.	Collection of adult lamprey for translocation, artificial propagation and radio-telemetry studies	No associated hydro project	Yakima, Wenatchee, Methow	In 2016, the Yakama Nation collected adult lamprey from Lower Columbia River mainstem dams. In total, 858 adults were captured and transported to the Prosser Fish Hatchery (Prosser, WA). These fish will be used for translocation programs in the Yakima, Wenatchee, and Methow subbasins; to support radio-telemetry and PIT tag assessments; and to support artificial propagation research.	Yakama Nation	Personal communication with Ralph Lampman, Yakama Nation (12/4/2016)
22.	Pacific lamprey in the Columbia River Estuary	No associated hydro project	Lower Columbia Estuary	Little is known about the basic biology and ecology of most native lampreys, including the use of estuaries by anadromous lampreys. To address this deficiency, we provide the first analysis of anadromous western river (Lampetra ayresii) and Pacific (Entosphenus tridentatus) lampreys in the Columbia River estuary, using data from 2 fish assemblage studies that span 3 decades (1980–1981 and 2001–2012). Pacific lamprey juveniles and adults in the estuary clearly were separated by size, whereas western river lamprey formed one continuous size distribution. Pacific lamprey juveniles and adults were present in the estuary in winter and spring, and western river lamprey were present from spring through early fall. Depth in the water column also differed by lamprey species and age class. During 2008–2012, we documented wounds from lampreys on 8 fish species caught in the estuary. The most frequently wounded fishes were non-native	NOAA Fisheries	Seasonal abundance, size, and host selection of western river (*Lampetra ayresii*) and Pacific (*Entosphenus tridentatus*) lampreys in the Columbia river estuary (Weitkamp et al. 2015) Personal communication with Laurie Weitkamp, NOAA Fisheries (10/10/2016)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				American shad (Alosa sapidissima), subyearling Chinook salmon (Oncorhynchus tshawytscha), shiner perch (Cymatogaster aggregata), and Pacific herring (Clupea pallasii). This basic information on western river and Pacific lampreys in the Columbia River estuary adds to the growing body of regional research that should aid conservation efforts for these ancient species. Sampling in the spring of 2016 has occurred but information was not available at the time of reporting.		
23.	Larval Pacific lamprey distribution	No associated hydro project	Wenatchee, Entiat, Chelan, Methow, and Okanogan	In 2015, the Mid-Columbia River Fishery Resource Office conducted larval lamprey distribution surveys in several rivers in North Central Washington. Larval lamprey presence/absence was evaluated using APB-2 electrofishers. Site selection was either randomized (GRTS for occupancy modeling), or targeted (to determine the upstream extent of lamprey in the system). Genetics were collected from lamprey sampled in the Wenatchee and Entiat rivers. Analysis and reporting for this work is ongoing.	USFWS	Personal communication with Ann Grote, USFWS (10/11/16)
24.	Juvenile lamprey habitat evaluation and presence/absence	Wells	Columbia	In 2015, Douglas PUD surveyed the Wells Reservoir for potential juvenile lamprey habitat and used backpack electrofishing to determine presence/absence of ammocetes in areas with suitable habitat. Eleven sites, 30 m in length, were sampled on four occasions from July to November including one occasion when the Wells Reservoir elevation was reduced to an elevation of 773 ft. Suitable juvenile lamprey habitat was limited in the Wells Reservoir and no Juvenile lamprey were encountered over the course of the entire study.	Douglas PUD	Personal communication with Chas Kyger, Douglas PUD (10/10/16)
25.	Genetic assay to distinguish lamprey species	No associated hydro project	N/A	Several species of lamprey belonging to the genera *Entosphenus* and *Lampetra*, including the widely distributed Pacific Lamprey *E. tridentatus* and Western Brook Lamprey *L. richardsoni*, co-occur along the West Coast of North America. These genera can be	University of Manitoba	Simple Genetic Assay Distinguishes Lamprey Genera *Entosphenus* and

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				difficult to distinguish morphologically during their first few years of larval life in freshwater, thus hampering research and conservation efforts. However, existing genetic identification methods are time consuming or expensive. Here, we describe a simpler genetic assay using the Pacific Lamprey microsatellite locus Etr-1; the assay was found to be 100% reliable in distinguishing *Entosphenus* from *Lampetra*, even in genetically divergent *Lampetra* populations.		*Lampretra*: Comparison with Existing Genetic and Morphological Identification Methods (Docker et al. 2016)
26.	eDNA methods for lamprey: validating and refining an emerging tool	No associated hydro project	Columbia and Snake	eDNA is an emerging tool that can be used to detect a species based on DNA (feces, gametes, skin cells, etc.) shed into the environment. Interpretation of an eDNA presence for a species is difficult because we lack information on its relation to biomass, distance, and persistence in the environment. This study is working to test and refine field sampling approaches to detect lamprey eDNA in water and sediment samples. Tests use ammocoetes in controlled lab settings to evaluate sampling approaches (water vs. sediment), eDNA relationships to lamprey biomass, detection capability relative to distance, and eDNA persistence in water and sediment.	USGS	Personal communication with T. Liedtke, USGS (9/29/16)
27.	Radio telemetry of spawning translocated lamprey and assessment of final carcass fate	No associated hydro project	Yakima, Umatilla	A stated goal of Pacific lamprey recovery programs is to restore lamprey marine-derived nutrients, but relatively little information is available on post-spawn lamprey carcass fate. In 2015 and 2016, UI, CTUIR, Yakama Fisheries, and CRITFC radio-tagged and tracked 146 lamprey released between Satus Creek, Yakima Watershed (2015) and Catherine Creek, Grande Ronde Watershed (2016) prior to spawning. Spawning movements were tracked for 6-8 weeks until no new movements were detected, at which point final carcass fates were determined. Habitat variables related to in-stream retention of carcasses were high channel complexity, woody debris dams, and boulders. Carcasses with a final tag detection on the bank were	University of Idaho, Yakama Nation, CTUIR	Personal communication with Matt Dunkle, University of Idaho (9/28/2016)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				associated more with low complexity, shallow riffle/run type habitats.		
28.	Pacific lamprey carcass decomposition and juvenile salmon behavioral response	No associated hydro project	Yakima, Umatilla	Lamprey carcass decomposition and benthic macroinvertebrate response was observed using video observation and sampling of artificial substrates in a natural stream channel in the Yakima Basin. Carcasses were placed in mesh bags and weighted to the stream bed and split between the open channel and a net-pen exclosure to prevent gastropod colonization. In the Umatilla Basin, lamprey carcasses were placed in artificial stream channels along with juvenile Chinook salmon. Salmon growth, emigration, and behavior was assessed for 30 days as carcasses decomposed.	University of Idaho, CTUIR	Personal communication with Matt Dunkle, University of Idaho (9/28/2016)
29.	Environmental (eDNA) sampling	Tumwater Dam	Wenatchee	In 2016, the Mid-Columbia River U.S. Fish and Wildlife Office began a pilot eDNA project in the Wenatchee River Basin evaluating the efficacy of eDNA sampling to 1) detect Pacific lamprey in a large river system, 2) accurately describe the known distribution of lamprey in the system, and 3) monitor recolonization of the Upper Wenatchee River and tributaries by translocated adult lamprey.	USFWS	Personal communication with Ann Grote, USFWS (10/11/2016)
	Lamprey Migration in Rivers					
30.	General migration and upstream passage patterns	Bonneville, The Dalles, John Day, McNary	Columbia and Snake	Monitoring adult Pacific lamprey migration in the Columbia River Basin is an important part of understanding how dams and environmental factors affect lamprey behavior, dam passage success, and distribution among spawning areas. Our 2014 adult Pacific lamprey studies assessed Pacific lamprey (Entosphenus tridentatus) migration in the Columbia River Hydrosystem at a variety of scales. The results summarized in this report primarily address reach-scale and system-wide migration using detection data from lamprey tagged with either half duplex (HD)	University of Idaho Cooperative Fish and Wildlife Research Unit and NOAA Fisheries	Adult Pacific Lamprey Migration in the Columbia and Snake Rivers: 2014 Radiotelemetry and Half Duplex PIT-TAG Studies and Retrospective Summaries (Keefer et al 2015)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				passive integrated transponder (PIT) tags or an HD PIT tag and a radio transmitter. The 2005-2014 HD PIT dataset is an important time series for understanding migration-scale questions about adult Pacific lamprey. For this report, we tested the hypothesis that lamprey escapement past dams has increased through the study period. The weight of evidence from logistic regression analyses suggests that upstream escapement has statistically increased during the study period through most single- and multi-dam reaches and for all lamprey size classes. We think it is likely that operational and structural modifications at USACE dams intended to improve lamprey fishway passage efficiency have contributed to an increase in upstream escapement, though other unexplored explanations (i.e., changing ocean productivity) may also have been important.		
31.	Evaluate movement and fate of adult Pacific lamprey in Bonneville Reservoir and Lower Columbia River	Bonneville	Columbia	Between 2011 and 2014, we tagged adult Pacific lamprey with Juvenile Salmon Acoustic Telemetry System (JSATS) transmitters and half-duplex (HD) PIT tags and monitored their upstream migration behavior and final distribution in the Bonneville tailrace and reservoir and upstream of The Dalles Dam to the Deschutes River. Monitoring focused on the Bonneville Dam tailrace and reservoir, two areas with high unaccounted lamprey loss in past telemetry studies. Our objectives were to calculate lamprey travel rates, to estimate survival past the monitored sites, and to estimate final fates and distributions of tagged lamprey. We double-tagged a total of 784 adult Pacific lamprey collected at Bonneville Dam with both JSATS transmitters and HD-PIT tags over three study years (2011-2013). We deployed 15 to 33 JSATS	University of Idaho Cooperative Fish and Wildlife Research Unit	Adult Pacific lamprey migration behavior and survival in the Bonneville Reservoir and Lower Columbia River Monitored Using the Juvenile Salmonid Acoustic Telemetry System (JSATS), 2011-2014 (Noyes et al 2015)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				autonomous receivers each year between the Bonneville Dam tailrace and the John Day River. Travel rates for tagged fish were variable among individuals, and were higher in reservoir reaches than in dam reaches. The annual survival estimates varied widely for lampreys released into the Bonneville Dam tailrace past the dam. Final distributions of JSATS-tagged fish was consistent with results from past studies at coarse scales, indicated tributary entry during both fall and spring periods, and revealed substantial proportions last detected in tailraces. Overall, the multi-year study demonstrated: 1) the utility of acoustic technology for tracking adult lamprey in mainstem habitats; 2) rapid migration with high survival through lower and mid-reservoir habitats; 3) substantial numbers of lamprey apparently overwintering in tailrace habitats; and 3) previously undocumented downstream and tributary entry movements by lamprey in spring. The primary remaining uncertainties include the fate of substantial numbers of adult lamprey last detected in tailraces, specifically, the proportions of undetected adults that move into downstream tributaries and spawn, spawn in dam tailraces, or perished in the tailrace or upper reservoir.		
32.	Vulnerability of larval lampreys to hydrosystem operations: Effects of dewatering on movements and survival	No associated hydro project	Columbia	This study evaluated the effects of dewatering on larval lamprey movement and survival. The objective of this controlled laboratory study was to document the response of larval lamprey to dewatering of their habitat, specifically – 1) their movement relative to	USGS	Vulnerability of Larval Lamprey to Columbia River Hydropower System Operations – Effects of

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				fish size and ramping rates, and 2) their survival relative to fish size and duration of exposure. Ammocoetes were able to survive short exposure to dewatering, but mortality increased steadily when exposure time exceeded 24 h, and was very high (>60%) after 48 h. Fish size significantly influenced survival and movement following dewatering, with smaller fish less capable of movement, and at greater risk for mortality. The odds of surviving dewatering increase by a factor of 2 for every 10 mm increase in total length. The fast dewatering rate we tested stranded more ammocoetes in the middle tank sections than the slow dewatering rate. Lamprey did not respond to the changing head pressure in the tank as it was dewatered, and they only initiated movements after the surface of the sediment had been exposed. Even a small amount of water over the sediment is protective because fish remain burrowed as if they were covered with deeper water.		Dewatering on Larval Lamprey Movements and Survival (Liedtke et al. 2015) Personal communication with T. Liedtke, USGS (9/29/16)
33.	Juvenile lamprey outmigration monitoring	No associated hydro project	Umatilla	In 2015-16, the CTUIR continue to operate a rotary screw trap at RM 2.5 of the Umatilla River to document juvenile lamprey outmigration timing. The trap is run from November to May of each year. Status and trend monitoring shows continued increases since initiating translocation. In December 2015 over 800 juvenile lamprey were tagged with 8.4-mm PITs to track downstream migration. Final reporting of this activity will become available soon.	CTUIR/NOAA	Personal communication with Mary Moser, NOAA (11/2/16)
34.	Larval / juvenile lamprey surveys in irrigation diversions	No associated hydro project	Yakima, Wenatchee	The Yakama Nation Pacific Lamprey Project has been active in October/November surveying dewatered irrigation canals within the Yakima and Wenatchee subbasins for larval / juvenile lamprey within these	Yakama Nation	Personal communication with Ralph Lampman,

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				diversions. There is a strong correlation between the amount of new fine sediment collected in diversions and the number of larvae found at these facilities. Lamprey of various sizes (sometimes in the thousands) were found behind screens. A new report summarizing this sampling from 2015 is available now. Multiple other reports were also made available in 2016, which focused on monitoring 1) larvae in the deep water during irrigation season using deep water electrofisher operated by PNNL, and 2) salvage and monitoring at key diversions, including Bachelor-Hatton Diversion (Ahtanum Cr), and Sunnyside and Wapato diversions from the Yakima River and Dryden Diversion from Wenatchee river and 3) PIT tagging of larvae and juvenile in and near Sunnyside and Chandler diversions to evaluate passage and survival. Also, larval/juvenile lamprey outmigration counts at Chandler Diversion are tallied annually from which movement timing and environmental variables triggering movement is analyzed.		Yakama Nation (12/4/2016)
35.	Juvenile lamprey data synthesis	Lower Granite, Little Goose, Lower Monumental, Rock Island, McNary, John Day and Bonneville	Columbia and Snake	We compiled and summarized previous sources of data and research results related to the presence, numbers, and migration timing characteristics of juvenile (eyed macropthalmia) and larval (ammocoetes) Pacific lamprey Entosphenus tridentatus, in the Columbia River basin (CRB). Included were data from various screw trap collections, data from historic fyke net studies, catch records of lampreys at JBS facilities, turbine cooling water strainer collections, and information on the occurrence of lampreys in the diets of avian and piscine predators. We identified key data gaps and uncertainties that should be addressed in a juvenile lamprey passage research program. The goal of this work was to summarize information from disparate sources so that managers can use it to prioritize and guide future research and monitoring	USGS	Synthesis of Juvenile Lamprey Migration and Passage Research and Monitoring at Columbia and Snake River Dams (Mesa et al. 2015)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				efforts related to the downstream migration of juvenile Pacific lamprey within the CRB. A common finding in all datasets was the high level of variation observed for CRB lamprey in numbers present, timing and spatial distribution. This will make developing monitoring programs to accurately characterize lamprey migrations and passage more challenging. Primary data gaps centered around our uncertainty on the numbers of juvenile and larval present in the system which affects the ability to assign risk to passage conditions and prioritize management actions. Recommendations include developing standardized monitoring methods, such as at juvenile bypass systems (JBS's), to better document numbers and timing of lamprey migrations at dams, and use biotelemetry tracking techniques to estimate survival potentials for different migration histories.		
36.	Assess lamprey passage success post fishway modifications, raw conversion rates via fishway window counts	Rocky Reach	Columbia	Window Count Conversions Rates and Fishway Passage Studies, Rocky Reach Dam- 2015 fishway window counts of adult lampreys at Rock Island Dam (14 April - 7 October) were 2,163 fish; Rocky Reach Dam fishway count were 2,131 adult lamprey for a raw unadjusted window count conversion rate of 98.52% at Rocky Reach. Raw conversions do not account for fall back and re-ascent/re-count of fish at Rock Island or Rocky Reach, or for escapement of fish into the Wenatchee River downstream of Rocky Reach Dam. 2016 in Progress Studies – Results are DRAFT. As of 10/29/16, the raw RIS-RRH top of fishway window count conversion rate for Pacific Lamprey is 98.60% (RIS count -2,165: RRH count -2,134). 2016 in progress (as of 10/26) - adult lamprey PIT tag passage study - 211 tagged lampreys released eight kilometers	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (10/25/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				below Rocky Reach in August-Sept 2016; 163 tagged lampreys detected at Rocky Reach thus far, 162 successfully moved through fishway and exited at top of ladder for passage rate of 99.4%. Rocky Reach reporting best adult Pacific Lamprey hydro passage on Columbia River.		
37.	Vulnerability of larval lampreys to hydrosystem operations: Effects of dewatering on movements and survival of cultured larval lamprey vs. recently captured	No associated hydro project	Columbia and Snake	This work is an expansion of work outlined in table item 32. The same approach was used, controlled laboratory tests of ammocoete movement and survival following dewatering, but it compares the responses of cultured lamprey (similar to those used for item 32) to those of ammocoetes recently captured from the field. Laboratory tests due to be completed Fall, 2016.	USGS and USFWS	Personal communication with T. Liedtke, USGS (9/29/16)
38.	Examine adult lamprey approach and passage	Wells	Columbia	Many of the previous adult Pacific lamprey passage studies at Wells Dam have relied on fish captured in the Columbia River at downstream locations and translocated and released in the Wells Dam tailrace. A key assumption of previous studies using translocated lamprey is that those fish will exhibit upstream migratory behavior and are motivated to approach and attempt to pass Wells Dam. However, the results of previous studies at Wells Dam showed that approximately half or less of radio-tagged translocated lamprey released in the tailrace interacted with the dam (LGL and Douglas PUD 2008; Robichaud and Kyger 2014). In addition, a pilot acoustic telemetry study by Grant County PUD in 2015 showed that only 1% of lamprey captured and acoustic tagged at Priest Rapids and released at two locations downstream of Rocky Reach Dam were detected within one mile of Wells Dam (Grant PUD 2015, unpublished data). The results from these investigations suggest that the assumption that translocated lamprey, and perhaps non-translocated lamprey, actively approach or are motivated to pass Wells dam may be invalid.	Douglas PUD	Personal communication with Chas Kyger, Douglas PUD (10/10/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				In order to identify potential passage issues and to effectively evaluate structural and operational modifications designed to improve lamprey passage, the assumption that lamprey are actively migrating and approaching Wells Dam with the intent to pass must be met. The primary goals of the 2016 study are to investigate the validity of this assumption using acoustic telemetry while also gleaning information on lamprey passage behavior and the effectiveness of recent structural modifications that are aimed at improving entrance efficiency. Results of the study will be available in 2017.		
39.	Migration data from translocated adults	No associated hydro project	Yakima, Wenatchee, and Methow	This project is composed of two parts: 1) summary of all 2015-2016 broodstock adult Pacific Lamprey releases within the Yakima, Wenatchee, and Methow subbasins and 2) analysis of migration data from those adults that were PIT tagged. From the 2015-2016 broodstock (adults collected in summer 2015 that primarily matured in 2016), approximately 700 adult Pacific Lamprey were released in three lower Yakima River tributaries (Satus, Toppenish, and Ahtanum) and mainstem Yakima River between summer 2015 and spring 2016. Between fall 2015 and summer 2016, 420 adults were placed in lower and upper Wenatchee River (none in the tributaries). In spring 2016, 250 adults were placed in the lower, mid, and upper reaches of Methow River (none in the tributaries).	Yakama Nation	Personal communication with Ralph Lampman, Yakama Nation (12/4/2016)
	Adult Passage at Hydroelectric Facilities					
	Structural and Operational Fishway Modifications					
40.	Ladder tours	McNary	Columbia and Snake	Completed a tour of fish ladders with regional fish managers and researchers to identify potential minor fishway modification opportunities.	ACOE	Personal communication with Sean Tackley,

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Although tours were again offered in 2015, participation has waned. Future tours will only include ladders with new modifications.		ACOE (10/14/16) and Steve Juhnke, ACOE (9/30/16)
41.	Inspect fishway at Priest Rapids and Wanapum dams and identify areas that could represent passage problems for adult Pacific lamprey	Priest Rapids, Wanapum	Columbia	In March 2016, Grant PUD conducted tours during scheduled maintenance outages with the PRFF members to evaluate the modifications to the fish ladders to improve adult lamprey passage (i.e., plating installation, adult lamprey collection facilities, newly designed count stations, and ramps downstream of perched orifices) and to identify any potential passage problem areas.	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)
42.	Design lamprey passage system (LPS) for Westland Diversion	Westland diversions	Umatilla	In 2015, the Umatilla Tribe continued refinement of design of the LPS for the Westland Diversion. The diversion dam is located in the Umatilla River watershed. Additional information was not available for inclusion in the 2016 report.	CTUIR	Personal communication with Aaron Jackson, CTUIR (11/17/16)
43.	Design LPS for Prosser Dam	Prosser, Sunnyside, Wapato, Horn Rapids dams	Yakima	In 2016, a Project Alternatives Solution Study (PASS) was completed by a consortium of agencies (e.g. BOR, Yakama Nation, and USFWS) and successive meetings were held to implement the best alternative to achieve improved adult Pacific Lamprey passage at Prosser Dam. On November 7, 2016, two vertical wetted wall lamprey structures were successfully deployed to help improve passage. The PASS report is available upon request.	Yakama Nation, USFWS, and Bureau of Reclamation	Personal communication with Ralph Lampman, YN (12/4/2016)
44.	Passage improvement design	McNary	Columbia	A prototype adult lamprey passage structure was installed in Oregon shore ladder (SFE2) in February 2014. Structure usage and passage success were monitored using DIDSON, optical video and HDX PIT-tags, during a two year evaluation. The two years (2014 and 2015) results are available in the cited annual reports.	ACOE	Evaluation of Adult Fish Ladder Modifications to Improve Pacific Lamprey Passage at McNary and Ice Harbor Dams,

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
						2014 (Thompson et al. 2015). Evaluation of Adult Fish Ladder Modifications to Improve Pacific Lamprey Passage at McNary Dam, 2015 (Thompson et al. 2016). Personal communication with Steve Juhnke, ACOE (9/30/16)
45.	Installation and/or utilization of slotted “keyhole” fishway entrance at Project	Priest Rapids, Wanapum	Columbia	Grant PUD currently utilizes the “keyhole” fishway entrance at Priest Rapids and Wanapum dams.	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)
46.	Modify dewatering procedures	All ACOE projects	Columbia and Snake	Modifications to dewatering procedures to reduce stranding and mortalities have occurred over the past several years. These include: managing dewatering to better flush fish down to the tailrace; to keep fish remaining in the ladder in standing water while dewatering to reduce the efforts by lamprey to move through gratings when stranded; and adequate personnel and equipment to ensure timely salvage. This is an ongoing action.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)
47.	Modify dewatering procedures	Wells	Columbia	Pursuant to the Wells Habitat Conservation Plan (HCP; Douglas PUD 2002), a dewatering protocol is in place.	Douglas PUD	Personal communication with Chas Kyger, Douglas PUD (10/10/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
48.	Modify dewatering procedures	Rocky Reach, Rock Island	Columbia	Pursuant to the Rocky Reach Unwatering/Water up Job Plan 1402 and Rock Island Standard Operating Procedures (SOP), fishway, dewatering protocols and fish recovery operations for all species are followed during annual winter fishway maintenance and dewatering activities. This is an ongoing activity.	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (10/25/16)
49.	Modify dewatering procedures	Priest Rapids, Wanapum	Columbia	Pursuant to the Project Fishway Operation Plan, dewatering protocols are followed annually during winter maintenance and dewatering activities.	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)
50.	Operation of old fishway for lamprey passage	Willamette Falls	Willamette	Based upon past lamprey evaluations conducted at Willamette Falls, activities to restore portions of the existing “old fishway” to operability were completed in 2011 with the completion of a 52m linear curb and an adjustable headgate. The facility began operation in early spring 2012 when flows decrease below a river elevation (upstream of the falls) of 54 feet. Current information indicated that lamprey congregate in an area of this fishway early in the migration season. Operations of this fishway allow lamprey volitional passage to the forebay of the project. In 2016, Portland General Electric (PGE) continued to operate the “old fishway” and install lamprey ramps to facilitate adult lamprey passage at Willamette Falls Dam. The CTWSR has been evaluating these structures using cameras and PIT tags. Results of these studies have shown lamprey utilizing these passage structures each year.	PGE	Personal communication with Dan Cramer, PGE (09/29/16)
51.	Passage design elements for new fishway construction	Trail Bridge Dam	McKenzie	As part of the implementation of the Carmen-Smith Project FERC license (currently awaiting issuance), the Eugene Water & Electric Board (EWEB) has included several design elements in the Trail Bridge Dam trap and haul that will assist in the upstream passage of Pacific Lamprey.	EWEB	Personal communication with Andy Talabere, EWEB (10/12/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				A lamprey ramp or other passage system for Pacific lamprey that 1) integrates with the trap and haul, 2) which could be installed at a future date if necessary, and 3) will exclude lamprey from the trap pool.		
52.	Reduced water velocities at fishway entrances	Bonneville	Columbia	Continued reduced nighttime flow operations at the Washington Shore Fish Ladder during the lamprey passage season to improve lamprey passage efficiency.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)
53.	Reduced water velocities at fishway entrances	McNary	Columbia	In 2013, continued reduced nighttime flow operations were implemented at the Oregon Shore Fish Ladder entrances, to improve lamprey passage efficiency. In 2014, reduced nighttime flow operation occurred only at SFE1. An adult lamprey passage structure was installed in SFE2, and normal flow operations were maintained. This is an ongoing action.	ACOE	Personal communication with Steve Juhnke, ACOE (09/25/15)
54.	Lift picket leads at count station	Bonneville	Columbia	In 2011, lifted picket leads by 1 inch at Bradford Island Fish Ladder count station to improve access to AWS channel LPS. The 1 inch spacers were removed mid-passage season (June 29) due to an incident in which dozens of sockeye salmon were found milling behind picket leads. During an emergency dewatering on June 30, it appeared that the sockeye were able to get behind the picket leads via inconsistencies in the floor surface at the base of the picket leads (some gaps were up to 3 inches). ACOE modified picket leads at Bradford Island during winter 2011-12 to allow lifting picket leads by 1 inch while ensuring a contiguous floor surface. University of Idaho monitored these picket leads in summer 2012. Results suggest that adult salmonids, including relatively small-bodied sockeye salmon, jack Chinook salmon, and steelhead, did not attempt to or successfully enter the AWS channel at Bradford Island during the viewing period. Observations from project biologists at Bonneville Dam also did not see sockeye	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				milling behind picket leads, despite the record-sized run. Accordingly, ACOE modified the Washington Shore Fish Ladder count station picket leads in winter 2012-13 to improve access to the AWS channel LPS in that fishway. This is now the standard configuration.		
55.	Lift picket leads at count station	The Dalles	Columbia	Lifted picket leads at East and North Fish Ladder count stations by 1.5 inches to provide alternative passage routes for Pacific lamprey. This is now the standard configuration.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)
56.	Lift picket leads at count station	John Day	Columbia	Lifted picket leads at South Fish Ladder (already lifted at North) count station by 1.5 inches to provide alternative passage routes for Pacific lamprey. This is now the standard configuration.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)
57.	Lift picket leads at count station	McNary, Ice Harbor, Lower Monumental, Little Goose, Lower Granite	Columbia and Snake	Lifted picket leads at fish ladder count stations by 1.5 inches to provide alternative passage routes for Pacific lamprey. This is an ongoing ladder operation.	ACOE	Personal communication with Steve Juhnke, ACOE (09/30/16)
58.	Maintain fishway operations criteria	Rock Island	Columbia	Pursuant to the Rocky Reach and Rock Island Fish Passage Plan (Chelan PUD 2012), fishway operations criteria are in place. In 2014, fish passage operations continued with denil extensions to all three Rock Island Dam fishways in response to the Wanapum emergency drawdown. Removal of these denils planned for winter 2016. Final passage counts of Pacific Lamprey at Rock Island Dam (April14-Nov 15, 2014) with fishway denils and lamprey passage structures in place during the Wanapum Reservoir drawdown was 2,451 adult lamprey which volitionally passed count stations at the top of the three Rock Island fishways.	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (10/25/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
59.	Maintain fishway operations criteria	Priest Rapids, Wanapum	Columbia	Pursuant to the Project Fishway Operation Plan (Grant PUD 2009), fishway operations criteria are routinely maintained.	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)
60.	Design, construction, and operation of lamprey collection and counting structure	John Day	Columbia	Modified count station area behind picket leads at John Day South Fish Ladder to facilitate 1) trapping for research or translocation activities, and 2) improved escapement estimates. Picket lead spacing was reduced to ¾ inches, except near the bottom, where openings allow lamprey to enter a small flume system leading to a trap and video counting mechanism still in development. When not in collection mode, the system allows lamprey to continue moving up the fishway. Evaluation in 2013-2015 was limited to monitoring the number of lamprey collected in the trap box, along with experimentation with various video configurations. Minor modifications to the system were completed in 2014 and in 2015 to improve functionality.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)
61.	Design, construction and testing of lamprey vertical climbing structure (wetted wall) for passage	Bonneville	Columbia	An experimental vertical climbing structure intended as a mechanism of passing lamprey out of a serpentine weir section of a fish ladder into a make-up water supply (MUWS) channel that features an LPS was tested in the FERL facility at Bonneville Dam in 2014. Lamprey climbing success was measured against three flow levels and three ways of supplying water to the structure. Lamprey passage was 100% under all experimental conditions for fish that interacted with the structure. A manuscript detailing this research has been submitted for publication and is currently in review.	NOAA Fisheries	Personal communication with Mary Moser, NOAA (11/2/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				The ACOE intends to field test this climbing structure in the Bonneville Dam Washington Shore Ladder in 2017.		
62.	Design of diffuser plating to provide attachment surface in fishways	Bonneville	Columbia	In 2014, ACOE re-designed diffuser plating that is to be installed at the Washington Shore Ladder at Bonneville Dam during the upcoming 2016-17 winter in-water work period. Plating designs used at The Dalles East and John Day South fish ladders was too large given the abnormally high diffuser velocities in this ladder. Hydraulic analysis suggests that the The Dalles/John Day style plating would drive average floor diffuser velocities to over 2 times the NOAA criteria of 0.5 ft/sec and would increase risk of diffuser grating blowouts.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)
63.	Design and construction of rounded caps and plating for fishway entrance weirs	Bonneville, The Dalles, John Day	Columbia	Modulating weirs located at fishway entrances are used to maintain consistent attraction flows under a variety of tailrace elevations. Radio-telemetry data have consistently shown delays and passage efficiency issues for Pacific lamprey at fishway entrances throughout the Columbia Basin, presumably due to the high velocities (> 8 fps) and turbulence associated with these features, and entrance weir geometry that makes attachment and entry challenging. As part of a broader minor fishway modifications project, in 2014 the ACOE designed novel, radiused weir caps to be installed on the flat crests of existing entrance weirs at the Bonneville Washington Shore Ladder. In addition to the rounded crests (to facilitate attachment) cap design included short plates on the ends of the weir crests to cover weir guide slots, along with approximately 2 ft of plating on the downstream faces of weirs to provide attachment surface for lamprey that are approaching the top of the weir. Caps were fabricated and installed by ACOE staff at the South Upstream Entrance (SUE) and South	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Downstream Entrance (SDE) at the Washington Shore Ladder in Winter 2014-15. Additional weir caps will be installed at the North Downstream Entrance (NDE) in Winter 2016-17. The ACOE intends to install similar structures at all applicable entrance weirs at Bonneville, The Dalles, and John Day dams through 2019.		
64.	Design of fishway modifications to improve lamprey passage conditions in serpentine weir (control) section of fishways	Bonneville	Columbia	The serpentine weir (control) sections of the Bradford Island and Washington Shore ladders at Bonneville Dam are known to be problematic for adult Pacific lamprey. This is probably due to a combination of high velocities, turbulence, confusing directional changes, cumulative effects of the passage experience, and lack of suitable cover/resting areas within the fishways. As part of a broader minor fishway modifications project, in 2015 the ACOE designed 1.5-in x 18-in weir orifices and prototype refuge boxes for testing in the serpentine weir sections of Bonneville Dam fishways. These structures are currently scheduled to be installed for initial evaluation at the Bonneville Washington Shore Ladder in Winter 2016-17.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)
65.	Install low-level fishway	Wells	Columbia	The low-level side fishway entrances on both Wells Dam fishways were re-opened and equipped with prototype lamprey entrances. The lamprey entrances consist of a fiberglass box with an opening to the tailrace one inch tall by eight feet wide. The interior of the box houses six rows of pipe bollards that serve to reduce water velocity and head differential. The designed water discharge and velocity of the lamprey entrances are approximately 1 cfs and 2 ft/s. Each lamprey entrance is equipped with a PIT antenna capable of reading half and full duplex PIT tags.	Douglas PUD	Personal communication Chas Kyger, Douglas PUD (10/10/16)
	Project Passage Effectiveness					

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
66.	Evaluate fishway modifications	Priest Rapids, Wanapum	Columbia	Grant PUD implemented a comprehensive adult passage evaluation study plan, titled "Assessment of Pacific lamprey behavior and passage efficiency at Priest Rapids and Wanapum dams" (Nass et al. 2009). The goal was to collect data in support of determining whether proposed modifications (plating, ramps at perched orifices, and lamprey-specific crowders at fish count stations) improved adult passage. HDX-PIT system were used to collect data from fish tagged downstream of Priest Rapids Dam. Pacific lamprey tagged at lower river facilities were passively monitored at PRP facilities as directed by the PRFF. In 2016, Grant PUD, in consultation with the PRFF, collected and tagged 150 adult Pacific lamprey with HDX PIT-tags to continue this multi-year evaluation. Preliminary cumulative data analysis will be completed as part of 2016 activities and included in the 2016 annual report. Final results will be included in Grant PUD's 2016 Comprehensive Annual Report and will be presented to the PRFF in early 2017 for review.	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)
67.	Evaluate passage at LPS structures	Threemile Falls Dam, Maxwell and Feed diversions	Umatilla	In the Umatilla River watershed, lamprey passage structures (LPS) have been completed and are operational at Threemile Falls Dam (July 2009), Feed Diversion (October 2010), and Dillon Diversion (2011). A flat plate was installed to aid upstream lamprey movement at Maxwell Diversion (August 2010). At Threemile Dam, 74% (n=515) of lamprey passed via the LPS and the remaining climbed the dam crest (n=186). Thirty-five adult lamprey used the lamprey passage structure at Dillon Diversion and two adult lamprey used the LPS at Feed Diversion.	CTUIR	Personal communication with Aaron Jackson, CTUIR (11/17/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Dillon diversion is scheduled for removal in 2017 therefore the LPS was removed in the fall 2016 and will be retrofitted for Westland Diversion in 2018.		
68.	Project passage evaluation	Clackamas	Clackamas	In 2013-2014, an active/passive tag evaluation using RT and HDX tags to evaluate passage success through the project was implemented. All fish were tagged at the trap in River Mill Fish ladder and released ~1 mile downstream to evaluate re-assent back through this facility and remaining NF ladder upstream. A total of 47 fish were active/HDX tagged and 45 HDX tagged. Results indicate high ladder passage success at River Mill Dam ladder (~84 - 96%). No fish were detected passing the NF Ladder though only 11 approached the North Fork Ladder. A follow up evaluation was conducted in 2015-2016 with a draft report nearing finalization. This evaluation also involved releases and tracking of radio and dual (PIT/radio) tagged lamprey adults. Passage rate estimates at River Mill Dam were high at 90-94%. Passage through the North Fork ladder was more problematic. Significant delay occurred at the ladder entrance with an entrance rate of 67%. Passage through the entire 1.9 mile ladder was quite low at 11.4% though other than the entrance, no specific problem areas were identified. A final report will be available by January 2017.	PGE	Evaluation of Adult Pacific Lamprey Upstream Passage Effectiveness through the Clackamas River Hydroelectric Project (Ackerman et al. 2014) Personal communication with Nick Ackerman, PGE 9/29/16
69.	Passage structure evaluations	Bonneville	Columbia River	Lamprey passage structures (LPS) have been installed at Bonneville Dam in an attempt to improve lamprey passage. The LPSs were operated from early April until late October to align with the lamprey migration past Bonneville Dam. Water temperatures in the LPSs were similar to Bonneville Dam forebay temperatures. Video captured during bi-weekly validations was used to calculate correction factors. These ranged from 0.58	ACOE	Darren Gallion, Presentation at AFEP, Portland, OR (11/30/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				– 1.0 (0.79 mean) at WA-AWS, 0.77 – 1.0 (0.95 mean) at CI, and 0.35 – 0.77 (0.51 mean) at BI-AWS. The majority of mechanical over counting (97%) was caused by lamprey attaching to the exit pipe and activating the counter when they attempted to reascend. The other 3% of over counting resulted from paddle bounce caused by the impact as lamprey exit the LPS. Our initial LPS passage estimate for 2016 at Bonneville Dam is 57k lamprey. This is the greatest number of lamprey to use the Bonneville Dam LPSs since testing began as a single LPS site in 2003 and is reflective of the large run this year. Routes of passage were, 41k (72%) WA-AWS, 12k (21%) BI-AWS, and 4k (7%), passed the CI LPS.		
70.	Evaluate migration characteristics of adult lamprey in the Priest Rapids Project	Priest Rapids, Wanapum	Columbia	In 2016, to evaluate passage behavior and travel times through various reaches of the Priest Rapids Project, including both reservoirs, 100 adult lamprey collected at Priest Rapids Dam were tagged with Vemco acoustic and FDX PIT tags and released at one of three locations; above Priest Rapids Dam (n=30 Desert Aire RM 400.3), or above Wanapum Dam at either the left bank boat launch (n=35 RM 416.0) or at Vantage (n=35 RM 419.9). Fixed receiver arrays were used to monitor lamprey that migrated within the Priest Rapids and Wanapum reservoirs. Detections of FDX PIT tags were queried using PTAGIS. Preliminary results of the study will be available in spring 2017.	Blue Leaf Environmental	Personal communication with Rod O'Connor (10/13/16)
71.	Evaluation of fishway modifications	Rocky Reach	Columbia	Based upon a literature review and site visit conducted in spring of 2010, Chelan PUD made modifications to the Rocky Reach fishway during the 2010-2011 and 2011-2012 fishway maintenance periods to improve adult lamprey passage at the Project. These improvements include installation of plating at diffuser gratings throughout the ladder, plating at orifices in the lower fish ladder sections where overflow weirs are	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (10/25/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				located, ramps at perched orifices in the upper ladder, and an HDX PIT tag detection system at key locations within the fishway and have been evaluated since 2013. In 2014, a total of 288 unique tagged lampreys detected at Rocky Reach in 2014 including 32 FCRPS tagged fish - 27 tagged at BON; 4 at John Day; and 1 Ice Harbor fish. 2014 and 2015 detections of tagged adults passing Rocky Reach indicate an ongoing passage rate of approximately 70%. Net ladder passage efficiency (NLPE) which considers drop back, fall back, and re-ascents of tagged fish is greatly improved. NLPE increased 23% from 2004 estimate of 47% using radio tagged fish at Rocky Reach. 2014 median in-fishway travel times for tagged lamprey from entrance to exit were 0.63 days; mean in-fishway travel times were 3.14 days. Fishway entrance efficiency from a release point 8 km downstream of Rocky Reach was 85.1%. 2016 – A Full Duplex PIT study is on going in 2016 at Rocky Reach. Currently 99.4% of adult lampreys detected at the dam have passed the dam.		
72.	Swimming behavior and performance	Bonneville	Columbia	The hydraulic and structural environment within the serpentine weir sections at Bonneville Dam are associated with both high turbulence and relatively long sections of high velocity at individual weirs that may act as a deterrent or barrier for lamprey passage. We assessed lamprey passage rates and behaviors at an experimental weir by varying treatment combinations of velocity, weir length, and turbulence similar to conditions found in the Bonneville Dam serpentine weir sections. We also compared results from the experimental flume to in-situ video observations of	University of Idaho, Department of Fish and Wildlife Sciences	Effects of water velocity, turbulence, and obstacle length on swimming capabilities of adult Pacific lampreys (Kirk et al. 2016)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				lamprey behavior within the serpentine weir sections of Bonneville Dam. We evaluated lamprey success rates and behavior in an experimental flume, which had a vertical slot structure similar in design to a serpentine weir at Bonneville Dam. This slot weir allowed us to manipulate three variables of interest. First, we had three different velocity treatments (1.2 m/s, 1.8 m/s, 2.4 m/s), which captured the range of velocities present within the Bonneville fishways. Second, we had three different slot lengths (0.33 m, 0.66 m, 1.00 m), because slot lengths differ considerably among serpentine weirs at Bonneville Dam. Third, we tested the effect of turbulence using treatments with or without a large deflector wall upstream of the weir, which produced large eddies representative of those in the serpentine weir sections. The overall experimental design consisted of 18 total treatment combinations (3 ×3 × 2) and each combination consisted of three replicates with 5-6 lamprey per replicate. There was no significant overall effect of velocity, turbulence, or slot length on lamprey success rates through the weir. There was however, a turbulence × slot length interaction, in which the lowest success rates (<70%) were observed for the high turbulence × long length treatments. There was no indication of direct body size effects on passage, but adults with larger inter-dorsal fin distance were more likely to pass. Subsequent monitoring of adults during upstream migration post-release provided no evidence of a correlation between passage success in the experimental flume and upstream migration distance, whereby lamprey that did not pass the experiments had similar upstream escapement estimates throughout the hydrosystem as lamprey that did pass the experiments.		

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Detailed results are presented and discussed in the relevant source citation.		
	Lamprey Counts at Dams					
73.	Conduct 24-hour lamprey counts	Bonneville, The Dalles, John Day, McNary, Lower Granite	Columbia and Snake	Counts include nighttime video window counts. Nighttime counting was expanded in 2012 to include The Dalles and John Day dams. This is an ongoing operation. Nighttime counts at Bonneville Dam, are problematic due to extensive up/down movement at the fish count windows (probably largely due to poor passage conditions in the control sections of the Washington Shore and Bradford Island fish ladders). The ACOE is discussing options for how to address this problem and communicate count uncertainties to regional fish managers in future years. Validated LPS counts from Bonneville Dam are reported in tabular format to interested parties via email, but are not posted directly to the ACOE or Fish Passage Center (FPC) fish count websites. The ACOE is considering options for incorporating LPS counts (which constitute a substantial portion of passage at the dam) into counts reported online. The ACOE currently anticipates that LPS counts will be integrated into the broader fish count data posted online by 2019.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)
74.	Conduct 24-hour lamprey counts	Wells	Columbia	On-going 24-hour fishway monitoring since the 1990's.	Douglas PUD	Personal communication with Chas Kyger Douglas PUD (10/10/16)
75.	Conduct 24-hour lamprey counts	Rocky Reach, Rock Island	Columbia	On-going 24-hour fishway monitoring since the late 1980's.	Chelan PUD	Personal communication with Steve

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
						Hemstrom, Chelan PUD (10/25/16)
76.	On-going 24-hour fishway monitoring since the mid 1990's.	Grant PUD	Columbia	On-going 24-hour fishway monitoring since the mid 1990's.	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)
77.	Conduct 24-hour lamprey counts	Prosser and Roza	Yakima	On-going 24-hour fishway monitoring since 1996 at Prosser Dam and since 1997 at Roza Dam.	Yakama Nation	Personal communication with Ralph Lampman, Yakama Nation (12/4/16)
78.	Estimate adult lamprey upstream passage success rates, ladder passage times, entrance slot preference and fallback rates at Snake River dams.	Ice Harbor, Lower Monumental, Little Goose, and Lower Granite	Snake	In 2014 and 2015, ACOE contracted with Cramer Fish Sciences, to conduct an adult lamprey migration behavior and passage success evaluation in the Lower Snake River. Adult Lamprey were captured at the John Day Dam (JDA) north ladder LPS, and the JDA South ladder lamprey trap, tagged onsite, and transported for release into Ice Harbor dam tailrace or forebay. Opportunistically, test fish included lamprey previously radio- and/or PIT-tagged for lower Columbia River lamprey modification evaluations, if detected migrating up the Snake River. Specific objectives are: Determine which ladder entrances slots (multiple entrance slots per ladder entrance) attract the majority of migrating adult lamprey to aid in developing future entrance design modifications. Estimate adult lamprey upstream passage success rates, relative fishway route use, passage times, turnaround/ladder fallout, and forebay fallback at Ice Harbor Dam (IHR), Lower Monumental Dam (LMN),	ACOE	Personal communication with Steve Juhnke, ACOE (09/30/16) Evaluation of Adult Pacific Lamprey Passage at Lower Snake River Dams, 2014 (Stevens et al. 2015). Evaluation of Adult Pacific Lamprey Passage at Lower Snake River Dams, 2015 (Stevens et al. 2016).

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				Little Goose Dam (LGO), Lower Granite Dam (LGR) using radio-telemetry, HDX-PIT technology, and visual counts. Determine conversion rates of migrating adult lamprey between Snake River dams based on a combination of RT and PIT-tag detections. The two years (2014 and 2015) results are available in the cited annual reports.		
	Predation					
79.	Establish predation control measures (sea lions)	Bonneville	Columbia	Ongoing implementation of predation control measures, such as sea lion removal efforts - although planned for salmon, are also expected to benefit adult Pacific lamprey. Efforts are being made to be sure to include concerns for lamprey and adequate monitoring of lamprey predation in future efforts.	ACOE	ACOE Pacific lamprey passage improvements implementation plan, 2008-2018 (ACOE 2009)
	<u>Juvenile Passage at Hydroelectric Facilities</u>					
	Structural and Operational Fishway Modifications					
80.	Delayed deployment of extended length screen during outmigration	McNary	Columbia	Installation of extended screens has been delayed each year since 2013 to reduce impacts to juvenile lamprey migrating out early.	ACOE	Personal communication with Steve Juhnke, ACOE (09/30/16)
81.	JBS modifications	McNary	Columbia	Extended the JBS raceway waste water outfall pipe and altered JBS raceway screen mesh size to allow juvenile lamprey to volitionally pass from the raceway back to the river. This is the current configuration and an ongoing action.	ACOE	Personal communication with Steve Juhnke, ACOE (09/30/16)
82.	JBS outfall relocation	McNary, Lower Monumental	Columbia / Snake	JBS outfalls were relocated downriver from existing locations. The outfall relocations were done to improve salmonid survival, but juvenile lamprey will benefit	ACOE	Personal communication

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				from the new locations as well. This is the current configuration and an ongoing action.		with Steve Juhnke, ACOE (09/30/16)
83.	Continue salvage activities during ladder maintenance de-watering	All ACOE projects	Columbia / Snake	Modifications to dewatering procedures to reduce stranding and mortalities have occurred over the past several years. These include: managing dewatering to better flush fish down to the tailrace; to keep fish remaining in the ladder in standing water while dewatering to reduce the efforts by lamprey to move through gratings when stranded; and adequate personnel and equipment to ensure timely salvage. This is an ongoing action.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16) and Steve Juhnke, ACOE (09/30/16)
84.	Continue salvage activities during ladder maintenance de-watering	Wells	Columbia	Pursuant to the Wells Habitat Conservation Plan (HCP; Douglas PUD 2002), a dewatering protocol is in place. Any adult lamprey captured during salvage activities are released upstream of Wells Dam, juveniles downstream per the Wells Pacific Lamprey Management Plan.	Douglas PUD	Personal communication with Chas Kyger Douglas PUD (10/10/16)
85.	Continue recovery activities during ladder maintenance de-watering	Rocky Reach, Rock Island	Columbia	Pursuant to the Rocky Reach Unwatering/Waterup Job Plan 1402 and Rock Island SOP, fishway dewatering protocols and fish recovery operations for all species are followed during annual winter fishway maintenance and dewatering activities.	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (10/25/16)
86.	Continue salvage activities during ladder maintenance de-watering	Priest Rapids, Wanapum	Columbia	Consistent with its Fishery Operations Plan (Grant PUD 2010), Grant PUD conducts collection operations for all fish species during annual ladder maintenance activities.	Grant PUD	Personal communication with Mike Clement (10/12/16)
87.	Maintain bypass operations criteria	Rock Island	Columbia	Pursuant to the Rocky Reach and Rock Island Fish Passage Plan (Chelan PUD 2012), bypass operations criteria are in place.	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (10/25/16)
88.	Maintain bypass operations criteria	Priest Rapids, Wanapum	Columbia	Grant PUD has existing bypass systems, which includes gatewells, spillways, the WFUFB, and Priest Rapids Top-Spill Bypass.	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
	Project Passage Effectiveness					
89.	Monitor passage timing, number, and mortalities of juvenile lamprey collected at projects with juvenile fish bypass facilities	Bonneville, McNary, Lower Monumental, Little Goose, Lower Granite	Columbia and Snake	Monitoring is occurring at all of the identified projects. This is an ongoing action.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16) and Steve Juhnke, ACOE (09/30/16)
90.	Juvenile lamprey monitoring	Bonneville, John Day, McNary, Lower Monumental, Little Goose, Lower Granite, and Rock Island	Columbia and Snake	The FPC continues to monitor juvenile and adult lamprey passage at many Columbia River dams. Adult passage data are from window counts while juvenile passage data are collected as part of the smolt monitoring project. Data is available for query at www.fpc.org	FPC	www.fpc.org
91.	Development of a juvenile lamprey acoustic transmitter	No associated hydro project	N/A	With co-funding from the ACOE and Department of Energy (DOE), a project has been implemented to design, prototype, and evaluate an acoustic microtransmitter that can be used to study the behavior and survival of juvenile eel and lamprey. Laboratory research will be used to guide the design of the transmitter and provide guidance for field deployment. In 2016 we completed the design of an acoustic micro-transmitter that can be used to study the behavior and survival of juvenile eel and lamprey. It is 2 mm in diameter and 12 mm in length. It weighs 0.08 g in air. The prototype tag lasts 20 to 30 days at 5-s ping rate interval. The biological tagging results from implanting juvenile Pacific lamprey showed that implantation is not likely to have an adverse impact on fish survival over a 28-day holding period. Additionally, there was minimal tag loss due to shedding for fish greater than 130 mm in length. The surgical procedure was effective at placing tags within	PNNL	Daniel Deng, Presentation at AFEP, Portland, OR (11/29/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				the body cavity without causing significant hemorrhaging or fungal infections at the tagging site. The sustained swimming tests showed no significant differences in swimming ability when comparing implanted fish to control fish for all size classes tested (120–160 mm).		
	Predation					
92.	Establish predation control measures (pike minnows and birds)	All ACOE projects	Columbia	Ongoing implementation of predation control measures such as harassment, avian lines, avian colony management, and the pikeminnow bounty program, although planned for salmon, are also expected to benefit juvenile Pacific lamprey. Efforts are being made to be sure to include concerns for lamprey and adequate monitoring of lamprey predation in future efforts.	BPA	ACOE Pacific lamprey passage improvements implementation plan, 2008-2018 (ACOE 2009)
93.	Predation control measures and gut sampling	Rocky Reach, Rock Island	Columbia	As part of its HCP obligations, Chelan PUD implements predation control activities. Controlling predators of juvenile salmonids, both fish and birds, is a tool Chelan PUD has used to achieve HCP survival standards for juvenile fish. In 2016, pikeminnow control programs continued in both Rock Island and Reach; Programs utilize long-line and rod-reel angling in tailrace and main reservoirs by Chelan PUD contractors and Chelan PUD fish crews. Chelan PUD's total pikeminnow catch in 2016 from Rock Island and Rocky Reach reservoirs combined was 91,522 fish.	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (1/5/17)
94.	Predation control measures	Priest Rapids, Wanapum	Columbia	Grant PUD implements predation control measures (avian and aquatic) to protect outmigrating, anadromous salmonids as a requirement of Grant PUD's NOAA Biological Opinion (NOAA Fisheries 2004). These measures include use of lethal and non-lethal control and monitoring presence and absence of juvenile lamprey through dietary sub sampling. It would be expected that these predation control	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				activities will indirectly benefit outmigrating juvenile lamprey throughout the project.		
	<u>Policy/Recovery Activities</u>					
95.	Develop/implement implementation plan for Pacific lamprey restoration	All ACOE projects	Columbia and Snake	In May 2009, the Nez Perce, Umatilla, Yakama and Warm Springs tribes ("tribes") developed a Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. A final draft of the Plan was completed in December 2011. The tribes propose the plan for restoration of the species to numbers adequate for tribal use and ecological health of the region. Activities to support the objectives identified in the plan are ongoing.	Nez Perce, Umatilla, Yakama and Warm Springs tribes	Tribal Pacific lamprey restoration plan for the Columbia River basin (Nez Perce, Umatilla, Yakama, and Warm Springs Tribes 2011)
96.	Develop/implement Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research	No associated hydro project	Columbia (Mid and Upper)	This Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research is a phased approach, emphasizing adaptive management, with the goal of making progress towards the supplementation, artificial propagation, and aquaculture research goals and biological objectives identified in TPLRP, Lamprey Conservation Agreement (USFWS 2012), the Framework for Pacific Lamprey Supplementation research in the CRB (CRITFC 2014), subbasin plans, and the Columbia Basin Fish Accords within a feasible, cost effective, and biological conservative manner. The Master Plan intends to continue utilizing adult translocation as well as the structured, strategic, and phased release of artificially reared Pacific Lamprey to reintroduce, augment, and/or supplement Pacific Lamprey within select Columbia River Basin subbasins to achieve the stated, long-term goals identified in various lamprey planning documents and restoration efforts. A draft report was shared with co-managing agencies and partners and the final draft for submission is scheduled to be complete in early 2017.	HDR Engineering, Inc., CRITFC, Yakama Nation, and CTUIR	Personal communication with Ralph Lampman, Yakama Nation (12/4/2016)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
97.	Implementation of Pacific lamprey restoration plan	All ACOE projects	Columbia and Snake	In May 2009, the Nez Perce, Umatilla, Yakama and Warm Springs tribes ("tribes") developed a Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. A final draft of the Plan was completed in December 2011. The tribes propose the plan for restoration of the species to numbers adequate for tribal use and ecological health of the region. Activities to support the objectives identified in the plan were implemented in 2013 (see other categories in Table 5).	ACOE	ACOE Pacific lamprey passage improvements implementation plan, 2008-2018 (ACOE 2009)
98.	Develop/implement management plan for Pacific lamprey restoration	Wells	Columbia	In 2010, a PLMP was filed as part of the Wells Hydroelectric Project FERC License Application. In addition to fishway evaluations and activities to improve adult lamprey passage and juvenile passage and survival (when technology exists), management plan activities also include implementation of adult fishway and juvenile bypass operations criteria at the Project, regional data sharing, protocol development, and participation in regional conservation and recovery activities. Implementation of some management plan activities is ongoing.	Douglas PUD	Personal communication with Chas Kyger, Douglas PUD (10/10/16)
99.	Develop/implement management plan for Pacific lamprey passage monitoring and improvement	Rocky Reach	Columbia	On-going implementation of the PLMP that was developed and finalized in 2005. In addition to fishway evaluations and activities to improve adult lamprey passage and juvenile passage and survival (when technology exists), management plan activities also include implementation of adult fishway and juvenile bypass operations criteria at the Project, regional data sharing and protocol development, and participation in regional conservation and recovery activities.	Chelan PUD	Rocky Reach Pacific Lamprey Management Plan (Chelan PUD 2005)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
100.	Develop/implement management plan for Pacific lamprey restoration	Priest Rapids, Wanapum	Columbia	On-going implementation of the PLMP that was developed, finalized, and approved by the PRFF, Ecology, and FERC in 2009. In addition to fishway evaluations and activities to improve adult lamprey passage and juvenile passage and survival (when technology exists), management plan activities also include, regional data sharing, protocol development, and participation in regional conservation and recovery activities.	Grant PUD	Priest Rapids PLMP (Grant PUD 2009)
101.	Lamprey Technical Work Group • Supplementation Subgroup • Passage Engineering Subgroup • NPCC lamprey synthesis Subgroup • FPC smolt monitoring program assistance	All ACOE projects, Wells, Rocky Reach, Rock Island, Priest Rapids	Columbia and Snake	The purpose of the Columbia River Basin Lamprey Technical Work Group (CRBLTWG) is to provide technical review, guidance, and recommendations for activities related to lamprey conservation and restoration. The CRBLTWG accomplishes this by: 1) identifying and prioritizing critical uncertainties regarding lamprey conservation; 2) providing a forum for discussion regarding lamprey-related concerns; and 3) disseminating technical information. Although the CRBLTWG was active in 2016 with subgroup activities, no additional information was available at the time of reporting.	USFWS	Personal communication with Christina Wang, USFWS (10/19/15)
102.	Pacific Lamprey Conservation Initiative	All ACOE projects	Columbia and Snake	The USFWS with signatories to the Pacific Lamprey Conservation Agreement and other partners continued to work on regional implementation plans for all regional management units in the Columbia and Snake rivers including the mainstem Columbia and Snake. The Conservation Team met March 16, June 15, and September 21, 2015. At the June 15, 2015, updates and presentations were provided by the Regional Management Unit Groups on their regional implementation plans. The Conservation Team is planning a meeting with the Policy Committee in December of 2015. The purpose of this meeting is to	USFWS	Personal communication with Christina Wang, USFWS (10/19/15)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				inform Policy level staff of the current needs for Pacific Lamprey and obtain potential funding sources for conservation actions and research. The Conservation Team is proposing Pacific Lamprey as a candidate partnership in the National Fish Habitat Action Plan (NFHAP). We submitted a candidacy letter in September 2015 to the NFHAP board. We will present the candidate partnership, Pacific Lamprey Fish Habitat Partnership, to the NFHAP board at their meeting October 20, 2015. If candidate status is granted the partnership may be asked to submit an application for full partner status. No additional information was available at the time of 2016 reporting.		

3.0 Status of Pacific Lamprey Activities at the Priest Rapids Project

Pursuant to the requirements of Grant PUD's PLMP (Grant PUD 2009) and specifically for this comprehensive annual report (as described in Section 1.2 above), activities at the Project related to Pacific lamprey are described in Table 6. The information is organized by the protection, mitigation and enhancement (PM&E) measures for each of the four objectives set forth in the Project's PLMP. Included for each PM&E is the timeframe for implementation/completion of the measure, the action taken by Grant PUD in 2016, and any variations in schedule. In general, measures are currently on or ahead of schedule.

Table 6 Schedule and status of Pacific Lamprey Management Plan implementation measures at the Priest Rapids Project.

	Implementation Measure	Evaluation Timeframe	Relevant to Current Reporting Period	Action Taken in 2016	Variation from Schedule (if applicable)
Objective 1: Identify, address, and fully mitigate Project effects to the extent reasonable and feasible to achieve No Net Impact (NNI)					
1.	Provide an annual report summarizing activities undertaken to identify and address Project impacts.	Annually (by March 31), starting 2010	Yes	Yes, report will be filed on or before March 31, 2017.	No
Objective 2: Provide safe, effective, and timely volitional passage for adult upstream and downstream migration					
2.	Maintain adult fishways.	Annually for the period 2009-2015	Yes	Grant PUD continues to maintain fishways at the Project in accordance with the NOAA Fisheries Fishway Operations and Criteria Guidelines for salmon (NOAA Fisheries 2008). The plan includes operational criteria for dewatering and the collection of all fish.	No
3.	Develop adult Pacific lamprey passage criteria.	To be determined by the PRFF Annual passage detection monitoring initiated in July 2010 – 2015.	Yes	Grant PUD installed HDX-PIT tag arrays in the fish ladders at Wanapum and Priest Rapids dams to measure adult Pacific lamprey passage. Passage metrics will be determined when a sufficient sample size has been achieved. Presently, Grant PUD has tracked a total of 447 unique PIT tags at Priest Rapids and 491 at Wanapum since 2010. Fish passage efficiency (FPE) and passage times are being calculated. Following the 2016 migration period, the cumulative sample size (2010-2016) should allow for empirical statistical review of the monitoring results.	No

	Implementation Measure	Evaluation Timeframe	Relevant to Current Reporting Period	Action Taken in 2016	Variation from Schedule (if applicable)
4.	Continue to operate and maintain fish count systems at the Project (upgrade count systems as new technology becomes available).	Annually for the period 2009-2015	Yes	Grant PUD maintains video stations at the Project to count fish in accordance with the PLMP, NOAA Fisheries Biological Opinion and agreements included in the FERC License. Newly designed and fabricated fish crowder facilities were installed and operated at both Priest Rapids and Wanapum dams prior to April 2010. Fish counts are for all species including adult lamprey are expected to be extremely accurate and are available at www.gcpud.org for review.	No

	Implementation Measure	Evaluation Timeframe	Relevant to Current Reporting Period	Action Taken in 2016	Variation from Schedule (if applicable)
5.	Develop and implement a comprehensive evaluation of adult lamprey passage at the Project.	Develop / implement: Within one year of license issuance (2009)	Yes	This annual report includes a comprehensive evaluation on adult lamprey passage in the Project area by addressing each measure in the PLMP. PRFF members conducted an on-site inspection of the Priest Rapids and Wanapum left bank fishway facilities during the 2015-2016 winter fish ladder maintenance outage.	No
		Determination of whether proposed modifications improve adult passage: Within four years of license issuance	Yes	Grant PUD implemented components of a comprehensive adult passage evaluation study plan, titled “Assessment of Pacific lamprey behavior and passage efficiency at Priest Rapids and Wanapum dams” (Nass et al. 2009). The goal of the evaluation was to collect data in support of determining whether the modifications improved adult passage. The assessment of plating and count station use in 2010 documented the effective use of these structures by migrating lamprey. FPE and passage times are being calculated for statistical comparisons. Data analyses have been conducted annually since 2010 and are ongoing.	No
6.	Implement improvements to the junction pool and the diffusion gratings at the Priest Rapids Dam as identified in the FLA.	Within two years of license issuance (2010)	No	None. Grant PUD completed improvements proposed in the FLA and included in the FERC License in 2010.	No

	Implementation Measure	Evaluation Timeframe	Relevant to Current Reporting Period	Action Taken in 2016	Variation from Schedule (if applicable)
7.	Implement an evaluation program to assess the effectiveness of fishway modifications on adult lamprey.	Within one year of completion of fishway modifications at Priest Rapids Dam (2011)	Yes	Grant PUD implemented an evaluation program in coordination with the PRFF to determine and assess the effectiveness of fish ladder modifications. HDX-PIT system were used to collect data from fish tagged downstream of Priest Rapids Dam. Pacific lamprey tagged at lower river facilities were passively monitored at PRP facilities as directed by the PRFF. The assessment of plating and count station use in 2010 documented the effective use of these structures by migrating lamprey. FPE and passage times are being calculated for statistical comparisons. Fishway passage efficiency was 73% at Priest Rapids Dam over the 2010-2015 period and 72% at Wanapum Dam over the 2010-2013 period and 2015 (2014 intentionally omitted).	Yes, ahead of schedule. An evaluation program was implemented in 2010 and was continued in 2016.
8.	Implement all modifications identified for adult fishways at the Project as identified in the FLA or as amended by the PRFF.	Within seven years of license issuance (2015)	Yes	Grant PUD has implemented improvements proposed in the FLA and included in the FERC License (see #6 above). Grant PUD will consider additional modifications based on the evaluation of the effectiveness of fishway modifications.	No

	Implementation Measure	Evaluation Timeframe	Relevant to Current Reporting Period	Action Taken in 2016	Variation from Schedule (if applicable)
9.	Begin investigation of the efficacy and advisability of reducing fishway flows at night during peak lamprey migration periods.	Following implementation and evaluation of identified fishway modifications	No	Grant PUD began to investigate the efficacy and advisability of reducing fishway flows at night and had incorporated this objective into the 2010 study plan. However, after consideration by the PRFF and NOAA Fisheries, this objective of the study plan was determined to be considered following evaluations of existing fishway modifications (see PRFF meeting minutes for May 5, 2010) if needed in the future.	No
10.	Complete a biological objectives status report for WDOE 401 water quality certification.	Every 5th year of the license term (Aug. 2013, 2018, 2023, etc.)	Yes	Biological objectives status report update for 2013 was included in the 2014 annual report.	Yes.
11.	Conduct a monitoring and evaluation study of adult Pacific lamprey passage at Project; if based on the 10-year status report, Ecology concludes that a Pacific Lamprey Biological Objective has not been met; Grant PUD shall continue to implement the Adaptive Management process.	Every 10th year of the license term (2018, 2028, 2038, 2048, 2058) or as recommended by the PRFF	No	None	No
12.	Participate in regional studies, forums and measures and cooperate with other entities performing those activities when useful information may be obtained about Project impacts on adult Pacific lamprey. Forums will include (but not limited to) the CRBLTWG.	Annually for the life of the license	Yes	Grant PUD currently participates in regional forums such as the Columbia River Basin Pacific Lamprey Technical Workgroup, the Lamprey Conservation Initiative (USFWS), and the Tribal Restoration Plan activities (CRITFC). Refer to Section 2.2 for specific activities.	No
13.	Continue to operate and maintain the adult PIT-tag detection system (full-duplex) at the Priest Rapids Dam fishway.	Annually for the life of the license	Yes	Grant PUD continues to maintain the adult PIT-tag detection system (full-duplex) at Priest Rapids Dam.	No

	Implementation Measure	Evaluation Timeframe	Relevant to Current Reporting Period	Action Taken in 2016	Variation from Schedule (if applicable)
<u>Objective 3: Provide safe, effective and timely volitional passage for juvenile migration</u>					
14.	Identify and mitigate for Project effects on juvenile Pacific lamprey	No later than 10 years following license issuance (2018)	Yes	Currently, options for measuring Project effects on juvenile Pacific lamprey are under consideration by the PRFF. At this time, technology does not exist to measure juvenile Pacific lamprey passage.	No
15.	Develop juvenile Pacific lamprey passage criteria	No later than 10 years following license issuance (2018)	No	None. At this time, technology does not exist to measure juvenile Pacific lamprey passage.	No
16.	Participate in regional studies, forums and measures and cooperate with other entities performing those activities when useful information may be obtained about Project impacts on juvenile Pacific lamprey. Forums will include (but not limited to) the CRBLTWG.	Annually for the life of the license	Yes	Grant PUD currently participates in regional forums such as the Columbia River Basin Pacific Lamprey Technical Workgroup, the Lamprey Conservation Initiative (USFWS), and the Tribal Restoration Plan activities (CRITFC). Refer to Section 2.2 for specific activities.	No

	Implementation Measure	Evaluation Timeframe	Relevant to Current Reporting Period	Action Taken in 2016	Variation from Schedule (if applicable)
<u>Objective 4: Avoid and mitigate Project impacts on rearing habitat</u>					
17.	Determine juvenile lamprey presence / absence, habitat use, and relative abundance in the Project area. If significant ongoing effects are identified, Grant PUD shall develop a plan and implement reasonable and feasible measures to address such effects.	No later than 10 years following license issuance (2018)	Yes	Grant PUD implemented a PRFF approved study plan to determine juvenile lamprey presence / absence, habitat use, and relative abundance in the Project area in 2012 and 2013. Additional sampling was completed in the Wanapum Reservoir in 2014, although the reservoir elevations were well below normal operations due to the fracture in the Wanapum Dam spillway. Only a few lamprey were captured or observed during these surveys. Given three years of sampling at varying reservoir elevations (2012-2014) have indicated that juvenile lamprey do not commonly occur within the Project operational zone, no additional assessments were conducted in 2015. A report addressing results from 2012-2013 is in development.	No

4.0 Evaluation of Activities in the Columbia River Basin Relative to the Priest Rapids Project

This section provides a comprehensive assessment of activities occurring in the Columbia River Basin and their applicability to the Project. Table 7 is designed to meet the requirement of the comprehensive annual report (described in Section 1.2 above) to determine whether measures being investigated and/or implemented in the Columbia River Basin are: (i) consistent with similar measures taken at other projects; (ii) appropriate to implement at the Project; and (iii) cost effective to implement at the Project.

For purposes of this evaluation, the definitions used for the three stated elements above are as follows:

1). "Consistent with similar measures taken at other projects" is "Yes" for an activity that has been implemented by a hydroelectric facility operator in a hydroelectric project area other than Grant PUD's Priest Rapids Project.
2). "Appropriate to implement at the Priest Rapids Project" is "Yes" for an activity that is a requirement of Grant PUD's PLMP (Grant PUD 2009) or is an activity subsequently agreed to by Grant PUD as a result of implementation of the PLMP.
3). "Cost-effective to implement at the Priest Rapids Project" is "Yes" for an activity where resource benefits are commensurate with the level of effort and cost to implement, and in a manner not inconsistent with anadromous fish passage criteria and habitat requirements. If a measure is "appropriate to implement", then it is also considered cost effective and the specific action being taken by Grant PUD is described. If a measure is not "appropriate to implement," then cost effectiveness is considered not applicable.

The activities identified in the table include both those that have been implemented (as identified and described in Table 5 of Section 2.2: Updated Information above), or planned or proposed pursuant to an existing and approved implementation, restoration, or management plan of another utility, the ACOE, or tribal entities. As such, for each activity, details include the project(s) where the activity has been implemented, planned or proposed, river of each project, and in the case of implemented items, a cross reference to Table 5. For planned or proposed efforts (which are not identified as current activities in Table 5) the source of the information is noted at the end of Table 7.

Table 7 Pacific lamprey activities in the Columbia River basin and applicability to the Priest Rapids Project.

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
	General Biology, Ecology, and Population Status						
1.	Identify spawning areas or determine the extent of adult spawning	BOR projects in Yakima (I) No associated hydro project (I)	Yakima Willamette	#5 #16	Yes	No. This activity is not required by Grant PUD's PLMP. Radio-telemetry studies conducted in 2001-2002 did not show use of any tributaries in the PRPA (Nass et al. 2003)	N/A
2.	Develop measures to protect spawning habitat	Wells (P) Rocky Reach (P)	Columbia Columbia	N/A[2] N/A[3]	No	No. This activity is not required by Grant PUD's PLMP.	N/A
3.	Monitor adult population status and trends (unrelated to counting at hydroelectric projects)	BOR projects in Yakima (I) Willamette Falls (I) No associated hydro projects (I)	Yakima Willamette Fifteenmile Creek Deschuttes, and tributaries Hood Umatilla Lower Columbia Estuary	#5 #6 #1 #2 #10 #20 #22	No	No. This activity is not required by Grant PUD's PLMP.	N/A
4.	Determine the extent of juvenile rearing habitat	The Dalles (I) No associated hydro projects (I)	Columbia Fifteenmile Creek	#7 #1	Yes	Yes. PLMP Objective 4 requires quantification of lamprey habitat in the Project area.	Yes. Stratified sampling habitat surveys were implemented in 2012, 2013, and again in 2014

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
		No associated hydro project (I) Wells (P)	Deschutes and tributaries Willamette Columbia	#2 #19 #24			(under abnormally low reservoir elevations) to detect presence/absence of juvenile lamprey within the Project operational zone. Required to be conducted within the PRPA within 10 years of license issuance. This activity has been completed.
5.	Develop measures to protect juvenile rearing habitat	No associated hydro project (I) Wells (P) Rocky Reach (P)	Fifteenmile Creek Columbia Columbia Columbia	#1 #32 N/A[2] N/A[3]	No	No. This activity is not required by Grant PUD's PLMP.	N/A
6.	Monitor juvenile population status and trends (unrelated to counting at hydroelectric projects)	Wells (P) Condit (I) No associated hydro projects (I)	Columbia White Salmon N/A Willamette Deschutes and other tributaries Hood Yakima, Entiat, Methow	#26 #9 #24 #8, 15 #2 #10 #12	No	Yes. PLMP Objective 4 requires the assessment of juvenile presence / absence and relative abundance.	Yes. Stratified sampling habitat surveys were implemented in 2012 to detect presence/absence and Project operational zone. Required to be conducted within the PRPA within 10 years of license issuance.

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
			and Klickitat Lower Columbia & tributaries (including Klickitat, White Salmon, Rock, Wind) Methow (Chewuch) Willamette Wenatchee, Entiat, Chelan, Methow and Okanogan Yakima	 #13 #14 #15 #23 #34			
7.	Evaluate lamprey physiology, energy use, swimming performance	Bonneville	Columbia	#72	No	No. This activity is not required by the PLMP. Evaluating lamprey physiology, energy use, and swimming performance are not objectives, goals, or measures outlined in the PLMP.	N/A

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
8.	Evaluate, implement and/or monitor translocation, supplementation, and artificial propagation programs	No associated hydro projects (I) Pelton Round Butte (I)	Umatilla Yakima Wenatchee Methow N/A Columbia and Snake Columbia (Mid and Upper) Willamette Deschutes	#20 #21 #21 #21 #18 #97 #96 #19 #11	Yes	No. This activity is not required by Grant PUD's PLMP. However, trap and transport is being evaluated by the PRFF as a potential implementation measure in fulfillment of an ongoing conceptual No Net Impact (NNI) agreement. Grant PUD successfully trapped and transported 2,269 adult Pacific lamprey above Rock Island Dam during 2014 as a result of fish passage activities in support of the Wanapum Dam fracture.	N/A
9.	Develop and test new technologies / methodologies / protocols for lamprey	John Day (I) McNary (I) No associated hydro projects (I)	Columbia Columbia Willamette N/A	#7 #7 #8, 19 #17. 18	No	No. This activity is not required by the PLMP. Developing technologies for sampling juvenile lamprey in deep water are not objectives, goals, or measures outlined in the PLMP. However, Grant PUD will determine juvenile lamprey presence / absence, habitat use, and relative abundance	N/A

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
						in the Project area, in coordination with the PRFF no later than 10 years following license issuance.	
10.	Determine genetic structure and maintain genetic integrity	No associated hydro project (I)	N/A	N/A[1]	No	No. This activity is not required by the PLMP. Determining genetic structure and maintaining genetic integrity are not objectives, goals, or measures outlined in the PLMP.	N/A
11.	Determine water quality impacts of hydropower projects on lamprey and implement actions to mitigate these impacts	PR (as identified in the Tribal Pacific Lamprey Restoration Plan for the Columbia River)	N/A	N/A[1]	No	No. This activity is not required by the PLMP. Grant PUD monitors and maintains water quality in compliance with freshwater designated uses and criteria for the Project as required by the Ecology 401 Certification; therefore, no further actions are required.	N/A
12.	Evaluate the need for a lamprey aquaculture facility based upon a limiting factor analysis	No associated hydro project	Columbia (Mid and Upper)	#96	No	No. This activity is not required by the PLMP. However, lamprey aquaculture is being evaluated by the PRFF as a potential implementation measure in fulfillment of an ongoing	N/A

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
						conceptual NNI agreement.	
13.	Restore tributary habitat and passage	PR (as identified in the Tribal Pacific Lamprey Restoration Plan for the Columbia River)	N/A	N/A[1]	No	No. This activity is not required by the PLMP. Radio-telemetry studies conducted in 2001-2002 did not show use of any tributaries in the PRPA (Nass et al. 2003).	N/A
	Lamprey Migration in Rivers						
14.	Evaluate adult migration in rivers and reservoirs	Bonneville (I) The Dalles (I) John Day (I) McNary (I) Ice Harbor (I) Lower Monumental (I) Little Goose (I) Lower Granite (I) Priest Rapids and Wanapum (I) Rock Island (I) Rocky Reach (I)	Columbia Columbia Columbia Columbia Snake Snake Snake Snake Columbia Columbia Columbia	#30, 31, 35 #30 #30, 35 #30 #30 #30, 35 #30, 35 #30, 52 #30, 70 #30, 35 #30	Yes	Yes. The PLMP does not include a specific PM&E related to this activity; however, Grant PUD has committed to collect and evaluate data on the passage of adult lamprey through the Project reservoirs as part of a telemetry evaluation (Objective 2). Grant PUD conducted this activity as part of its 2001-2002 radio-telemetry studies on adult lamprey (Nass et al. 2003).	Yes. Monitoring of lamprey through the Project reservoirs was conducted using HDX-PIT tags in 2010 through 2016 for fish detected at both Priest Rapids and Wanapum dams. Where detection systems are present at upstream projects, the additional data will be evaluated during future adult Pacific lamprey fishway evaluations. Also in 2016, Grant PUD tagged 100 adult lamprey with both acoustic tags (Vemco V7) and FDX-PIT tags. These fish were released in either the Priest Rapids Forebay at Desert Aire (RM 400.4; n=30) or in the

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
							Wanapum Forebay at either RM 415.8, (n=35) or RM 419.9, (n=35). An array of fixed acoustic receivers deployed throughout the Project area was used to monitor the tagged fish after release. This evaluation will help determine and inform trends in reservoir and upstream tributary passage.
15.	Assess impacts of irrigation water withdrawal structures on juvenile passage/habitat	No associated hydro project (I)	Yakima Wenatchee	#34 #34	No	No. This activity is not required by the PLMP. Assessing the impacts of irrigation water withdrawal are not objectives, goals, or measures outlined in the PLMP.	N/A
16.	Assessing juvenile lamprey outmigration	No associated hydro project (I)	Umatilla Yakima, Wenatchee	#33 #34	No	No. This activity is not required by the PLMP. Assessing the impacts of irrigation water withdrawal are not objectives, goals, or measures outlined in the PLMP.	N/A
	Adult Passage at Hydroelectric Facilities						
	Structural and Operational Fishway Modifications						
17.	Inspect / inventory / document / assess structural improvements for fishway	Bonneville (I) McNary (I)	Columbia Columbia Snake	#40 #40 #40	Yes	Yes. PLMP Objectives 1 and 2 specifically identify methods and reporting requirements for assessing and	Yes. Grant PUD implemented an evaluation program in coordination with the PRFF to determine and

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
		Lower Monumental (I) Lower Granite (O) Priest Rapids and Wanapum Prosser, Sunnyside, Horn Rapids dams (P) Rocky Reach (I) Wells (P)	Snake Columbia Yakima Columbia Columbia	#40 #41 #43 #71 N/A[2]		improving passage conditions for adult lamprey. These activities are a continuation of efforts started in 2001.	assess the effectiveness of fish ladder modifications. HDX-PIT system were used to collect data from fish tagged downstream of Priest Rapids Dam. Pacific lamprey tagged at lower river facilities were passively monitored at Project facilities as directed by the PRFF. The assessment of plating and count station use in 2010 documented the effective use of these structures by migrating lamprey. Fish passage efficiency (FPE) and passage times are being calculated. Following the 2016 migration period, the 2010 – 2016 cumulative passage dataset will be empirically and statistically evaluated. Results will be presented to the PRFF for review in spring 2017.
18.	Conduct a literature review of upstream passage improvements	Wells (I)	Columbia	#101	Yes	Yes. PLMP Objective 1 requires compilation of measures taken in the Columbia River basin and an assessment of their applicability to the Project.	Yes. This activity is documented in this PLMP Comprehensive Annual Report (see Section 2.2: Updated Information).

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
19.	Design / install / evaluate lamprey passage system (LPS) and entrance structures	Bonneville (I) McNary (I) Westland diversions (I) Prosser, Sunnyside, Wapato, Horn Rapids dams (P)	Columbia Columbia Umatilla Yakima	#64 #44 #42 #43	Yes	No. The LPS has been evaluated with respect to application in the Project (2001-2002 radio-telemetry study; Nass et al. 2003) and determined that because there are no areas where lamprey concentrate at either facility, this method would not be appropriate to implement.	N/A
20.	Install / evaluate / operate slotted "keyhole" fishway entrances	Priest Rapids and Wanapum John Day McNary	Columbia Columbia Columbia	#45 N/A[5] N/A[6]	Yes	Yes. Keyhole entrances are currently utilized at both Wanapum and Priest Rapids dams.	Yes. See adjacent response.
21.	Develop / implement / evaluate ladder dewatering procedures	No associated hydro project (I) All ACOE projects[7] (I) Wells (I) Rocky Reach (I) Rock Island (I) Priest Rapids and Wanapum (I)	Yakima, Wenatchee Columbia, Snake Columbia Columbia Columbia Columbia	#34 #46 #47 #48 #48 #49	Yes	Yes. Dewatering procedures were identified as existing at the Project in the PLMP.	Yes. Grant PUD operates its fishways according to the NOAA Fisheries Fishway Operations and Criteria Guidelines for salmon (NOAA Fisheries 2008). The plan includes operational criteria for dewatering and the recovery of all fish.
22.	Rehabilitate and/or operate old or existing	Willamette Falls (I)	Willamette	#50	No	Yes. Subsequent to fishway modifications completed in 2009-2010	Yes, as determined appropriate by Grant PUD and the PRFF.

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
	fishway for lamprey passage					outage at Priest Rapids and Wanapum dams, Grant PUD and the PRFF will continue to assess the applicability, feasibility, and appropriateness of other potential modifications.	
23.	Address issues with diffuser gratings and picket leads, e.g., replace gratings with material of ¾-inch spacing (and replace other related structures: e.g., track rack cleaning system and grating support system)	John Day (I) Other ACOE projects (exact one unspecified) (P) Wells (P)	Columbia Columbia, Snake Columbia	#60 N/A[5] N/A[2]	No	No. These issues have not been identified in the Project fishways. Members of the PRFF toured the fish ladders at Priest Rapids and Wanapum dams and did not identify that these issues existed at either dam. However, Grant PUD replaced the fish count stations at both dams in 2010 with picket-lead gratings that is 11/16-inch gap to ensure accurate adult counts.	N/A
24.	Install/evaluate plates over diffuser along the bases of walls and weir	Bonneville (I)	Columbia	#60, 63	Yes	Yes. PLMP Objective 2 requires installation of plating along the edges and through the orifices in the pools with diffusion chambers at Priest Rapids Dam.	Yes. Grant PUD installed aluminum plating on diffuser grates at Priest Rapids during the 2009-2010 winter fish ladder maintenance outage. The effectiveness of the plating was evaluated through the use of underwater video as part of the 2010 assessment of

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
							Pacific lamprey behavior and passage efficiency at Priest Rapids and Wanapum dams (Nass et al. 2009). This study showed that lamprey effectively used the plating to move through a weir orifice or past the counting station.
25.	Round sharp corners	Trail Bridge Dam (I) Ice Harbor (P)	McKenzie Snake	#51 N/A[6]	Yes	No. Sharp corners have not been identified in the Project fishways. Members of the PRFF toured the fish ladders at Priest Rapids and Wanapum dams and did not identify that sharp corners were an issue at either dam.	N/A
26.	Design / install water supply or auxillary water supply systems	Trail Bridge Dam (I)	McKenzie	#52	No	No. This activity is not required by the PLMP.	N/A
27.	Reduce/evaluate ladder entrance flow velocities at night	Bonneville (I) McNary (I) Priest Rapids (P) Ice Harbor (P)	Columbia Columbia Columbia Snake	#52 #53 N/A[8] N/A[5]	Yes	Yes. PLMP Objective 2 requires that Grant PUD and the PRFF evaluate the efficacy of reducing fishway flows at night.	Yes. Grant PUD developed a PRFF-approved comprehensive study plan to evaluate improvements and modifications to the fish ladders at Priest Rapids and Wanapum dams in 2010. Grant PUD began to investigate the efficacy and advisability of

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
							reducing fishway flows at night and had incorporated this objective into the 2010 study plan. However, after consideration by the PRFF and NOAA Fisheries, this objective of the study plan was considered to be unnecessary (see PRFF meeting minutes for May 5, 2010).
28.	Modify/evaluate weir head differentials	Bonneville (I)	Columbia	#63, 72	No	No. Fishway operational procedures were identified as existing at the Project in the PLMP.	N/A. Grant PUD operates its fishways according to the NOAA Fisheries Fishway Operations and Criteria Guidelines for salmon (NOAA Fisheries 2008). The plan includes operational criteria for weir head differentials.
29.	Manage flows to a peaking hydrograph	PR (as identified in the Tribal Pacific Lamprey Restoration Plan for the Columbia River)	N/A	N/A[1]	No	No. Grant PUD operates its facilities as part of a seven dam coordination schedule of flows. The proposed activity is not consistent with operations for power generation, flood control and recreational activities.	N/A
30.	Establish protocol for formal inspection of passage facilities	Priest Rapids and Wanapum (I)	Columbia	#107	No	Yes. PLMP Objective 2 requires inspection of passage facilities by	Yes. Inspection by the PRFF is coordinated with annual winter fish

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
						PRFF members.	ladder maintenance outages.
31.	Establish protocols for formal inspection of passage facilities	Priest Rapids and Wanapum (I)	Columbia	#101	No	Yes. PLMP Objective 1 requires an annual report summarizing all PLMP activities.	Yes. Lamprey activities at the Project are documented in this PLMP Comprehensive Annual Report.
32.	Develop and/or maintain fishway operations criteria	Bonneville (I) The Dalles (I) John Day (I) McNary (I) Ice Harbor (I) Lower Monumental (I) Little Goose (I) Lower Granite (I) Wells (I) Rocky Reach (I) Rock Island (I) Priest Rapids and Wanapum (I)	Columbia Columbia Columbia Columbia Snake Snake Snake Snake Columbia Columbia Columbia Columbia	#54 #55 #56 #57 #57 #57 #57 #57 #101 #101 #58 #59	Yes	Yes. PLMP Objective 2 requires Grant PUD to maintain its fishways in a manner that is consistent with the NOAA Fisheries Fishway Operations and Criteria Guidelines for salmon (NOAA Fisheries 2008). In 2011, Grant PUD implemented a Standard Operating Procedure (SOP) for operation of the OLAFT vertical orifice gate to remain open when the OLAFT is not operating.	Yes. Specific operations criteria are presented in Grant PUD's Project Adult Fishways Operational Plan (Grant PUD 2008).
	Project Passage Effectiveness						
33.	Develop adult lamprey passage criteria	Rocky Reach (P)	Columbia Columbia	N/A[3] N/A[4]	No	Yes. PLMP Objective 2 requires the development of adult	Yes. Grant PUD and the PRFF will consider success achieved at

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
		Priest Rapids and Wanapum (P)				lamprey passage criteria that are not inconsistent with the Fishery Operations Plan (Grant PUD 2010).	other Columbia River basin projects and site specific conditions related to Priest Rapids and Wanapum dams.
34.	Evaluate effectiveness of dam passage	Bonneville (I) Rocky Reach (I) John Day (I) Ice Harbor (I) Lower Monumental (I) Lower Goose (I) Lower Granite (I) Priest Rapids and Wanapum (I) Threemile Falls Dam, Maxwell and Feed diversions (I) Clackamas	Columbia Columbia Columbia Snake Snake Snake Snake Columbia Umatilla Clackamas	#31. 69. 72 #36 #69 #78 #78 #78 #78 #66, 70 #67 #68	Yes	Yes. PLMP Objective 2 requires a comprehensive passage evaluation.	es. Grant PUD implemented an evaluation program in coordination with the PRFF to determine and assess the effectiveness of fish ladder modifications. HDX-PIT systems were used to collect data from fish tagged downstream of Priest Rapids Dam. Pacific lamprey tagged at lower river facilities were passively monitored at PRP facilities as directed by the PRFF. The assessment of plating and count station use in 2010 documented the effective use of these structures by migrating lamprey. Fish passage efficiency (FPE) and passage times are being calculated, although the sample size is insufficient for statistical comparisons. Through

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
							2016, Grant PUD has tracked a total of 447 unique PIT tags at Priest Rapids and 491 at Wanapum since 2010. Estimated FPE for 2010-2014 for Priest Rapids Dam is 74% and estimated FPE for 2010-2013 Wanapum Dam is 73%. Median passage times at Priest Rapids Dam are 70 h at the left bank and 5 h at the right bank. Median passage times at Wanapum Dam are 23 h at the left bank and 21 h at the right bank.
35.	Evaluate upstream passage modifications	Priest Rapids and Wanapum (I) [Note: evaluations performed on existing structural / operational improvements at ACOE dams are identified earlier in this table, under the heading, Structural and Operational Fishway Modifications.]	Columbia	#66	No	Yes. PLMP Objective 2 requires a comprehensive passage evaluation of modifications to fishways as required per the FERC License Order and PLMP.	Yes. Grant PUD conducted an adult passage evaluation to determine the effectiveness of fish ladder modifications made during the 2009-2010 winter fish ladder maintenance outage (Nass et al. 2009). Specific modifications included diffusion grate plating and new fish crowder structures. HDX-PIT systems were

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
		Rocky Reach Bonneville	Columbia Columbia	#36 #72			used to collect data from fish tagged downstream of Priest Rapids Dam. Pacific lamprey tagged at lower river facilities were passively monitored at PRP facilities as directed by the PRFF. The assessment of plating and count station use in 2010 documented the effective use of these structures by migrating lamprey. Estimated FPE for 2010-2016 for Priest Rapids Dam is 74% and estimated FPE for 2010-2013 Wanapum Dam is 73%. Median passage times at Priest Rapids Dam are 70 h at the left bank and 5 h at the right bank. Median passage times at Wanapum Dam are 23 h at the left bank and 21 h at the right bank.
	Lamprey Counts at Dams						
36.	Develop feasibility, techniques, and protocols to improve 24-hour counting / conduct counts	McNary (I) Lower Granite (I) Bonneville (I)	Columbia Snake Columbia	#73 #73 #73	Yes	Yes. PLMP Objective 2 requires maintenance and feasible improvements to adult fish counting systems.	Yes. Grant PUD currently provides counts of all fishes 24 hours per day, 7 days per week for the period

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
		Wells (I) Rocky Reach (I) Rock Island (I) Prosser and Roza	Columbia Columbia Columbia Yakima	#74 #75 #75 #77			April 15 – November 15, annually.
37.	Develop/evaluate passage alternatives related to count facilities	Bonneville (I) John Day	Columbia Columbia	#69 #69	Yes	Yes. PLMP Objective 2 requires maintenance and feasible improvements to adult fish counting systems.	Yes. Grant PUD installed newly designed, lamprey-specific fish crowder structures for all count stations at Priest Rapids and Wanapum dams during the 2009-2010 winter fish ladder maintenance outage. Based on design criteria for the new video fish count crowders (picketed lead gap of 11/16 inches). Grant PUD expects fish count accuracy to be at or near 100% for adult lamprey and other fishes passing through all count stations.
	Predation						
38.	Establish predation control measures (sea lions)	Bonneville (I)	Columbia	#79	Yes	No. Sea lions are not present in the PRPA.	N/A

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
	Juvenile Passage at Hydroelectric Facilities						
	Structural and Operational Fishway Modifications						
39.	Conduct a literature review of juvenile Pacific lamprey passage and survival	Priest Rapids and Wanapum (I) Wells (P)	Columbia Columbia	N/A N/A[2]	No	Yes. PLMP Objective 1 requires compilation of measures taken in the Columbia River basin and an assessment of their applicability to the Project.	Yes. This activity is documented in this PLMP Comprehensive Annual Report.
40.	Replace turbine intake screens with smaller spacing	All ACOE projects (P)	Columbia, Snake	N/A[6]	No	No. Grant PUD dams are not equipped with turbine intake or diversion screens.	N/A
41.	Lift/remove extended length screens during outmigration	McNary (I)	Columbia	#80	Yes	No. Grant PUD has existing turbines bypass systems, gatewells and spill, but does not have a system into which a separator could be installed.	N/A
42.	Manage flows to a peaking hydrograph	PR (as identified in the Tribal Pacific Lamprey Restoration Plan for the Columbia River)	N/A	N/A[1]	No	No. Grant PUD operates its facilities as part of the seven dam coordinated system. The proposed activity is not consistent with operations for power generation, fish protection, flood control and recreational activities.	N/A
43.	JBS modifications	McNary (I)	Columbia	#80, 81, 82	Yes	No. Grant PUD has existing bypass systems, which	N/A

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
		Lower Monumental (I)	Snake	#82		includes gatewells, spillways, the WFUFB, and Priest Rapids Top-Spill Bypass. The WFUFB and experimental Priest Rapids Top-Spill Bypass are operated to achieve safe passage of out-migrating salmonids. It would be expected that juvenile lamprey would also benefit as a result of these operations.	
44.	Establish/continue salvage activities during ladder maintenance de-watering	All ACOE projects (I) Wells (I) Rocky Reach (I) Rock Island (I) Priest Rapids and Wanapum (I)	Columbia, Snake Columbia Columbia Columbia Columbia	#83 #84 #85 #85, 87 #86	Yes	Yes. Dewatering procedures were identified as existing at the Project in the PLMP.	Yes. Grant PUD operates its fishways according to the NOAA Fisheries Fishway Operations and Criteria Guidelines for salmon (NOAA Fisheries 2008). The plan includes operational criteria for dewatering and the recovery of all fish during all maintenance activities.
45.	Develop and/or maintain bypass operations criteria	Wells (I) Rocky Reach (I) Rock Island (I)	Columbia Columbia Columbia	#84 #85 #85, 87	Yes	Yes. Grant PUD has existing bypass systems, which includes gatewells, spillways, the WFUFB, and Priest Rapids Top-Spill Bypass.	Yes. The WFUFB and experimental Priest Rapids Top-Spill Bypass are operated to achieve safe passage of out-migrating salmonids. It would be expected that

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
		Priest Rapids and Wanapum (I)	Columbia	#86, 88			juvenile lamprey would also benefit as a result of these structural modifications and spill operations.
	Project Passage Effectiveness						
46.	Evaluate tagging and development of miniature tags	No associated hydro project (I)	N/A	N/A	No	No. This activity is not required by the PLMP. Evaluation and development of tags are not objectives, goals, or measures outlined in the PLMP.	N/A
47.	Develop juvenile lamprey passage criteria	Priest Rapids and Wanapum (P)	Columbia	N/A[4]	No	Yes. PLMP Objective 3 requires the development of juvenile lamprey passage criteria.	Yes. Grant PUD and the PRFF will include consideration of success achieved at other Columbia River basin projects and site specific conditions when the technology exists to measure juvenile lamprey passage.
48.	Evaluate downstream passage and survival when technology available	Wells (P) Rocky Reach (P) Priest Rapids and Wanapum (P) No associated hydro project (I)	Columbia Columbia Columbia N/A	N/A[2] N/A[3] N/A[4] #94	No	Yes. The PLMP does not include a specific PM&E related to this activity; however, Grant PUD has committed to providing safe, effective and timely passage which could be evaluated when adequate technology exists.	Yes

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
49.	Laboratory passage evaluation	No associated hydro project (I)	N/A	N/A	No	No. This activity is not required by the PLMP. Lab passage evaluations are not objectives, goals, or measures outlined in the PLMP.	N/A
50.	Monitor passage timing, number, and mortalities of juvenile lamprey collected at projects with juvenile fish bypass facilities	Bonneville (I) John Day (I) McNary (I) Rock Island (I) Lower Monumental (I) Little Goose (I) Lower Granite (I)	Columbia Columbia Columbia Columbia Snake Snake Snake	#89, 90 #90 #89, 90 #90 #89, 90 #89, 90 #85, 89, 90	Yes	No. Grant PUD does not have juvenile collection facilities at either Priest Rapids or Wanapum dams that could be used for this purpose.	N/A
51.	Monitor and report on juvenile impingement	Rocky Reach	Columbia	#101	Yes	No. Priest Rapids and Wanapum dams are not equipped with turbine intake or diversion screens.	N/A
	Predation						
52.	Continue predation control measures (Northern pikeminnow and birds)	Pikeminnow only. All ACOE projects (I) Pikeminnow and birds Rocky Reach (I)	Columbia, Snake Columbia	#92 #93	Yes	Yes. The PLMP does not include a specific PM&E related to this activity. However, Grant PUD maintains predator control programs for	Yes. Grant PUD maintains both avian and Northern pikeminnow control programs to minimize the effects of predation to salmonids which would also be

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
		Pikeminnow and birds Rock Island (I) Pikeminnow and birds Priest Rapids and Wanapum (I)	Columbia Columbia	#93 #94		piscivorous birds and Northern pikeminnow in the PRPA.	expected to provide a benefit to lamprey.
	Policy and Recovery Activities						
53.	Develop/implement Pacific Lamprey Management Plans	All ACOE projects (I) Wells (I) Rocky Reach (I) Priest Rapids and Wanapum (I)	Columbia, Snake Columbia Columbia Columbia	#95, 97, 101, 102 #98 #99 #100	Yes	Yes. Grant PUD is required by FERC to develop and implement a PLMP.	Yes. Grant PUD has a FERC- approved PLMP (Grant PUD 2009). Implementation of that plan is in progress.
54.	Establish regional data protocols for collection, storage and analysis; develop means to widely access and share information	All ACOE projects (I) Wells (I) Rocky Reach (I) Priest Rapids and Wanapum (I)	Columbia, Snake Columbia Columbia Columbia	#95, 97, 98, 101, 102 #98 #99 #100	Yes	Yes. PLMP Objectives 2 and 3 require “Regional Studies” which includes participation and cooperation in studies where useful information may be obtained about project impacts to lamprey.	Yes. Grant PUD participates in regional forums such as the CRBLTWG the USFWS Lamprey Conservation Initiative and the CRITFC Pacific Lamprey Recovery Plan planning processes.
55.	Establish coordinated public education and other outreach programs	Priest Rapids and Wanapum (I)	Columbia	#100	No	Yes. The PLMP does not include a specific PM&E related to this activity; however, Grant PUD participates in	Yes. Grant PUD participates in the annual Wanapum Indian Archeological Days program and provides technical support and

	Activity in Basin (Proposed, Planned or Implemented)	Project where Implemented = I Planned = P Proposed = PR[1]	River(s)	Table 5 Cross-Reference	Consistent with Measures Taken at Other Projects	Appropriate to Implement at Priest Rapids Project	Cost Effective for Priest Rapids Project
						education programs regarding lamprey.	displays regarding the importance of lampreys.
56.	Participate in regional lamprey activities	All ACOE projects (I) Wells (I) Rocky Reach (I) Priest Rapids and Wanapum (I)	Columbia, Snake Columbia Columbia Columbia	#95, 97, 101, 102 #98 #99 #100	Yes	Yes. PLMP Objectives 2 and 3 require "Regional Studies" which includes participation and cooperation in studies where useful information may be obtained about Project impacts to lamprey.	Yes. Grant PUD participates in regional forums such as the CRBLTWG the USFWS Lamprey Conservation Initiative and the CRITFC Pacific Lamprey Recovery Plan planning processes.
57.	Environmental analysis and feasibility investigations	All ACOE projects (I)	Columbia, Snake	#101, 102	No	No. This activity is not required by the PLMP. Environmental analysis and feasibility investigations related to public transportation and lamprey propagation are not objectives, goals, or measures outlined in the PLMP.	N/A

5.0 Summary

One of the goals of Grant PUD's PLMP is to improve Pacific lamprey passage efficiency through the implementation of structural and, potentially, operational modifications to the Project fishways. In the sixth year of PLMP implementation, several planned activities were conducted on schedule. Grant PUD continued to conduct components of a PRFF-approved study plan titled, "Assessment of Pacific Lamprey Behavior and Passage Efficiency at Priest Rapids and Wanapum Dams" (Nass et al. 2009). The study was conducted to evaluate the effectiveness of structural modifications to Priest Rapids Project fishways that are intended to facilitate lamprey passage.

The study plan objectives were to:

1. Determine the fishway passage efficiency for adult lamprey at Priest Rapids and Wanapum dams; and
2. Evaluate the passage of adult lamprey through sections of the Priest Rapids fishways where new structures have been installed to facilitate upstream movement.

In 2016, Grant PUD, in consultation with the PRFF, continued to passively monitor Pacific lamprey tagged at downstream facilities and added valuable information to the cumulative Project data set. The intent of the PIT data collection program is to provide sufficient sample size over time to calculate relevant passage metrics. Analysis of the data available from 2010 – 2016 was completed as part of 2016 reporting activities. During this time period, data available indicates that fishway passage efficiency for lamprey at Priest Rapids Dam during the 2010-2015 period was 73% and at Wanapum Dam during the 2010-2013 and 2015 period was72%. Note that 2014 data for Wanapum Dam was intentionally omitted due to anomalous conditions associated with the Wanapum fracture. Passage efficiencies for 2016 were not available at the time of reporting and will be included in the 2017 annual report. Interpretation of fishway passage efficiency should include consideration of fish that overwintered during migration (fish tagged in the previous study year). Overwintering fish typically made up ~ 6.0% of detected tags during the 2010-2016 period. These detections indicate the complexity of adult lamprey migration behavior.

In 2015, two new HDX-PIT stations installed during the 2014-2015 fishway maintenance period in the vicinity of the OLAFT were used to increase detection resolution in the Priest Rapids left bank upper fishway after monitoring results showed increased travel time through the upper fishway in previous years. In 2016, a small sample (n=12) of run-of-river HDX-PIT tagged fish had a median passage time of 3.8 hours through the Priest Rapids left bank upper fishway, which is a considerable improvement over the median passage time of 76.6 hours for all tagged fish monitored in 2010-2014. Additionally,150 fish captured from the Priest Rapids Dam lower fishways, tagged with HDX-PIT tags, and released into the lower left bank fishway in July and August 2016 had a median passage time of 9.1 hours through the upper left bank fishway. As such, it appears that the slower passage times at the Priest Rapids left bank upper fishway observed in previous years is not a consistent phenomenon. Worth noting is that adult White sturgeon have been observed in the upper Priest Rapids left bank ladder in proximity to areas previously thought to show higher than average travel times in previous years.

Initial results of the voluntary study initiated by Grant PUD in 2016 to assess passage of adult lamprey through the PRP reservoirs suggests the large majority of tagged lamprey (78 of 100) reached the upstream Project boundary at the tailrace of Rock Island Dam by October 2016. One hundred adult lamprey captured with mechanical traps from the Priest Rapids Dam lower fishways during the peak migration period in July and August were implanted with both acoustic tags (Vemco V7) and FDX-PIT tags. These fish were released in either the Priest Rapids forebay at Desert Aire (RM 400.4; n=30) or in the Wanapum Forebay at either RM 415.8 (n=35) or at RM 419.9 (n=35). An array of fixed acoustic receivers deployed throughout the Project area was used to monitor the tagged fish after release. Additionally, mobile tracking was employed to locate tagged individuals in the study area during the remainder of the migration period. The median travel time to reach Rock

Island Tailrace was 3.6 days for fish released in the Wanapum Reservoir and 9.9 days for fish released in the Priest Rapids Reservoir. Travel rates to reach the Rock Island Tailrace ranged from 1.4-38.5 km/d for fish released in the Wanapum Reservoir and from 3.9-15.4 km/d for fish released in the Priest Rapids Reservoir. Three fish had not been detected after release and were assumed to have either been mortalities or have failed acoustic tags. Complete results will be summarized in the 2017 annual report.

In 2016, Grant PUD also continued its regional approach to monitoring lamprey by coordinating among other utilities, participating in forums, and the sharing of PIT data with other researchers.

In 2017, Grant PUD plans to complete PLMP-required activities and study planning/implementation efforts including:

1. PRFF on-site inspection of Priest Rapids and Wanapum fish facilities during the 2016-2017 winter fish ladder maintenance outage.
2. Pre-season testing and calibration of HDX-PIT arrays, and maintenance of arrays during the migration season. Continue to operate HDX-PIT arrays to assess passage metrics (passage efficiency, etc.) and coordinate detection of tagged fish with regional monitoring efforts to evaluate Pacific lamprey passage; both downstream and upstream of the Priest Rapids Project.
3. Tracking lamprey enumeration statistics for the Priest Rapids Project and lower Columbia River dams.
4. Summarizing results from field surveys completed in 2012 and 2013 to assess the distribution and relative abundance of juvenile lamprey in the operational zone of the PRPA.

Pursuant to the requirements identified in the PLMP, Grant PUD will continue to monitor lamprey-related efforts occurring throughout the Columbia River Basin, will actively participate in regional research and forums, and will assess opportunities for lamprey restoration at the Project.

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Appendix A
A Monitoring Study to Quantify Migration Characteristics of Adult Pacific Lamprey in the Priest Rapids Project Area, 2015-2015

A Monitoring Study to Quantify Migration Characteristics of Adult Pacific Lamprey in the Priest Rapids Project Area

SUBMITTED TO:
Public Utility District No. 2 of Grant County. Washington
30 C Street South West
Ephrata, WA 98823

SUBMITTED BY:
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January 16, 2017

Executive Summary

On April 17, 2008, Public Utility District No. 2 of Grant County (Grant PUD) received a new Federal Energy Regulatory Commission (FERC) operating license for the Priest Rapids Hydroelectric Project (PRP) (FERC 2008). As required by FERC License Article 401(a)(12) and Clean Water Act 401 Water Quality Certification Section 6.2 (5)(b), Grant PUD , in consultation with the Priest Rapids Fish Forum (PRFF), developed and submitted to FERC for approval a Pacific Lamprey Management Plan (PLMP) on February 19, 2009. On May 1, 2009, FERC issued an "order modifying and approving" the PLMP.

The goals and objectives of the PLMP are to be achieved through a series of Protection, Mitigation, and Enhancement (PME) measures. In support of the PME to provide safe, effective, and timely volitional passage of adult upstream and downstream migration, a voluntary monitoring study to quantify adult Pacific lamprey migration characteristics in the PRP area was initiated in 2015. The results of the study are intended to better inform decisions regarding future required evaluations.

The objectives of this study were to estimate the proportion of tagged lamprey that:

1. Migrate upstream to the Rock Island Dam Tailrace (RM 453).
2. Overwinter in the study area and resume migration.
3. Experience pre-spawn or predation mortality in the study area.
4. May engage in undetected spawning in reservoir tributaries
5. May engage in spawning in the tailrace of Wanapum and/or Rock Island dams.

In order to estimate successful dam and reservoir passage through the PRP, 100 adult Pacific lamprey were implanted with paired active acoustic and full duplex passive integrated transponder (FDX-PIT) tags during each peak migration period in 2015 and 2016 (total n=200 lamprey). The paired tags also allowed us to detect them at upstream dams and tributaries outside the PRP. Tagged fish were released either above Priest Rapids (n=60) or Wanapum (n=140) dams and monitored within the PRP for a period of approximately 10 months. Acoustic receivers deployed at fixed locations throughout the PRP area were used to monitor the migration behavior of tagged individuals in the study area. In the event that not all individuals are detected at fixed location receivers, mobile tracking was employed to locate individuals within the project PRP area. Fixed location receivers were downloaded at regular intervals to collect detection records. A detection history was created for each tagged lamprey and used to calculate metrics related to the study objectives. This report only includes the 2015 results, as the 2016 tags are still active and being monitored. Final results will be included in the 2017 Pacific Lamprey Management Plan Comprehensive Annual Report.

Of the 100 total acoustic tagged lamprey released in 2015, 83 were detected by the receivers in the Rock Island Dam Tailrace. The release locations of those 83 lamprey were Vantage (33), Wanapum Left Bank (30) and Desert Aire (20). Of those fish detected at the Rock Island Tailrace, 74.7% were last detected upstream of the PRP (Rock Island Tailrace or above). Travel times from release site to first detection in the tailrace of Rock Island Dam varied by release site. Median travel times were 2.9, 3.7, and 16.8 days for lamprey being released at Vantage, Wanapum Left Bank, and Desert Aire, respectively. Overall, lamprey released in the Priest Rapids Reservoir travelled much slower than lamprey released in the Wanapum Reservoir. The

median travel rate to reach the Rock Island Tailrace for fish released in the Priest Rapids Reservoir was 5.1 rkm/day (range 0.9-12.7 km/d) compared to 16.3 rkm/day and 18.0 rkm/day for the Wanapum Left Bank and Vantage releases, respectively (range 0.2-28.2 km/d). Three lamprey were never detected on any acoustic receiver, PIT tag antenna, or while mobile tracking after release, and one was only detected once on a receiver just over 1 RM downstream of the release site, 29 days after release, indicating possible mortality or tag failure. Four lamprey were last detected in the Priest Rapids Reservoir on the receiver near RM 410.5 in the spring of 2016. Upstream of the study area (i.e., above Rock Island Dam), 15 fish were detected entering tributaries. A total of 27 lamprey were last detected in the tailrace of either Wanapum or Rock Island dam.

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1.0 INTRODUCTION

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1.1 Adult Lamprey Passage

Pacific lamprey (*Entosphenus tridentatus*) numbers have declined since the 1940's as a result of spawning habitat loss, impediments to migration, changing ocean conditions, and decreased water quality (Close et al. 1995, 2002). Over the past 10 years, lamprey research in the Columbia River basin has focused on studying migrating adults. Operational and structural modifications have been made to many dams to improve lamprey passage. To assess the efficacy of passage improvements, passive tags, such as half duplex passive integrated transponder (HDX- PIT) tags, and active tags, such as radio-telemetry (RT) tags or acoustic tags (i.e. Juvenile Salmonid Acoustic Transmitter System [JSATS]) have been employed to monitor adult lamprey passage at dams in the Federal Columbia River Hydropower System (FCRPS), primarily in the lower Columbia River (Keefer et al. 2009a, Keefer et al. 2009b, Keefer et al. 2009c, Noyes et al. 2014). While much work has been done to improve dam passage, comparatively little effort has been devoted to investigating lamprey migration characteristics between dams in the Columbia River basin.

Determining the migration characteristics of adult lamprey in Columbia River basin reservoirs can be achieved with either passive or active tags. These technologies allow identification of individual fish but have notable strengths and weaknesses. The use of HDX- PIT tags likely provides the best estimate of dam passage and conversion rates between dams due to the smaller tag effects than observed with RT tags (Noyes et al. 2014). However, reservoir passage and fate are best determined with active tags. Studies have shown that potential fates of tagged Pacific lamprey that are not detected at mainstem dams include 1) overwintering in the reservoir and resuming upstream migration the following spring; 2) pre-spawn mortality or predation mortality; 3) undetected spawning in reservoir tributaries; or 4) spawning in the tailrace of a dam or elsewhere in the reservoir (Noyes et al. 2014). Among active tag technology, acoustic tags have the advantage of allowing detections in water >10 m deep (RT tags do not have this ability), which is common in many mainstem Columbia River reservoirs. This greater detection ability allows the opportunity to monitor the locations of tagged lamprey that remain in the tailrace or reservoir by using an array of autonomous receivers deployed in fixed locations. Additionally, mobile tracking can be employed to detect tags that may be in locations outside the detection range of fixed receivers.

In the PRP area, HDX- PIT tag detection systems were installed in the fishways at Priest Rapids and Wanapum dams in 2009 and have been used to monitor passage of tagged Pacific lamprey. For the 2010 through 2016 migrations, Grant PUD monitored a total of 447 and 491 HDX-PIT tagged lamprey at Priest Rapids and Wanapum dams, respectively (Le et al. 2017). However, because of detection limitations, it is unknown how many of those fish reached the upstream PRP boundary and approached the fishway entrances at the tailrace of Rock Island Dam (owned and operated by Public Utility District No. 1 of Chelan County).

In order to estimate successful dam and reservoir passage through the PRP, 100 adult Pacific lamprey were implanted with paired active acoustic and full duplex passive integrated transponder (FDX-PIT) tags during each peak migration period in 2015 and 2016 (total n=200 lamprey). The paired tags also allowed us to detect them at upstream dams and tributaries outside the PRP. Tagged fish were released either above Priest Rapids (n=60) or Wanapum (n=140) dams and monitored within the PRP for a period of approximately 10 months. This report only includes the 2015 results, as the 2016 tags are still active and being monitored. Final results of both years will be included in the 2017 Pacific Lamprey Management Plan Comprehensive Annual Report.

The objectives of this study were to estimate the proportion of tagged lamprey that:

1. Migrate upstream to the Rock Island Dam Tailrace (RM 453).
2. Overwinter in the study area and resume migration.
3. Experience pre-spawn or predation mortality in the study area.
4. May engage in undetected spawning in reservoir tributaries
5. May engage in spawning in the tailrace of Wanapum and/or Rock Island dams.

1.2 Study Area

The study area was defined by the FERC licensed PRP area which includes Wanapum and Priest Rapids dams and their respective tailrace areas and reservoirs. The PRP spans from the tailrace of Priest Rapids Dam (RM 397) to where the Wanapum Reservoir meets the tailrace of Rock Island Dam (RM 453), of the Columbia River. The Wanapum Reservoir is 38 miles long and has a surface area of approximately 14,680 acres. The Priest Rapids Reservoir is 18 miles long and has a surface area of approximately 7,725 acres.

2.0 STUDY METHODS

2.1 Collection

In 2015, adult Pacific lamprey were collected using mechanical fish traps located in the lower fishways at Priest Rapids Dam from 19 July to 2 August. All fish were scanned for an existing PIT tag. Previously tagged fish were released upstream of Priest Rapids Dam. All other fish were transported to a holding facility at Priest Rapids Dam left bank. Fish were placed in 20.5

gallon insulated containers (coolers) plumbed with flow-through river water, with a maximum of 15 fish per container (Figure 1).

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

2.2 Tagging

All lamprey were double tagged with Vemco V7 acoustic tags (22.5 mm L x 7.0 mm Dia., 1.8 g) and a FDX-PIT tag (12.5 mm L x 2.1 mm Dia, 0.1 g). The dimension of the V7 tags are nearly identical to the JSATS tags used by Noyes et al. (2014). Total combined weight of both tags, 1.9 g, represented a tag burden of <0.75% for all lamprey, well below the recommended 2% (Winter 1996). At the beginning of each tagging and release day, Blue Leaf Environmental (BLE) staff activated the proper number of acoustic tags and paired each one with an FDX-PIT tag both physically in numbered tag boxes and in an ACCESS database. Each acoustic tag was confirmed to be activated with a Vemco VR2 acoustic receiver. The tag boxes, containing the paired tags, were placed in a Nolvasan (Chlorhexidine diacetate) solution for ten minutes then rinsed with distilled water. All surgical tools were also disinfected in a Nolvasan solution for ten minutes and then held in trays filled with distilled water. Surgical tools were disinfected and rinsed in the same manner between each fish. Physical metrics and surgery times for each fish were recorded on data sheets.

One lamprey at a time was transferred from a container by hand, using water soaked cotton gloves, to a heavy anesthetic bath with 120 parts per million (ppm) clove oil, until the fish lost equilibrium and swimming motion ceased (approximately 5 minutes). Start and end time (i.e., surgery start time) was recorded. Once the lamprey was fully anesthetized, length, girth, inter-dorsal distance (IDD) to the nearest mm, and weight in grams, was measured and recorded (Figure 2). The lamprey was then transferred to a surgical trough, inspected for general health and condition, and positioned ventral side up so the gills were submerged in a light anesthetic bath with 60 ppm clove oil. A < 10 mm incision was made approximately 1 cm above the ventral midline, in the softer, thinner part of the abdomen between the ventral midline and the muscular "rib cage". The midpoint of the incision was in line with the anterior insertion of the first dorsal fin. First the PIT tag was inserted into the body cavity through the incision, followed by the Vemco V7 tag. The skin above the tags was rubbed with a finger to ensure both tags were laying flat, reducing the probability of tag shedding. Two sutures were placed to close the incision using 5-0 coated VICRYL (absorbable) suture with a taper point needle. Surgery end time was recorded. The lamprey was then scanned to confirm PIT tag ID, transferred to a holding/transport container on flow-through river water, labeled with the appropriate release location and number, and container number. There were no more than 12 lamprey per release container. Lamprey were held in the holding/transport containers until fully recovered from anesthetic, and released later the same day.

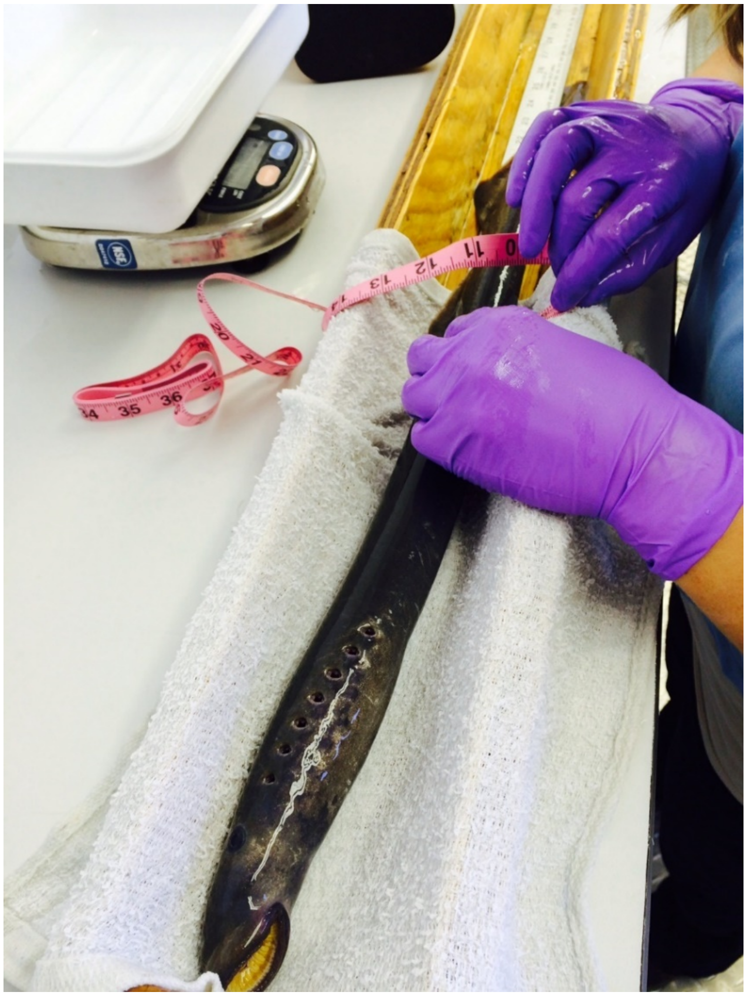

Figure 2. Girth was measured at the anterior insertion of the first dorsal fin. Length, inter-dorsal distance (IDD) to the nearest mm, and weight in grams, was measured and recorded before each lamprey was tagged.

2.3 Releases

After recovery, fish were transported in aerated containers filled with river water and released in the Priest Rapids Reservoir at Desert Aire (n=30) or in the Wanapum Reservoir at just downstream of the Vantage Bridge (n=35) or the boat launch immediately upstream of Wanapum Dam left bank (n=35) (Figure 3). Upon arriving at the release location, coolers were carried out onto the dock and lowered onto the water. The cooler lid was then opened while tipping one end up to empty the water and release the fish (Figure 4). Time of release was recorded. Two release events occurred at each release location between 22 July and 5 August.

Figure 3. Release location of acoustic tagged lamprey in the Priest Rapids Reservoir at Desert Aire (n-30) and the Wanapum Reservoir at either just downstream of the Vantage Bridge (n=35) or the boat launch immediately upstream of Wanapum Dam left bank (n=35).

Figure 4. Release of adult tagged lamprey at the Vantage Bridge release site.

2.4 Monitoring

The study took advantage of efficiencies created by an existing array of Vemco VR2 acoustic receivers deployed throughout the PRP in support of white sturgeon monitoring (Figure 5 and 6). In addition to the existing acoustic array, two VR2 acoustic receivers were deployed at the upstream boundary of the PRP, where the Wanapum Reservoir meets Rock Island Tailrace, to improve detection capabilities at the upper boundary of the study area (Figure 7). Fixed location acoustic receivers were also augmented with mobile tracking, to determine migration characteristics of adult Pacific lamprey in the Priest Rapids and Wanapum reservoirs and verify approach to Rock Island Dam.

Figure 5. Locations of existing Vemco VR2 acoustic receivers in Wanapum Reservoir deployed for the white sturgeon monitoring program. The last four digits of each label (VRRMXXX.X) represent the river mile at the deployed location.

Figure 6. Locations of existing Vemco VR2 acoustic receivers in Priest Rapids Reservoir deployed for the white sturgeon monitoring program. The last four digits of each label (VRRMXXX.X) represent the river mile at the deployed location.

Figure 7. Locations of the two additional Vemco VR2 acoustic receivers (W452.7 and W453.1) at the upstream boundary of the PRP, where the Wanapum Reservoir meets Rock Island Tailrace.

The receivers located at the Rock Island Dam Tailrace were downloaded every two weeks for the first six weeks after all releases were completed and then at 6 week intervals for the duration of the life of the tags (approximately 299 d at 120 s burst rate). The remaining receivers in the study area were downloaded in coordination with scheduled downloads associated with the white sturgeon monitoring program.

In the event that not all individuals were detected on fixed receivers, mobile tracking was used to attempt to locate fish that remained at-large. Mobile tracking commenced after the first download of the receivers at the Rock Island Tailrace (approximately two weeks after the final release). Mobile tracking was completed from a boat by drifting or slowly motoring downstream with an omnidirectional hydrophone placed 1-2 m beneath the surface of the water, attached to a VEMCO VR100 acoustic receiver with an internal GPS. All detections were automatically logged with a GPS location.

2.5 Detection Analysis

Detection records from Vemco VR2 acoustic receivers were compiled in a relational database maintained by BLE staff. A detection history was generated for each tag. Detection records were used to determine migration characteristics of tagged lamprey in the study area and to address the five objectives of the study (see Section 1.1). Detections on receivers located upstream of the study area (i.e., receivers in the Rocky Reach Reservoir deployed and maintained under direction of Chelan PUD) were evaluated as they became available. Detections of FDX-PIT tags at regional fixed detection sites were queried using the PIT TAG Information System (PTAGIS). Detections on receivers outside the PRP, detections of FDX-PIT tags, and detections from mobile tracking were used to augment detections of acoustic tags from the fixed receiver array within the PRP.

3.0 RESULTS

3.1 Migration upstream to the tailrace of Rock Island Dam

Of the 100 total acoustic tagged lamprey released in 2015, 83 were detected by the receivers in the tailrace of Rock Island Dam. The release locations of those 83 lamprey were Vantage (33), Wanapum Left Bank (30) and Desert Aire (20) (Table 1). Of those fish detected at the Rock Island Tailrace, 74.7% were last detected at the Rock Island Tailrace or above while the other 25.3% were last detected downstream of the Rock Island Tailrace, within the PRP. Travel times from release to first detection in the tailrace of Rock Island Dam varied by release site. Median travel times were 2.9, 3.7, and 16.8 days for lamprey being release at the Vantage, Wanapum Left Bank, and Desert Aire, respectively (Table 2). The order of median travel times corresponds with the distance from release site to the Rock Island Dam Tailrace. Overall, lamprey released in the Priest Rapids Reservoir travelled much slower than lamprey released in the Wanapum Reservoir. The median travel rate to reach the Rock Island Tailrace for fish released in the Priest Rapids Reservoir was 5.1 rkm/day (range 0.9-12.7 km/d) compared to 16.3 rkm/day and 18.0 rkm/day for the Wanapum Left Bank and Vantage releases, respectively (range 0.2-28.2 km/d) (Table 3). Eighty-nine percent of the 83 lamprey were detected at the tailrace of Rock Island Dam within weeks of being released. However, there were exceptions including; one fish from each release site that weren’t detected in the Rock Island Dam Tailrace until November of 2015, two fish from the Vantage release site and three fish from the Wanapum Left Bank release site that weren’t detected in the tailrace until spring of 2016, greatly increasing their travel times. We assumed these fish were not migrating the entire time before they were detected at the Rock Island Dam Tailrace because of large gaps in detection times between initial migration after release and when they resumed moving upstream to the Rock Island Tailrace. The travel time and travel rates of the fish excluding these outliers are in Tables 4 and 5, respectively.

Table 1. The quantity and percent detected of acoustic tagged lamprey by the receivers in the tailrace of Rock Island Dam by release location.

Release Site	Released	Detected	Percent Detected
Vantage	35	33	94.3%
Wanapum Dam	35	30	85.7%
Desert Aire	30	20	66.7%
Total	100	83	83.0%

Table 2. Travel time, in days, from release site to the first detection by the receivers in the tailrace of Rock Island Dam.

	Travel Time (days)				
Release Site	Min	Max	Median	Mean	SD
Vantage	1.9	262.7	2.9	22.7	64.1
Wanapum Dam	2.5	293.8	3.7	34.0	80.6
Desert Aire	6.8	95.9	16.8	24.9	20.8

Table 3. Travel rates, in river kilometers per day, from release site to the first detection by the receivers in the tailrace of Rock Island Dam.

	Travel Rate (rkm/d)				
Release Site	Min	Max	Median	Mean	SD
Vantage	0.2	28.2	18.0	15.0	6.6
Wanapum Dam	0.2	23.6	16.3	14.1	7.8
Desert Aire	0.9	12.7	5.1	5.3	3.0

Table 4. Travel time, in days, from release site to the first detection by the receivers in the tailrace of Rock Island Dam, excluding all fish first detected in the fall of 2015 or later.

	Travel Time (days)				
Release Site	Min	Max	Median	Mean	SD
Vantage	1.9	26.8	2.9	4.1	4.5
Wanapum Dam	2.5	21.7	3.6	4.9	4.2
Desert Aire	6.8	45.6	15.8	21.2	12.7

Table 5. Travel rates, in river kilometers per day, from release site to the first detection by the receivers in the tailrace of Rock Island Dam, excluding all fish first detected in the fall of 2015 or later.

	Travel Rate (rkm/d)				
Release Site	Min	Max	Median	Mean	SD
Vantage	2.0	28.2	18.2	16.5	4.9
Wanapum Dam	2.8	23.6	16.7	16.2	5.9
Desert Aire	1.9	12.7	5.5	5.5	2.9

3.2 Overwinter in the study area and resume migration in spring 2016

Two acoustic tagged lamprey overwintered in the PRP and resumed migration out of the PRP in the spring. One fish (Vantage release) overwintered in the Wanapum Reservoir and resumed upstream migration out of the PRP the following spring. It was last detected in December 2015 just downstream of the Rock Island Tailrace (RM 452.4) and then above the PRP at the Lower Wenatchee River PIT tag antenna in July 2016. One fish (Wanapum Left Bank release) was last detected in July 2015, approximately 10 rkm upstream of the release site (RM 426.5), and then downstream of the PRP on a receiver in the McNary Reservoir (RM 396.1) in April 2016.

3.3 Experience pre-spawn or predation mortality in the study area

Of the 100 acoustic tagged lamprey released within the PRP, three were never detected on any acoustic receiver, PIT tag antenna, or while mobile tracking after release, indicating possible mortality or tag failure. Two of the fish were released at Desert Aire and one was released at Wanapum Left Bank. A fourth fish, released from Desert Aire, was only detected once on a receiver just over 1 RM downstream of the release site, 29 days after release, also indicating possible mortality. It is impossible to determine if tags detected in 2015 but not redetected in 2016 (29%) were a result of tag failure, pre-spawn mortality, or overwintering and main-stem spawning in an area without a receiver within detection range.

3.4 Undetected spawning in reservoir tributaries

Four lamprey were last detected in the Priest Rapids Reservoir on the receiver near RM 410.5 in the spring of 2016. Of the fish that migrated upstream of the PRP, 10 were last detected on PIT tag antennas in the Entiat River and five were last detected on the PIT tag antenna on the lower Wenatchee River.

3.5 Spawning in the tailrace of Wanapum and/or Rock Island dams

A total of 27 lamprey were last detected in dam tailraces, five at Wanapum and 22 at Rock Island. However, 30.8% of these fish were last detected in the spring of 2016 so their tags could have expired before they had an opportunity to migrate upstream.

4.0 DISCUSSION

Migration rates through the study area varied by release group, median rates ranged from 5.1 to 18.0 rkm/d, but were similar to studies elsewhere in the Columbia River Basin and in other river systems. By comparison, radio-tagged lamprey in the Snake River had a typical summer-fall migration rate of between 5-15 rkm/d (McIlraith et al. 2015), Willamette River rates varied from 0-14.5 rkm/d (Courter et al. 2012), while John Day River and Yakima River rates averaged 11 rkm/d (Robinson and Bayer 2005; Johnsen et al. 2011). Overall, migration rates were slower in the release group that had to pass Wanapum Dam to reach the tailrace of Rock Island Dam. This was also observed in RT and JSATS tagged lamprey passing the lower Columbia River dams (Noyes et al. 2014; Keefer et al. 2015).

Previous studies have found that few lamprey travel long distances after overwintering to spawn (Courter et al. 2012; McIlraith et al. 2015). Thirty-two out of the 100 released acoustic tagged lamprey were last detected within the PRP. These fish may have spawned in the mainstem of the Columbia River or adjoining tributaries, within the PRP. Although there is little support for tributary spawning within the PRP. Nass et al. (2003) monitored a total of 125 RT lamprey over two years released within the PRP and did not detect lamprey entering any of the small tributaries that empty into the Columbia River within the PRP. In addition, during three years of juvenile lamprey sampling (2012-2014) within the PRP no juvenile lamprey were found at the mouth or in the lower reaches of any tributary creeks (Le et al. 2015; Le et al. 2017). The substantial proportion (27%) of tagged lamprey last detected in the tailrace of either Wanapum or Rock Island dam indicates there may be large numbers of lamprey engaging in undetected tailrace spawning; however, this is only speculation as current technology does not allow evaluation of spawning locations in large mainstem rivers. Fall Chinook salmon are known to spawn in the tailraces of large hydroelectric dams in the Columbia and Snake rivers therefore it is not unreasonable to assume lamprey also use that habitat to spawn (Dauble et al. 1999; McMichael et al. 2005).

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Appendix B
Assessment of Juvenile Lamprey Presence/Absence, Habitat Use, and Relative Abundance in the Priest Rapids Project

Assessment of Juvenile Lamprey Presence/Absence, Habitat Use, and Relative Abundance in the Priest Rapids Project Area

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EXECUTIVE SUMMARY

A 401 Water Quality Certification (401 Certification) was issued by the Washington State Department of Ecology (WDOE) on April 3, 2007, and amended March 6, 2008, for the operation of the Priest Rapids Hydroelectric Project (Project). A new license for the Project was issued by the Federal Energy Regulatory Commission (FERC) on April 17, 2008 (FERC 2008). Under FERC License Article 401(a)(12) and the 401 Certification (6.2 (5)(b)), Public Utility District No. 2 of Grant County (Grant PUD) is required, in consultation with the Priest Rapids Fish Forum (PRFF), the collaborative working group tasked with the implementation of fish-related license measures, to develop and submit for approval a Pacific Lamprey Management Plan (PLMP). On February 19, 2009 Grant PUD filed its PLMP with FERC and received on May 1, 2009 an "order modifying and approving" the PLMP.

The goals and objectives of the PLMP are to be achieved through a series of Protection, Mitigation, and Enhancement (PME) measures. This report summarizes the results of a study in support of the following PME measure as identified in the PLMP:

4.4.1- Juvenile Lamprey Presence/Absence, Habitat Use, and Relative Abundance in the Project Area: use existing aerial photographs, bathymetry, shoreline slope, velocity, and substrate characteristics to segregate habitat types into those areas with high, medium, and low potential for use by juvenile lamprey, and assess presence/absence in areas that may be affected by Project operations using electrofishing sampling.

The objective of this study was to:

1) Assess presence/absence, habitat use, and relative abundance of juvenile lamprey in areas that may be affected by Project operations.

Existing Grant PUD bathymetry data were analyzed using a Geographic Information System (GIS) to identify areas affected by the Project's operation. This area, known as the operational zone, was layered onto existing aerial photographs and further segregated into habitat types with high (Type 1), medium (Type 2), and low potential (Type 3) for use by juvenile lamprey (Close and Aronsuu 2003; Hansen et al 2003). Sample sites were chosen favoring Type 1 habitat, but including Type 2 and Type 3 habitat, and water less than 1 meter in depth. Catch Per Unit Effort (CPUE) was calculated for each habitat type within a reservoir and sample period as an index of relative abundance. Each site was sampled for 20 minutes of collection effort using an ABP-2 backpack electrofisher at a slow walking pace. The initial electrofisher power settings were recommended by Yakama Nation Fisheries staff (125 volts [DC] with 3 pulses/second, a 25% duty cycle, and a 3:1 pulse train) but were adjusted in October 2013 to match settings used by other regional sampling crews (voltage increased to 350). Sampling commenced in June 2012 and continued through October 2013, totaling 73 sample locations in Wanapum Reservoir and 41 in Priest Rapids Reservoir. A total of 8 Pacific lamprey ammocoetes were captured and measured for length and identified to species, and released at the location of capture. Eleven others were observed but not captured. Seven of the ammocoetes captured were collected during October 11-12, 2013 when the elevation of Priest Rapids Reservoir was unusually low (480 feet above mean sea level; normal pool elevation is 485-487), exposing areas that were normally inundated with water. CPUE ranged from 0 to 0.03 and 0 to 2.13 in the Wanapum and Priest Rapids Reservoirs respectively. This suggests that juvenile lamprey are present, but rare, in the operational zone of the Priest Rapids Project.

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1.0 INTRODUCTION

A 401 Water Quality Certification (401 Certification) was issued by the Washington State Department of Ecology (WDOE) on April 3, 2007, and amended March 6, 2008, for the operation of the Priest Rapids Hydroelectric Project (Project). A new license for the Project was issued by the Federal Energy Regulatory Commission (FERC) on April 17, 2008 (FERC 2008). Under FERC License Article 401(a)(12) and the 401 Certification (6.2 (5)(b)), Public Utility District No. 2 of Grant County (Grant PUD) is required, in consultation with the Priest Rapids Fish Forum (PRFF), the collaborative working group tasked with the implementation of fish-related license measures, to develop and submit for approval a Pacific Lamprey Management Plan (PLMP). On February 19, 2009 Grant PUD filed its PLMP with FERC and received on May 1, 2009 an "order modifying and approving" the PLMP.

The goals and objectives of the PLMP are to be achieved through a series of Protection, Mitigation, and Enhancement (PME) measures. In 2012, a monitoring study was initiated in support of the following PME measure as identified in the PLMP:

4.4.1- Juvenile Lamprey Presence/Absence, Habitat Use, and Relative Abundance in the Project Area: use existing aerial photographs, bathymetry, shoreline slope, velocity, and substrate characteristics to segregate habitat types into those areas with high, medium, and low potential for use by juvenile lamprey, and assess presence/absence in areas that may be affected by Project operations using electroshocking sampling.

This study was originally intended to span three years, but on February 27, 2014, a horizontal fracture was discovered in the spillway monolith No. 4 at Wanapum Dam. The fracture opened a crack on the upstream face of the structure approximately 2 inches high by 65 feet long on the spillway monolith. Grant PUD immediately initiated its Emergency Action Plan (EAP; level B) and began to draw the Wanapum Reservoir down in a steady controlled state. In relation to this study, one result of the drawdown was that previous conditions in the Wanapum Reservoir were altered to such a degree that results from sampling after the drawdown in 2014 (third year of study) would likely not be comparable with sampling that occurred prior to the drawdown. As such, this report documents sampling that occurred in 2012 and 2013. Results from 2014 can be found in Le et al. 2015.

1.1 Pacific Lamprey

Pacific Lamprey (*Entosphenus tridentatus*) numbers have declined since the 1940's as a result of spawning habitat loss, impediments to migration, changing ocean conditions, decreased water quality, declines of marine host fish, and possible bioaccumulation of contaminants (Close et al. 1995, 2002, Murauskas et al. 2012, Nilsen et al. 2015). Much focus over the past 10 years has been placed on studying migrating adults at hydroelectric facilities and identifying passage impediments. Modifications have been made to many dam operations and structures to improve lamprey passage. Little work, however, has been devoted to investigating lamprey while in their juvenile stages and in the vicinity of the mainstem mid and upper Columbia River.

Pacific lamprey eggs hatch after approximately 19 days (Pletcher 1963 as cited in Close et al. 1995, Lê et al. 2004, Luzier and Silver 2005). Once hatched, larvae drift downstream until encountering a silt/sand substrate and low velocity flow conditions (Pletcher 1963 as cited in Close et al. 2002). They reside and burrow in fine sediment (Close et al. 2002) filter feeding on diatoms, algae, and detritus (Beamish and Levings 1991) for up to seven years (Beamish and

Northcote 1989, Hammond 1979 as cited in Close et al. 1995). At this stage, the juvenile lamprey are known as ammocoetes. During this time they may move down stream during high water flows (Lê et al. 2004). Pacific lamprey then enter a transformation phase characterized by morphological and physiological changes that begin in the latter period of substrate residence and continues into their downstream migration to the ocean. After a parasitic life in the ocean, Pacific lamprey return to freshwater to spawn then die.

River (*Lampetra ayresii*) and Western Brook (*L. richardsonii*) lampreys are also present in Columbia River Basin (Wydoski and Whitney 1979). Less research has been conducted on these two species but their life cycles have been observed to be somewhat similar to that of Pacific lamprey. Western Brook lamprey do not migrate to the ocean for the parasitic portion of their life and prefer smaller substrate that Pacific lamprey for spawning. Adults of both species are much smaller than that of Pacific lamprey (Scott and Crossman 1973 as cited in Luzier 2005). River and Western Brook are found at much smaller numbers than Pacific lamprey and Western Brook lamprey distribution tends to be associated with coastal streams (Wydoski and Whitney 1979). Juveniles of all three species are difficult to distinguish.

There have been recent efforts to address knowledge gaps regarding juvenile lamprey habitat use and response to fluctuating reservoir elevations in the Columbia Basin. Jolley et al. (2016) used deepwater electrofishing techniques to collect juvenile lamprey in various habitat types in the John Day and McNary pools, including shallow water likely to be influenced by reservoir operations. The presence of juvenile lamprey in shallow water suggests that resource managers need to be aware of potential impacts of dewatering habitat. Liedtke et al. (2015) tested the ability of juvenile Pacific lamprey in a lab setting to move from dewatered habitat and survive exposure to dewatered conditions similar to those created by simulated rapid ramping rates at hydroelectric facilities. While larger fish were able to survive dewatered conditions for a longer duration than smaller fish, dewatering habitat created survival risks for all size classes of juvenile lamprey in the trials.

The Priest Rapids Project shoreline is affected by the operation of Priest Rapids, Wanapum, and Rock Island dams and is subject to fluctuating reservoir water levels as allowed by the FERC license. The normal pool operating range for Priest Rapids Dam is between 481.5-488.0 feet mean sea level (ft msl) and 560-571.5 ft msl for Wanapum Dam. This area, known as the operational zone, contains a variety of habitat types including soft sediment, sand/gravel, or hard rock with the latter two being the most frequent. Depending on shoreline slope, near-shore juvenile lamprey habitat within the operational zone may be dewatered during operations. This reservoir fluctuation has the potential to impact juvenile lamprey inhabiting the operational zone. Areas below minimum pool elevations were not of interest for this study because they are unaffected by normal project operations.

The objective of this study was to:

1) Assess presence/absence, habitat use, and relative abundance of juvenile lamprey in areas that may be affected by Project operations.

1.2 Study Area

Wanapum and Priest Rapids dams are operated by Grant PUD and span 58 miles of the Columbia River. The Wanapum Reservoir is 38 miles long and has a surface area of approximately 14,680 acres. A total of ten tributaries; Johnson, Skookumchuck, Whisky Dick, Sand Hollow, Quilomene, Trinidad, Tarpiscan, Colockum, Douglas, and Brushy creeks enter into the reservoir. The Priest Rapids Reservoir is 18 miles long and has a surface area of approximately 7,725 acres. Two tributaries; Crab, and Hanson creeks, enter into the reservoir.

2.0 JUVENILE LAMPREY DISTRIBUTION AND ABUNDANCE SAMPLING METHODS

2.1 Habitat Mapping

The computer software package ArcGIS and existing reservoir bathymetry data were used to map the shoreline elevations affected by typical operation of Priest Rapids Project as allowed by the FERC license (vertical change in reservoir elevation associated with dewatered shoreline). The area that encompassed these elevations, known as the operational zone, was further segregated into habitat areas (Close and Aronsuu 2003; Hansen et al 2003) with high (Type 1), medium (Type 2), and low potential (Type 3) for use by juvenile lamprey based on local knowledge of the substrate type in the area (Table 1). A final Geographic Information System (GIS) map was developed outlining the operational zone and habitat types (Figure 1). Prior to selecting areas to sample, Type 1 habitats were visited by boat to confirm the results of the desktop habitat assessment.

Table 1. Habitat type description. Adapted from [1]Close and Aronsuu 2003, [2]Hansen et al 2003.

Habitat Type	Description
Type 1	[1]Mixture of soft sediment particles including silt, clay, fine organic matter, and some sand [2]Preferred juvenile lamprey habitat that usually consists of sand, fine organic matter, and cover (detritus, aquatic vegetation), which is usually formed in areas of deposition
Type 2	[1]Similar to Type I habitat but with a larger component of sand [2]Acceptable, but not preferred, juvenile lamprey habitat that usually consists of shifting sand, gravel, or rubble, and very little or no fine organic matter, but is soft enough for juvenile lamprey to burrow into
Type 3	[1]Bedrock, hard clay, cobble, or coarse gravel substrates [2]Cannot be penetrated by juvenile lamprey, so is unacceptable habitat, and usually consists of bedrock or hardpan clay, with rubble and coarse gravel

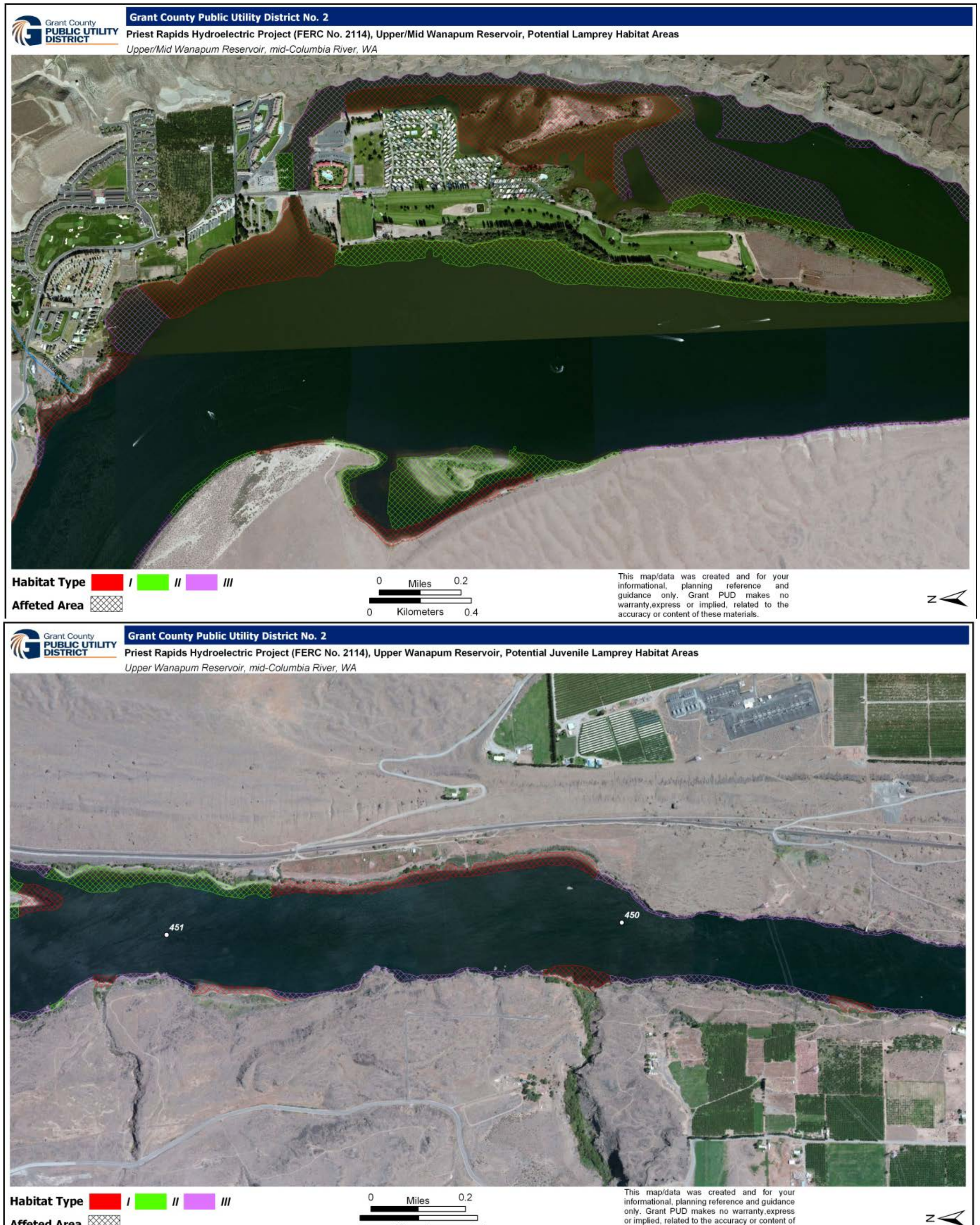

Figure 1. Examples of Type 1, 2, and 3 juvenile lamprey habitat types in the Priest Rapids Project in a GIS map.

2.2 Sample Site Selection

At the beginning of each sampling period, delineated by spring and fall seasonal efforts over two years (see Section 2.4 for additional details), all sample sites generated from the habitat mapping task were grouped according to habitat type and reservoir (e.g., Priest Rapids Type 1, Priest Rapids Type 2, Wanapum Type 2, etc.). Habitat areas in each group were assigned a unique number ID and a random number generator was used to assign an order of sampling. Randomly chosen sites were grouped by proximity to boat launches to reduce time spent travelling between locations. Not all areas in each reservoir and habitat type were sampled in each sampling period but the predetermined list of sites provided an efficient sequence of sampling effort. More sites were sampled in Type 1 habitat than 2 and 3 in an effort to produce the highest probability of capture. In the process of identifying sample sites, a target of 80% Type 1 habitat, 10% Type 2 habitat, 10% Type 3 habitat was used (Table 2). Sampling effort was weighted proportionally higher in the Wanapum Reservoir as it contained three times more area than Priest Rapids in its operational zone. The overall distribution of planned effort reflected this difference; 66% of sites sampled were in Wanapum Reservoir while 33% were in Priest Rapids Reservoir.

In anticipation that sample sites would be too large to sample in their entirety, specific locations to subsample within each site were to be chosen by field crews familiar with juvenile lamprey ecology and were to be based on both safe access to the habitat and highest probability of holding juvenile lamprey. When time and conditions allowed, some sites were subsampled more than once, in non-overlapping locations, during a sampling period to better explore the potential for juvenile lamprey abundance. While sites were expected to vary in slope and substrate type, sampling effort was standardized to 20 minute intervals with the backpack electrofisher in operation per sampling event. Reservoir elevations at the time of sampling were not planned by the sampling crew; rather, reservoir elevation varied throughout the day. As a result, the sampling crews sampled the best available habitat at each location.

Table 2. Percentage of habitat area in the entire Priest Rapids Project operational zone available to be sampled. Effort was weighted proportionately towards Wanapum Reservoir as it had a larger operational zone area (km^2) than Priest Rapids Reservoir, and towards Type 1 habitat as it was considered preferred habitat for juvenile lamprey. Total km^2 for each reservoir and Type are included in the ( ) and calculations to determine percentages are in the [ ].

Habitat Type	Priest Rapids	Wanapum	Total
1	29% (0.9 km^2) [0.9 km^2/ 2.5 km^2 x .8]	51% (1.6 km^2) [1.6 km^2/ 2.5 km^2 x .8]	80% (2.5 km^2)
2	3% (0.8 km^2) [0.8 km^2/ 2.7 km^2 x .1]	7% (1.9 km^2) [1.9 km^2/ 2.7 km^2 x .1]	10% (2.7 km^2)
3	3% (1.6 km^2) [1.6 km^2/ 4.7 km^2 x .1]	7% (3.1 km^2) [3.1 km^2/ 4.7 km^2 x .1]	10% (4.7 km^2)
Total	33% (3.3 km^2) [3.3 km^2/ 9.9 km^2]	66% (6.6 km^2) [6.6 km^2/ 9.9 km^2]	100% (9.9 km^2)

2.3 Data collection

Sampling was conducted by two, two-person survey crews in 2012 and a single, two-person crew in 2013. Each crew used an ABP-2 backpack electrofisher and was ferried from site to site by a designated boat driver. During sampling efforts with two crews, each crew was dropped off at a different site and ferried on to the next site throughout the day in an effort to reach as many sites as possible.

Sites were planned to be sampled in an 8:16:1:2:1:2 ratio (Priest Rapids Type 1, Wanapum Type 1, Priest Rapids Type 2, Wanapum Type 2, Priest Rapids Type 3, Wanapum Type 3, respectively) in order to obtain the goals set in 2.3. Twenty minutes (based on each electrofisher's operational clock time) of electrofishing effort was used for each sample site, moving continuously into new habitat within a sample site (crews did not double back along the sampling path). The sampling path was recorded using a high-precision Global Positioning System (GPS) (Trimble Model GeoXT) and later imported into a GIS to estimate sampling area (length [m] of path sampled x 3 m width = sample area).

The settings for the ABP-2 backpack electrofisher started with 125 volts (DC) with 3 pulses/second, a 25% duty cycle, and a 3:1 pulse train (recommended by Patrick Luke, Yakama Nation Fisheries). In fall of 2013, the voltage was increased to 350 volts (DC) based on successful juvenile lamprey sampling completed by another crew working in the Hanford Reach of the Columbia River (Lindsey et al. 2013). All sampling was conducted at a slow walking pace.

At each sampling site, electrofishing was conducted in depths from 0-1 m. Electrofishing at depths greater than 1 m increased the risk of submerging the backpack components which could result in damaging the equipment and/or electrical shock. At each sample site, GPS was used to record the start and end points as well as the path of each sampling event. Additionally, date, beginning and end time, location code, field staff, water temperature, conductivity, starting and ending water depth during sampling, substrate description, and comments regarding water visibility and incidental species encountered were recorded for each sampling event. The forebay elevation (feet above mean sea level) at the time of sampling was also obtained from a Grant County PUD fisheries specialist.

Sampling crews attempted to catch all lamprey that that were observed during electrofishing but not all were captured. Lamprey that were seen, but not caught, were counted and recorded as observed. Captured lamprey were placed in an aerated bucket and anesthetized with a tricaine methanesulfonate (MS-222) solution. Ammocoetes were measured for length and a sterile fingernail clipper was used to attempt to remove a small tissue sample from the end of the caudal fin. Fin clips were not successfully collected. Lamprey were held in a bucket of aerated river water until they had recovered (swimming vigorously), and then released near the location of capture. Ammocoetes were identified and enumerated as Pacific, River, or Western Brook species using a U.S. Fish & Wildlife Service key (Figure 2) and characteristics described in "Lampreys of the Columbia Basin Field ID Key" by Stewart Reid. Sampling crews took photos and notes describing features of each location where a lamprey was observed.

When lamprey were captured or observed, Catch Per Unit Effort (CPUE) was calculated for each habitat type within a reservoir and sample period as an index of relative abundance. Catch Per Unit Effort was calculated by dividing the quantity of juvenile lamprey captured or observed by the total quantity of sites sampled of each habitat type in a reservoir. For example, if one lamprey was captured or observed in the course of sampling 12 sites of type 1 habitat in the Wanapum Reservoir, the CPUE = 1/12, or 0.08 lamprey per site. The total CPUE for all sites sampled in each reservoir, regardless of habitat type, was also calculated for each sampling period.

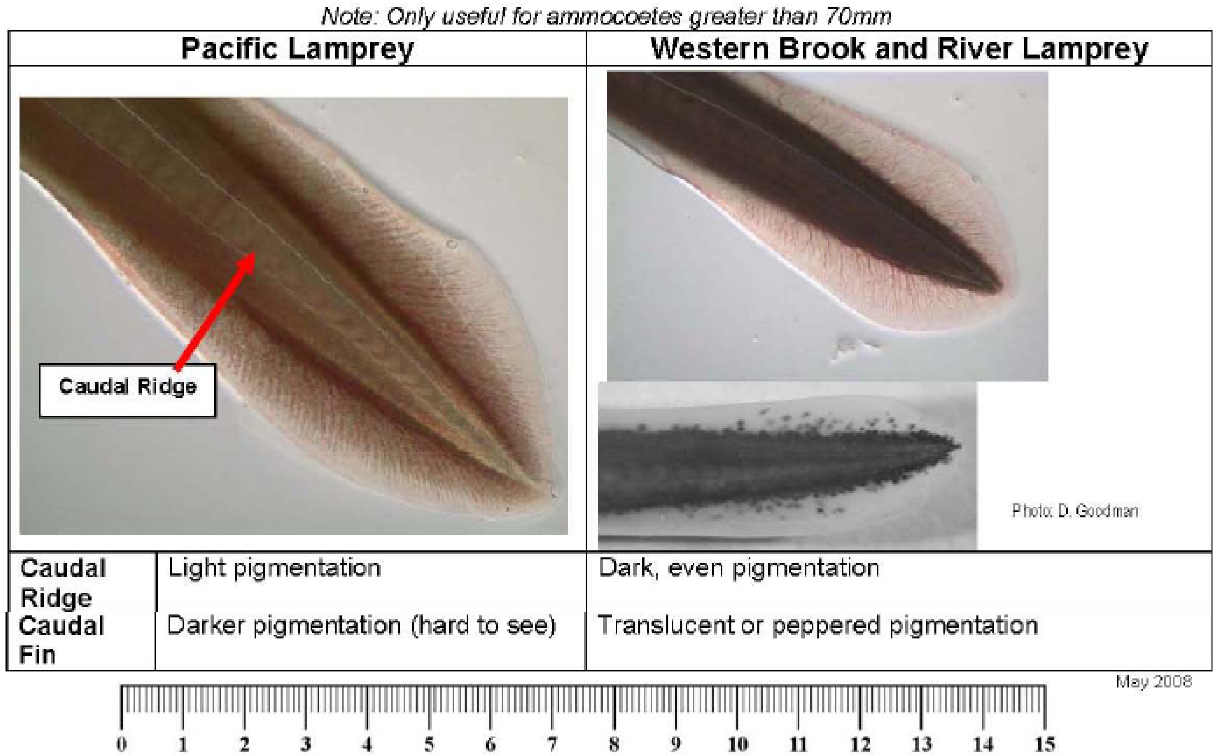

Figure 2. Key to identify ammocoetes of Pacific, River, and Western Brook Lamprey (USFW 2008)

2.4 Sampling schedule

Sampling effort was scheduled in an attempt to assess juvenile lamprey presence and relative abundance within the range of normal Project reservoir elevations. Grant PUD biologists coordinated with Project operators to opportunistically select representative sampling periods, although operations were not altered to accommodate the study. The study was comprised of four sampling periods, delineated by spring and fall seasonal efforts over two years. The first sampling period included June 4-8 and 11-15, 2012; the second November 13-16 and December 11-14, 2012; the third occurred during May 11-12, 2013; and the final sampling period was October 11-12, 2013. As many sites as possible were sampled each day, dependent on conditions.

3.0 RESULTS and DISCUSSION

3.1 Collection of juvenile Pacific lamprey

A total of 36 sites were sampled in the Wanapum Reservoir and 12 sites were sampled in the Priest Rapids Reservoir during the first sampling period on June 4-8 and 11-15, 2012, however, the sampling effort yielded only one captured ammocoete and another that was observed but not captured. The resulting CPUE was 0.03 for Wanapum Reservoir type 1 habitat and 0.09 for Priest Rapids Reservoir type 1 habitat. One lamprey was captured downstream of Hanson Creek (river right bank, Priest Rapids Pool, RM 406.7) in a Type 1 habitat in Priest Rapids Reservoir, on June 7, 2012 (Table 3). This capture, however, did not occur during the standard sampling protocol. Upon concluding the 20-minute standard pass, the electrofisher was used in a small pool just above the water line, formed by the dropping reservoir at the base of emergent shoreline vegetation. A single Pacific lamprey ammocoete (length = 140 mm) emerged from the substrate and was captured. The shoreline substrate at the location of this small pool consisted of soft mud and had a very gradual slope. Another Pacific lamprey ammocoete was seen, but not captured, upstream of Crescent Bar Estates (river left bank, RM 442.1, Figure 3) in a Type 1 habitat in Wanapum Reservoir on June 14, 2012. The ammocoete was observed emerging and quickly exiting from the substrate and appeared to be approximately 150 mm. The shoreline substrate consisted of loose sand and had a steep slope. Reservoir elevations during these sampling periods were within the mid-level of the operational zone; approximately 570.0 ft above mean sea level (msl) in the Wanapum Reservoir and between 485-487 ft above msl in the Priest Rapids Reservoir.

Table 3. Juvenile lamprey sampling results from June 4-8 and 11-15, 2012.

Reservoir	Habitat Type	Sites sampled once	Sites sampled twice	Total samples	Area sampled (m2)	Total lamprey caught (observed)	CPUE	Reservoir Elevation
Wanapum	1	30	2	32	2400	(1)	0.03	Normal - approx. 570 feet above msl
	2	2	0	2	150	0	0	
	3	2	0	2	150	0	0	
	Total	34	2	36	2700	(1)	0.03	
Priest Rapids	1	8	3	11	825	1	0.09	Normal - approx. 485-487 feet above msl
	2	0	0	0	0	0	n/a	
	3	1	0	1	75	0	0	
	Total	9	3	12	900	1	0.08	

Figure 3. One ammocoete was observed, but not captured, during shoreline sampling upstream of Crescent Bar in the Wanapum Reservoir in June, 2012.

During the second sampling period November 13-16 and December 11-14, 2012, a field crew continued sampling efforts in the Project area. Twenty-seven and 21 shoreline habit locations were sampled in the Wanapum and Priest Rapids reservoirs, respectively (Table 4). During this sample period, lower reaches of tributary streams including Sand Hollow Creek and Crab Creek were targeted in addition to previously identified mainstem sample sites. Sampling was conducted at mid-range elevations of the operational zone; approximately 570.0 ft above msl at the Wanapum Forebay and between 485.3-487.5 ft above msl at the Priest Rapids Forebay. No juvenile lamprey were collected or observed.

Table 4. Juvenile lamprey sampling results from November 13-16 and December 11-14, 2012. No lamprey were caught or observed, therefore no estimate of CPUE is included in the table.

Reservoir	Habitat Type	Sites sampled once	Sites Sampled twice	Total samples	Area sampled (m2)	Total lamprey caught (observed)	Reservoir Elevation
Wanapum	1	26	0	26	1147.4	0	Normal - approx. 570 feet above msl
	2	1	0	1	79.7	0	
	3	1	0	1	65.2	0	
	Total	28	0	28	1292.3	0	
Priest Rapids	1	19	0	19	1618.6	0	Normal - approx. 485-487 feet above msl
	2	1	0	1	55.7	0	
	3	1	0	1	0	0	
	Total	21	0	21	1674.3	0	

Sampling effort continued with a third sampling period on May 11 and 12, 2013. Ten shoreline habitat locations in the Wanapum Reservoir were sampled; no juvenile lamprey were collected or observed (Table 5). The pool elevation at the Wanapum Forebay was 569.0 ft above msl (mid-level) during this sampling period.

The fourth and final sampling period was completed on October 11 and 12, 2013. Eight potential shoreline habit locations in the Priest Rapids Reservoir were sampled, resulting in the collection of seven Pacific lamprey ammocoetes (length = 76-105 mm) (Table 6 and Figure 4). An additional 10 ammocoetes were observed but not captured. The resulting CPUE was 2.67 for type 1 habitat and 1.0 for type 2 habitat. The elevation of the Priest Rapids Forebay was low, 480.2 ft above msl, during this effort (near allowable minimum reservoir elevation per the FERC license). As a result, the reservoir was unusually low during this sampling period and macrophyte beds were exposed and available to sample that otherwise would have been too deep to safely reach with backpack elecrofishing gear (Figures 5 and 6). The sampling crew observed that when conditions allowed safe access to these previously submerged macrophyte beds, they consistently were able to capture and observe ammocoetes using the standard sampling protocol. The sampling crew for this effort adjusted the power settings on the backpack elecrofisher to match the settings reported by Lindsey et al. (2013) (increasing the voltage from 125 to 350 in an effort to achieve 2 amps, as recommended by the manufacturer). This adjustment, in concert with the low reservoir elevation providing access to previously unavailable lamprey habitat, appears to have created conditions for successful collection and observation of juvenile lamprey in the Project area (Figures 7 and 8).

Table 5. Juvenile lamprey sampling results from May 11-12, 2013. No lamprey were caught or observed, therefore no estimate of CPUE is included in the table.

Reservoir	Habitat Type	Habitats sampled once	Habitats Sampled twice	Total samples	Area sampled (m2)	Total lamprey caught (observed)	Reservoir Elevation
Wanapum	1	9	0	9	740	0	Normal - approx. 569 feet above msl
	2	0	0	0	0	0	
	3	0	0	0	0	0	
	Total	9	0	9	740	0	

Table 6. Juvenile lamprey sampling results from October 11-12, 2013.

Reservoir	Habitat Type	Habitats sampled once	Habitats Sampled twice	Total samples	Area sampled (m2)	Total lamprey caught (observed)	CPUE	Reservoir Elevation
Priest Rapids	1	6	0	6	808.4	6 (10)	2.67	Low - approx. 480 feet above msl
	2	1	0	1	110.8	1	1.0	
	3	1	0	1	165.6	0	0	
	Total	8	0	8	1084.8	7 (10)	2.13	

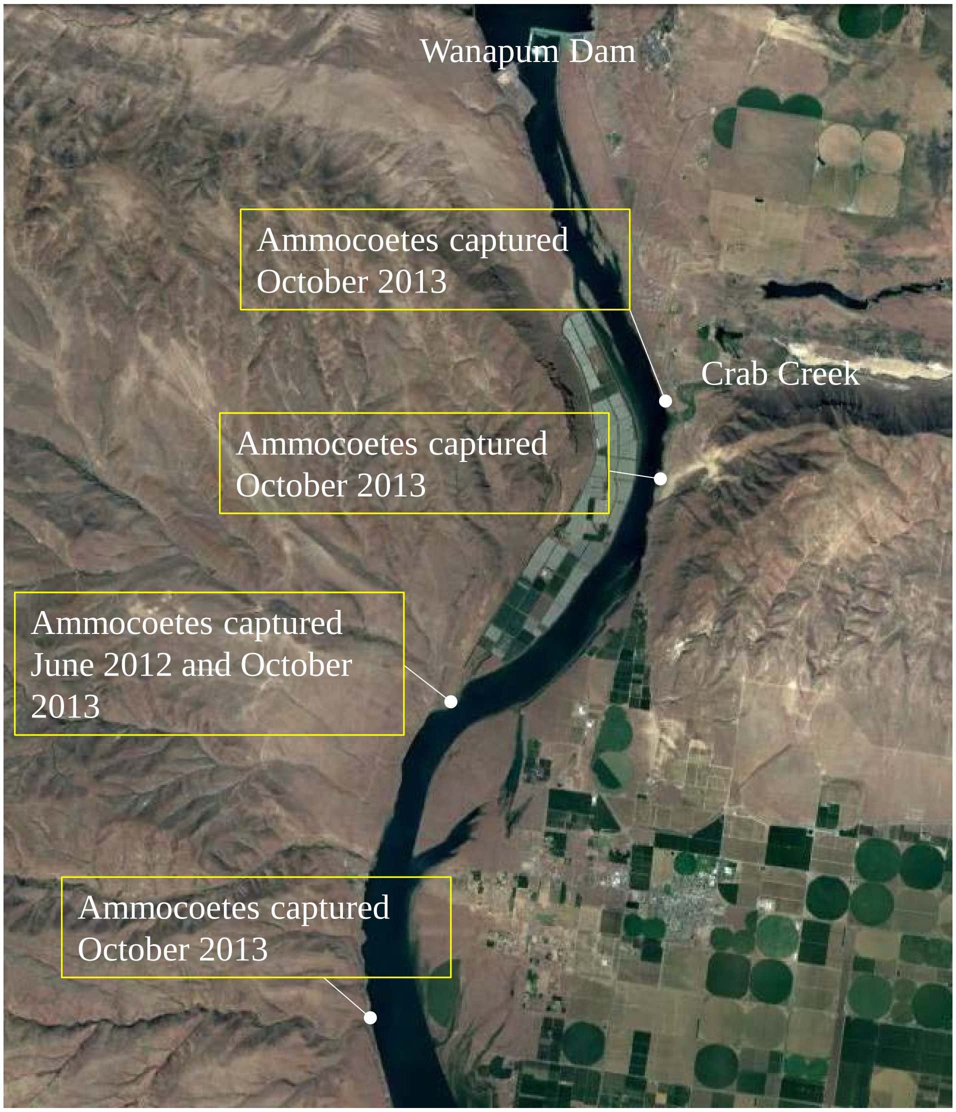

Figure 4. One Pacific lamprey ammocoete was captured during shoreline sampling in June 2012 and seven more were captured in October 2013 at four sites in the Priest Rapids Reservoir.

Figure 5. A sampling crew from Blue Leaf Environmental was able to access previously submerged macrophyte beds during a period of unusually low elevation in the Priest Rapids Reservoir; approximately 480 feet above mean sea level in the Priest Rapids Dam Forebay, in October 2013. Normal reservoir elevations range from 485-487 feet above mean sea level.

Figure 6. Macrophytes present in a designated Type 1 habitat for juvenile lamprey in the Priest Rapids Reservoir, October 2013.

Figure 7. A Pacific lamprey ammocoete (length = approximately 95 mm) collected during shoreline sampling with an ABP-2 backpack electrofisher in the Priest Rapids Reservoir, October 2013.

Figure 8. A Pacific lamprey ammocoete (length = approximately 76 mm) collected during shoreline sampling with an ABP-2 backpack electrofisher in the Priest Rapids Reservoir, October 2013.

3.2 Assessment of presence/absence, habitat use, and relative abundance of juvenile lamprey

The sampling crews for this effort were trained by Yakama Nation Fisheries staff at field sites in the Yakima River basin prior to beginning sampling in the Columbia River. Even though the field training sites were selected by a biologist with extensive knowledge of juvenile lamprey ecology (Patrick Luke, Yakama Nation Fisheries), no juvenile lamprey were captured during training. This underscores the difficulty in capturing these fish. As such, extensive sampling efforts were anticipated in order to achieve a representative amount of sampling to adequately evaluate the Project area.

Our results indicate that after considerable sampling effort, Pacific lamprey ammocoetes are present, but rare, in shoreline areas of the Project that are accessible during normal reservoir elevations. These findings are consistent with the Rocky Reach Reservoir assessment where five ammocoetes were found at one of eight locations (Chelan PUD 2012), with work completed in the Hanford Reach, where nine locations were sampled but ammocoetes were collected at only two (Lindsey et al. 2013), and with a Wells Reservoir assessment where 11 sites were sampled and no ammocoetes were observed or collected (Douglas PUD 2015).

The delineation of lamprey habitat in the Project prior to beginning the study appears to have been an effective method of stratifying sampling effort. When Pacific lamprey ammocoetes were found, they tended to be in locations consistent with the description of Type 1 habitat, including the presence of aquatic vegetation. The majority of these aquatic macrophytes occurred below the operational zone of the project in habitat that is generally always inundated and typically too deep to safely access on foot (> 1 m deep), making the opportunity to sample around them rare and present safety concerns.

Catch Per Unit Effort (CPUE) estimates are based around the assumption that the quantity of fish caught is proportional to the effort expended to take the sample. A primary assumption is that one unit of sampling effort is assumed to catch a fixed proportion of the population. Specific assumptions include that, 1) the population is closed, 2) the probability of capture is constant throughout the study and is the same for each individual, and 3) all individuals have the same probability of being caught in each sample (Seber 1982). Unfortunately, variability that occurs due to factors other than abundance of the target organism can confound the assessment (Murphy and Willis 1996). Specifically, Hangsleben et al. (2013) discussed that many biotic and abiotic factors, such as abundance of the target organism, characteristics of the habitat being sampled, water temperature and clarity, power output of the electrofisher, season, and body of water can affect electrofishing results. While these factors were challenging, efforts were made to reduce sources of sampling variability by standardizing sampling gear, methods, and study design. As such, CPUE results presented here were compromised by low catch rates and substantial biotic and abiotic variability.

The very low number of ammocoetes collected and observed during sampling in 2012 and 2013 were expected based on conversations with regional biologists and comparative to previous regional study results. However, the relatively successful sampling during the period in October 2013 when the elevation of Priest Rapids Reservoir was unusually low suggests that juvenile lamprey were likely more abundant in habitat that was typically inundated in all but very rare instances. This unusually low elevation for the Priest Rapids Reservoir was two feet below the lowest daily average elevation recorded in the previous 10 years (Figure 9). Also during this period, the sampling crew adjusted the power settings to obtain greater effectiveness with the backpack electrofisher, which may have confounded results from earlier sampling periods. However, ammocoetes were captured and observed prior to October 2013 using the original power settings, which were also used by Douglas PUD (2015) and Chelan PUD (2012). All other sampling for this study was conducted at typical forebay elevation ranges for both reservoirs, encompassing 31.1% and 75.8% of the daily average elevations from 2004-2013 in the Wanapum and Priest Rapids Forebays respectively.

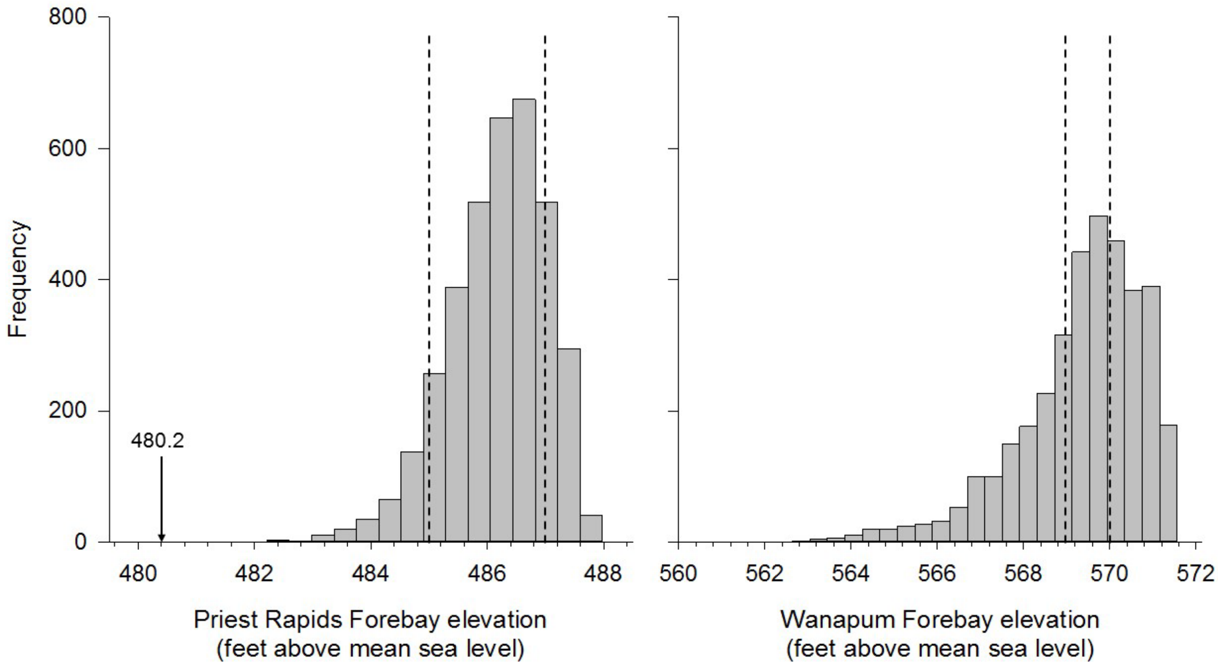

Figure 9. Frequencies of daily average Priest Rapids and Wanapum Forebay elevations for a 10-year period (2004-2013). The dashed lines indicate the upper and lower boundaries of the forebay elevations during sampling for all sampling periods in the Wanapum Reservoir and two out of three sampling periods in the Priest Rapids Reservoir. The third Priest Rapids Reservoir sampling period occurred during an unusually low forebay elevation (480.2 feet above mean sea level).

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Appendix C
Summary Table of Agency/Tribal Comment and Grant PUD Responses

Submitting Entity	Date Received	Section /Page	Agency Comment	Grant PUD Response
WDFW	2/27/2017	1	I recommend Grant PUD capture within this report attempts to reach a pacific lamprey settlement agreement. The Priest Rapids Fish Forum (PRFF) and Pacific Lamprey subgroup of the PRFF worked diligently to reach a settlement. Albeit a settlement was not reached. This work represented a substantial amount of time invested by the PUD and the members of the PRFF. The WDFW appreciates the efforts of Grant PUD in developing a settlement agreement and the PUD's interest in working through adaptive management to address No Net Impact to lamprey at the Priest Rapids Project. We encourage Grant PUD to continue to employ adaptive management and to work towards a settlement agreement that is agreeable to all parties.	Grant PUD generally agrees that the PRFF has diligently worked to collectively define No Net Impact and has included additional summary information related to these ongoing discussions in Section 1.2 of this report.
WDOE	3/14/2017	1	The Department of Ecology (Ecology) has reviewed the 2016 Pacific Lamprey Management Plan Comprehensive Annual Report that was e-mailed to Ecology on January 24, 2017. This report is a requirement of Section 6.2(5)(c) for the Pacific Lamprey Management Plan and Section 6.2(5)(d) of the 401 certification.	Comment noted.
WDOE	3/14/2017	1	Ecology recognizes Grant County PUD's efforts in developing a settlement agreement and working through adaptive management to address No Net Impact (NNI) to lamprey at the Priest Rapids Hydroelectric Project. We support and encourage Grant PUD to continue to work toward a settlement agreement through adaptive management that is agreeable to all parties.	See Grant PUD's response to comment #1 above.

Appendix D
Agency Comments

From: Verhey, Patrick M (DFW)
To: Debbie Firestone; Zimmerman, Breean (ECY); Aaron Jackson (AaronJackson@ctuir.org); Bob Rose; Brian McIlbraith (MCIB@critfc.org); CarlMerkle@ctuir.com; Doris Squeochs; Erin McIntyre; Gary James (GaryJames@ctuir.org); Jason McLellan (Jason.McLellan@colvilletribes.com); Korth, Jeff W (DFW); Keith Hatch (keith.hatch@bia.gov); Mike Clement; Rex Buck, Jr.; Steve Lewis (Stephen_Lewis@fws.gov); Tom Dresser; Tracy Hillman
Cc: Tom Dresser; Ross Hendrick; Mike Clement
Subject: RE: Grant County PUD"s Draft Pacific Lamprey Management Plan annual report for 2016
Date: Monday, February 27, 2017 10:22:30 AM
Attachments: image001.png

Mike, good report. I recommend Grant PUD capture within this report attempts to reach a pacific lamprey settlement agreement. The Priest Rapids Fish Forum (PRFF) and Pacific Lamprey subgroup of the PRFF worked diligently to reach a settlement. Albeit a settlement was not reached. This work represented a substantial amount of time invested by the PUD and the members of the PRFF. The WDFW appreciates the efforts of Grant PUD in developing a settlement agreement and the PUD's interest in working through adaptive management to address No Net Impact to lamprey at the Priest Rapids Project. We encourage Grant PUD to continue to employ adaptive management and to work towards a settlement agreement that is agreeable to all parties.

Patrick Verhey
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WDFW Habitat Program
Renewable Energy Section
1550 Alder St N.W.
Ephrata, WA 98823
(509) 754-4624 ex. 213
Patrick.Verhey@dfw.wa.gov
Work schedule is M-Th

From: Debbie Firestone [mailto:Dfirest@gcpud.org]
Sent: Tuesday, January 24, 2017 10:06 AM
To: Zimmerman, Breean (ECY); Aaron Jackson (AaronJackson@ctuir.org); Bob Rose; Brian McIlbraith (MCIB@critfc.org); CarlMerkle@ctuir.com; Doris Squeochs; Erin McIntyre; Gary James (GaryJames@ctuir.org); Jason McLellan (Jason.McLellan@colvilletribes.com); Korth, Jeff W (DFW); Keith Hatch (keith.hatch@bia.gov); Mike Clement; Verhey, Patrick M (DFW); Rex Buck, Jr.; Steve Lewis (Stephen_Lewis@fws.gov); Tom Dresser; Tracy Hillman
Cc: Tom Dresser; Ross Hendrick; Mike Clement
Subject: Grant County PUD's Draft Pacific Lamprey Management Plan annual report for 2016

Good morning,

Attached please find Grant County PUD's draft 2016 annual report for the Pacific Lamprey Management Plan consistent with the requirements of license article 401(a)(12) of the Federal Energy Regulatory Commission license and condition 6.2(6)(b) (Appendix C) of the Washington Department of Ecology 401 Water Certificate for the Priest Rapids Hydroelectric Project.

Your comments would be appreciated by February 24, 2017. If you have questions, please contact at Mike Clement at mcleme@gcpud.org .

Thanks!

Deb Firestone
Regulatory Specialist
Public Utility District No. 2 of Grant County, Washington
P.O. Box 878
Ephrata, WA 98823
509-793-1583

Appendix E
Washington Department of Ecology March 14, 2017 Approval Letter

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
1250 W Alder St • Union Gap, WA 98903-0009 • (509) 575-2490

March 14, 2017

Mr. Mike Clement
Senior Biologist
Grant County PUD
PO Box 878
Ephrata, WA 98823

RE: Request for Ecology Review and Comment –
2016 Pacific Lamprey Management Plan Comprehensive Annual Report.
Priest Rapids Hydroelectric Project No. 2114

Dear Mr. Clement:

The Department of Ecology (Ecology) has reviewed the *2016 Pacific Lamprey Management Plan Comprehensive Annual Report* that was e-mailed to Ecology on January 24, 2017. This report is a requirement of Section 6.2(5)(c) for the *Pacific Lamprey Management Plan* and Section 6.2(5)(d) of the 401 certification.

Ecology recognizes Grant County PUD's efforts in developing a settlement agreement and working through adaptive management to address No Net Impact (NNI) to lamprey at the Priest Rapids Hydroelectric Project. We support and encourage Grant PUD to continue to work towards a settlement agreement through adaptive management that is agreeable to all parties.

If you have any questions for Ecology, please call me at (509) 575-2808, or e-mail me at breean.zimmerman@ecy.wa.gov .

Sincerely,

Breean Zimmerman

Breean Zimmerman
Hydropower Projects Manager
Water Quality Program