Synthesis of Threats, Critical Uncertainties, and Limiting Factors in Relation to Past, Present, and Future Priority Restoration Actions for Pacific Lamprey in the Columbia River Basin

Response to the Independent Scientific Advisory Board
Review of "Synopsis of Lamprey-Related Projects Funded through the Columbia River Basin Fish and Wildlife Program"
ISAB 2012-3

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1 INTRODUCTION

Pacific Lamprey *Entosphenus tridentatus* belong to the order Petromyzontiformes, a lineage that has occupied rivers of western North America for the last ~350 million years. These ancient fish are distinct from other fish within their range – lampreys are jawless, have no scales, and lack paired fins. Pacific Lamprey are also anadromous, spending a portion of their life history in the marine environment. Since pre-historic times, tribal members have utilized lamprey for important subsistence, ceremonial, and medicinal purposes. Pacific Lamprey are also important ecologically because they provide marine-derived nutrients to the freshwater riverine environment and the aquatic and terrestrial food web (Beamish 1980; Brown et al. 2009) and provide a high-calorie prey source for various marine and freshwater species.

In 2010, the Independent Scientific Review Panel (ISRP) suggested that a synthesis of Pacific Lamprey information would be appropriate to inform subsequent reviews of lamprey projects (ISRP 2010a, 2010b). The Northwest Power and Conservation Council (NPCC) formalized the request to lamprey project proponents (NPCC 2011). The Columbia River Inter-Tribal Fish Commission (CRITFC), in collaboration with its partners at the U.S. Fish and Wildlife Service (USFWS) and its member tribes [Confederated Tribes of the Umatilla Indian Reservation (CTUIR), Confederated Tribes of Warm Springs Reservation of Oregon (CTWSRO), Confederated Tribes and Bands of the Yakama Nation (YN), and Nez Perce Tribe (NPT)], agreed to respond to the request, and submitted the "Synopsis of Lamprey-Related Projects Funded through the Columbia River Basin Fish and Wildlife Program" (Synopsis; CRBLTWG and CBFWA 2012) to the NPCC. The NPCC forwarded the Synopsis to the Independent Scientific Advisory Board (ISAB) for review. The ISAB released its review of the Synopsis in May 2012 (ISAB 2012).

This document provides a response to the ISAB review of the Synopsis, and is organized so that it (1) responds specifically to questions, suggestions, and concerns contained in the ISRP (2010a) and ISAB (2012) review processes and (2) responds generally to broad, systematic appeals related to developing a conceptual framework for understanding, classifying, and prioritizing lamprey projects to guide future lamprey restoration efforts. This document includes (1) the background and context important to the requests and response, (2) an overview of Pacific Lamprey in the Columbia River Basin (CRB), (3) a summary of pertinent documents and events intended to guide Pacific Lamprey restoration in the CRB, (4) a summary of lamprey-focused projects implemented since 1995 in the CRB, (5) responses to specific questions from ISRP and ISAB reviews, and (6) an overview of regional and range-wide efforts to restore Pacific Lamprey.

1.1 Background

In June 2011, as part of the Research, Monitoring, and Evaluation and Artificial Production Category review, the NPCC (2011) called for the development of a synthesis report on the lamprey efforts under the Fish and Wildlife Program (Program), addressing the issues and questions raised by the ISRP in its December 2010 review (ISRP 2010a, 2010b). The NPCC noted that the synthesis should summarize project results and develop conclusions on the data gathered so far about the status and trends of lamprey populations, limiting factors, and critical uncertainties and risks. The report should also

prioritize actions based on these conclusions. Although the ISRP categorical review (ISRP 2010b) focused primarily on two lamprey restoration projects from the CTUIR Project #1994-026-000 and the CTWSRO Projects #2002-001-600, #2007-007-00, and #2008-308-00, the synthesis request (ISRP 2010a) was directed at all Program projects including the YN Project #2008-470-00 and the CRITFC Project #2008-524-00. Critical questions to analyze included the value of tributary habitat projects in helping to improve lamprey returns, whether mainstem dam passage is the key limiting factor, and the relative role of other factors such as ocean conditions and toxic contaminants. The NPCC suggested that the synthesis should focus on general conclusions that can be drawn from the body of the work since project initiation, with supporting evidence, and possible future directions for the work. In addition, the NPCC suggested that the Columbia River Basin Lamprey Technical Working Group (CRBLTWG) could be a possible group of experts that could write a basin-wide lamprey synthesis.

In response to this recommendation, the CRBLTWG, under the guidance of the Columbia Basin Fish and Wildlife Authority (CBFWA), completed the Synopsis (CRBLTWG and CBFWA 2012). In the Synopsis, the CRBLTWG and the CBFWA noted that the ISRP review of lamprey projects funded through the Program (ISRP 2010a) included a series of questions regarding the status of Pacific Lamprey in the CRB and the degree of coordination among lamprey projects. To address these questions, the Synopsis included two primary sections: (1) a synopsis of ongoing and past lamprey-related projects funded through the Program, and (2) answers to specific lamprey questions asked by the ISRP. The specific questions that the Synopsis was tasked with answering are:

- Question 4.1. – What are the general conclusions of the studies to date? Are lamprey recovering in the Basin?
- Question 4.2. – What have emerged as primary limiting factors for lamprey basinwide? The ISRP noted that lamprey are declining coast wide, suggesting that ocean factors may be affecting survival, but no studies are being conducted in the marine environment. Lampreys are also likely very susceptible to toxic contaminant effects but very limited work is being done on this issue. Most proponents are focusing on key limiting factors in tributary habitat but the ISRP, as well as ISAB (2009-3) has pointed out this approach is too restrictive for anadromous lamprey. A comparison of lamprey stocks in various rivers might be useful, including those outside the Columbia River Basin.
- Question 4.3. – What are the major impediments to implementation of recovery plans? Will mainstem passage problems be resolved to enable sufficient numbers of adults to migrate into tributaries to initiate recovery in synchrony with translocation and habitat improvements such as ramps on low head dams and irrigation screens?
- Question 4.4. – Is the draft lamprey master plan for Tribal Pacific Lamprey Restoration that will guide recovery efforts completed? (Project #2008-524-00)
- Question 4.5. – Are study designs and sampling methods coordinated among projects? Some proponents noted that key technical issues, such as sampling efficiency for juvenile lamprey during instream trapping, as well as our inability to tag juvenile life stage lamprey to obtain travel time and survival information, have yet to be resolved. Others did not, suggesting increased communication among groups is needed. The ISRP is therefore concerned that data

may not be comparable between projects, or that critical information is lacking, e.g., juvenile travel time and survival.

- Question 4.6. – What are the escapement goals for lamprey, recognizing that development of these metrics is difficult because of lack of historical information?
- Question 4.7. – What is the status of lamprey in various subbasins and can a comparison of their status inform an analysis of limiting factors?
- Question 4.8. – Comparative data on the non-anadromous brook lamprey might help determine if limiting factors in the ocean are important for the Pacific Lamprey.

The Synopsis (CRBLTWG and CBFWA 2012) was submitted to the NPCC in March 2012 and was in turn, submitted to the ISAB for review. NPCC staff requested that the ISAB review the Synopsis and consider the following questions:

1. Does the synopsis clearly summarize the known status and trends of lamprey populations, limiting factors, and critical uncertainties and risks?
    a. The value of tributary habitat projects in helping improve returns
    b. The importance of mainstem dam passage
    c. The relative role of ocean conditions and toxic contaminants
2. Does the synopsis speak to priorities for future actions, or a path to prioritize actions?
3. Is the information well synthesized and described?

On May 14, 2012, the ISAB provided its review (ISAB 2012) stating that that the Synopsis is "useful in demonstrating the type and extent of new information being acquired about Pacific Lamprey in the Columbia River Basin." However, the Synopsis "did not compile new findings on lamprey into a form that adequately addresses the NPCC's questions and a synthesis of the current state of understanding of factors limiting lamprey recovery was not developed."

The ISAB recommended that the Synopsis be revised to include the information identified in specific comments and questions below.

1. Tabular summaries by topic, for example use of tributary habitat, escapements, larval densities, mainstem passage, migration times, straying, translocation, and artificial propagation.
2. A figure showing project locations, their coverage with respect to the overall historical range of lamprey in the Basin, and the conservation status for the areas assessed by Luzier et al. (2011).
3. Responses to specific questions 4.1-4.8 (ISRP 2010a)

In response to the ISAB review (ISAB 2012), the CRITFC, in collaboration with its partners at the USFWS and its member tribes (CTUIR, CTWSRO, YN, and NPT), agreed to respond to the original ISRP synthesis request (ISRP 2010a, 2010b), the NPCC synthesis request (NPCC 2011), and the subsequent ISAB Synopsis review (ISAB 2012) in a format that addresses the synthesis request from a basin-wide perspective. In 2016, the CTWSRO completed a "Synthesis of Pacific Lamprey studies by the Confederated Tribes of the Warm Springs Reservation of Oregon, 2003 to 2013" (Baker 2016) in response to ISRP (2010b) which synthesizes results from CTWSRO lamprey projects since 2003.

This document is organized in a way that responds to the basin-wide synthesis request by the NPCC by (1) responding specifically to questions, suggestions, and concerns contained in ISRP (2010a) and ISAB (2012) and by (2) responding generally to broad, systematic appeals related to identifying, classifying, and prioritizing lamprey projects to guide future lamprey restoration efforts. Sections 1 through 3 and 6 provide relevant background and context for this response to the synthesis requests. Sections 4 and 5 provide the information specifically requested.

In Section 4, tables and figures specifically requested by the ISAB (ISAB 2012) summarize Program funded tribal projects within the CRB over the past 20 years. Tables provide information on geographic area, project duration, and general conclusions from each lamprey project within the basin with links to full project reports. Projects identified within tables are also organized by CRBLTWG "Critical Uncertainties" (CRBLTWG 2005) and USFWS Assessment "Threats" (Luzier et al. 2011), both of which are regionally evaluated lists. Figures provide a spatial context for CRB lamprey projects by identifying where these projects occur in relation to the overall historical range of lamprey in the basin. In Section 5, specific questions from ISRP and ISAB reviews (ISRP 2010a; ISAB 2012) are addressed and/or updated. Section 6 provides information on how the region is working together to address critical uncertainties and threats throughout the CRB through a variety of established and developing processes. This section provides information on existing and future conservation, management, and restoration actions as well as a prioritized list of threats and critical uncertainties that need to be addressed given existing information.

1.2 Regional and Tribal Context

Pacific Lamprey are of great importance to tribes throughout the CRB for cultural, spiritual, ceremonial, medicinal, subsistence, and ecological reasons. From a tribal perspective, the symptoms of Pacific Lamprey decline include: 1) loss of an important nutritional source, 2) loss of harvest opportunities in traditional harvest areas, and 3) necessity to travel large distances to lower Columbia River tributaries to harvest lamprey (e.g., the Willamette River). The cultural loss due to lamprey declines is also profound. Many young tribal members have not learned how to harvest and prepare lamprey for drying. In addition, young tribal members are losing opportunities to learn historically important legends associated with lamprey and lamprey fishing.

Today, Pacific Lamprey return to the CRB at a fraction of their historical numbers; daytime counts of adult Pacific Lamprey at Bonneville Dam have declined from an estimated 400,000 in the 1960's and 1970's to lows of under 10,000 in 2009 and 2010 (CRITFC 2011; Figure 1-1). Counts rebounded somewhat from

2011 through 2017 (18,000-82,554;

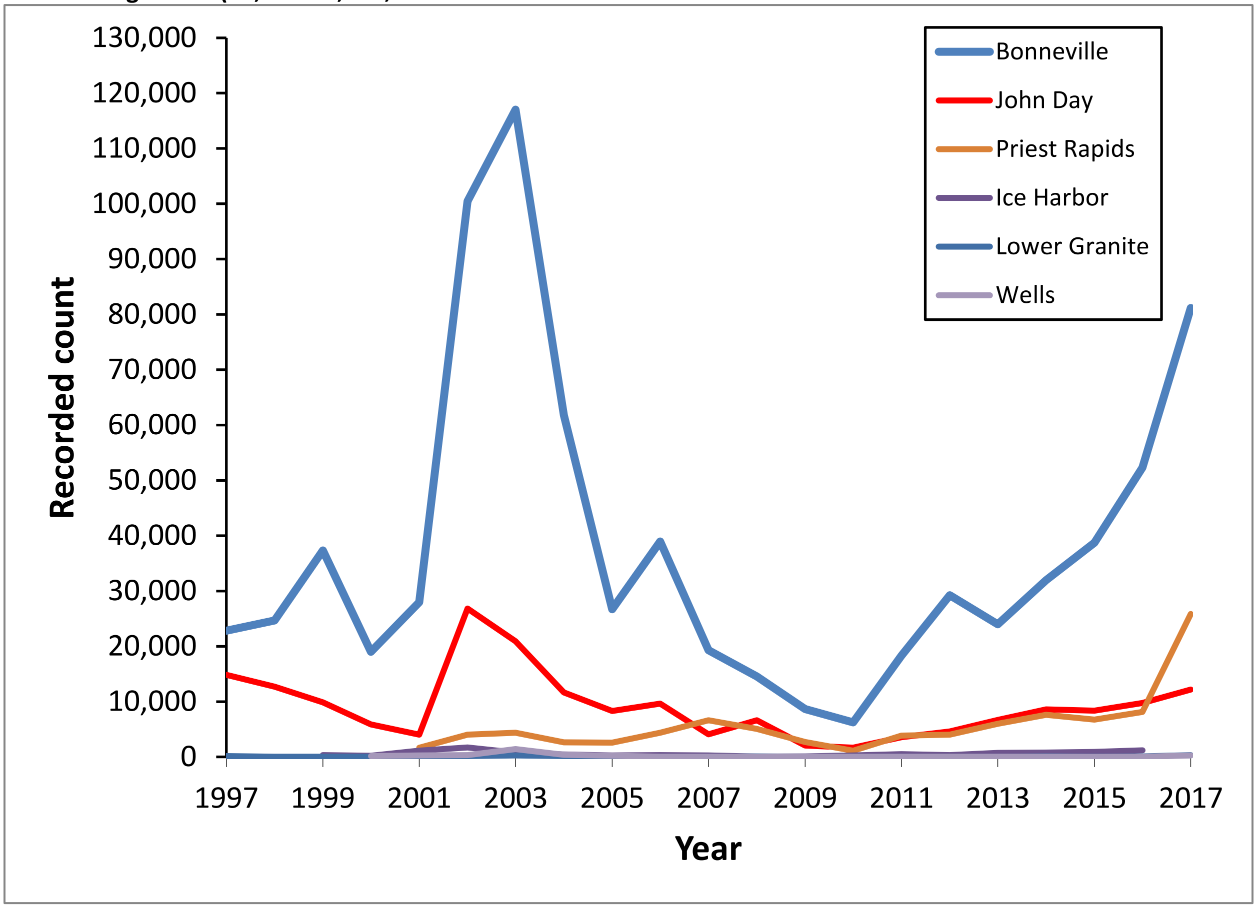

Figure 1-2), but still remain far below historic levels. At Willamette Falls, a traditional harvest location on the Willamette River, estimates of harvest declined from about 400,000 in the 1940's to about 4,000 in 2001 (Ward 2001; Figure 1-3). Reduced ability to harvest lamprey has produced cross-generational cultural impacts for many tribes within the CRB (Close et al. 2004; Sheoships 2014).

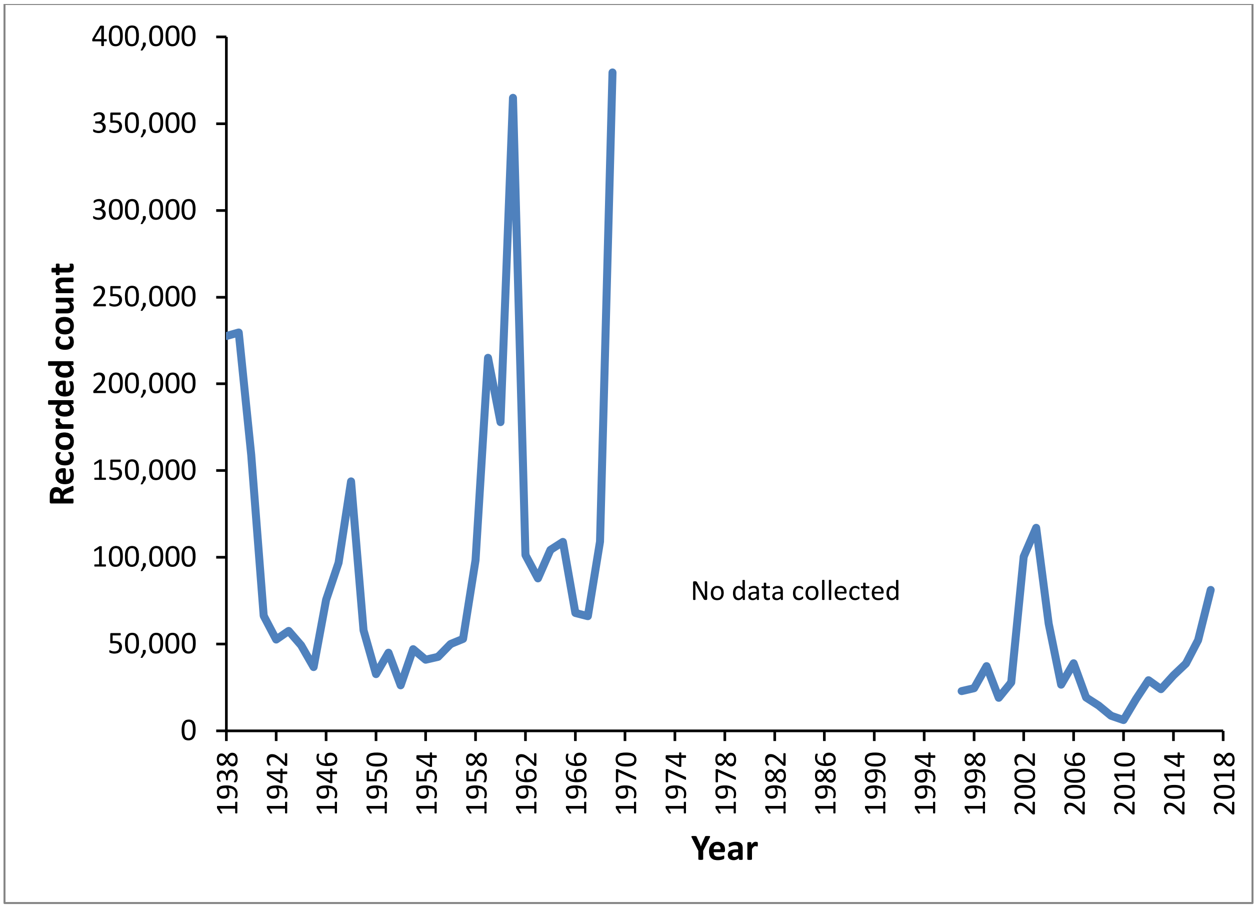

Figure 1-1. Adult Pacific Lamprey annual daytime counts at Bonneville Dam from 1938 to 2017. Data based on 2013 Annual Fish Passage Report (USACE 2014) and Fish Passage Center (www.fpc.org) annual daytime counts.

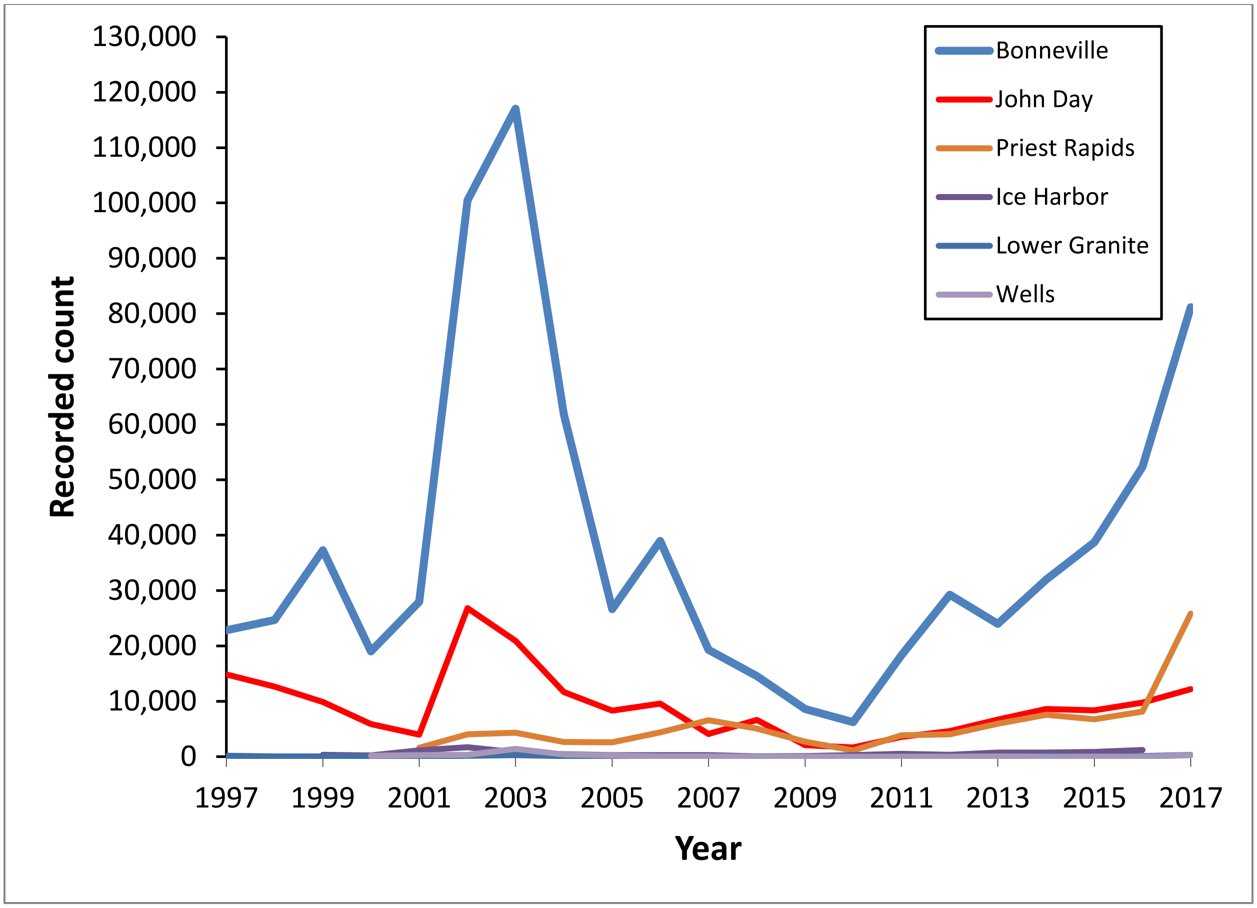

Figure 1-2. Adult Pacific Lamprey annual daytime counts at Columbia and Snake River dams from 1997 to 2017. Data based on Fish Passage Center (www.fpc.org) annual daytime counts.

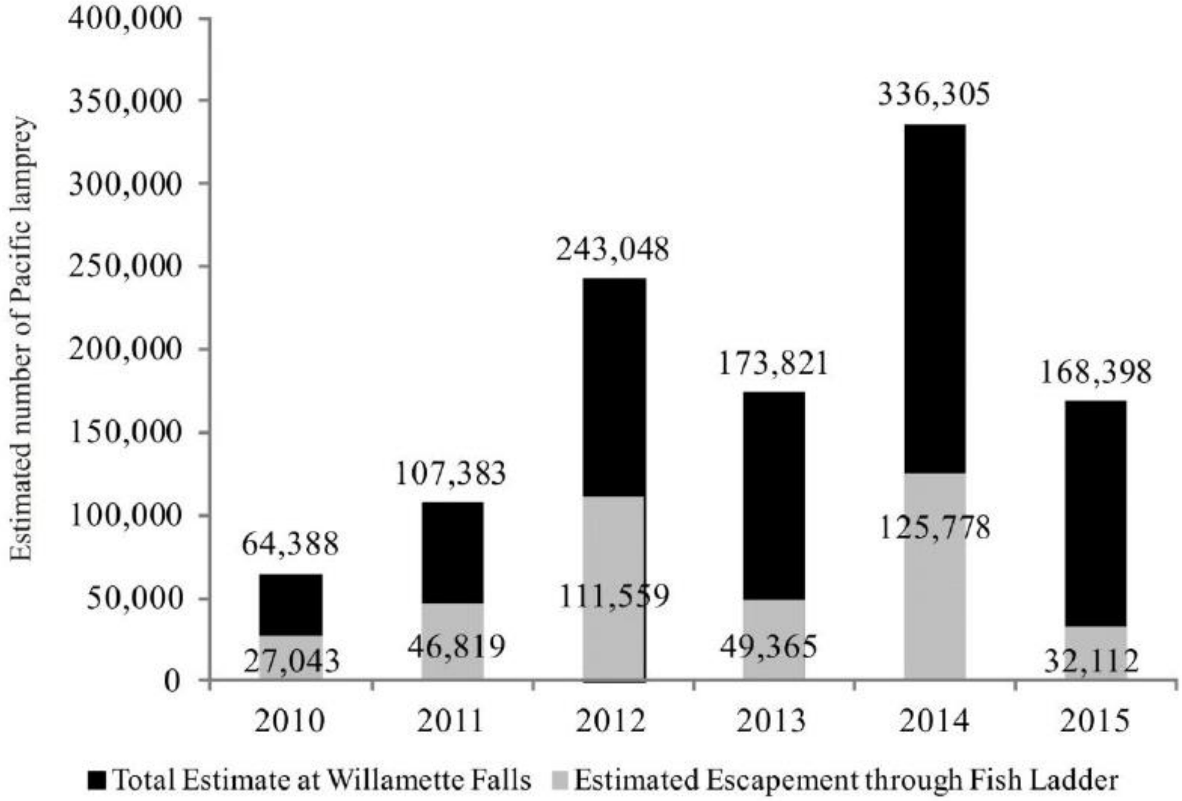

Figure 1-3. Estimates of Pacific Lamprey escapement through the fish ladder and total abundance at Willamette Falls, 2010-2015 (Baker and McVay 2016).

Recent studies on the decline of Pacific Lamprey in the CRB cite the construction of hydroelectric and flood control dams, irrigation and municipal water diversions, habitat degradation and loss, poor water quality, excessive predation, contaminants, ocean cycles, prey-species availability, and chemical eradication as major contributors (Close et al. 1995; CRITFC 2011; Luzier et al. 2011; Murauskas et al. 2013). Despite recent implementation of passage improvements at mainstem and tributary dams, habitat improvements, and adult lamprey translocation efforts (CRITFC 2011; Luzier et al. 2011; Ward et al. 2012), adult returns remain relatively low. The spatial distribution of Pacific Lamprey is confined to the lower portions of the CRB due to extirpation in many subbasins of the interior CRB (Close et al. 1995; USFWS 2007; Luzier et al. 2011).

Considering the low numbers of Pacific Lamprey, their value to the ecological health of the CRB, and their cultural significance, the time to address and recover lamprey stocks is now. The CRITFC and its members developed the Tribal Pacific Lamprey Restoration Plan (TPLRP) for the restoration of Pacific Lamprey in the CRB to numbers adequate for the basin's ecological health and tribal cultural use (CRITFC 2011; see Section 3.8). The goals of the TPLRP are to immediately halt the decline of Pacific Lamprey and ultimately restore these fish throughout their historic range in numbers that provide for ecological

integrity and sustainable tribal harvest. The TPLRP addresses lamprey issues at the CRB scale, generally focused on the mainstem Columbia and Willamette rivers and the issues affecting lamprey at these locations.

Due to the long, complex, and poorly understood life history of Pacific Lamprey, existing environmental conditions in the CRB, and scarcity of data, it remains unclear how soon lamprey will recolonize extirpated streams, especially in the upper reaches of the CRB. Lamprey must pass through a series of dams before reaching the Snake River and interior Columbia River (Keefer et al. 2012a), so natural recolonization of upper reaches may require extensive time, perhaps decades, considering that lamprey life history spans approximately 10-15 years.

2 OVERVIEW OF PACIFIC LAMPREY WITHIN THE COLUMBIA RIVER BASIN

Pacific Lamprey exhibit a complex and lengthy life history, creating significant challenges to managers working to restore diminished abundance and distribution in the CRB (Figure 2-1). Pacific Lamprey are a native anadromous species that evolved hundreds of millions of years before salmon. Pacific Lamprey larvae rear in freshwater streams for 5 to 9 years before transforming to the migrant stage (juveniles), akin to smolts, while migrating to the marine environment. After several years feeding in the ocean they return to freshwater, sometimes residing for as long as 2 years before completing the migration to spawn and then die. Although more work is needed to better understand lamprey genetics, Pacific Lamprey appear to exhibit low genetic differentiation among regional stocks, and population structure reflects a single broadly distributed population across much of the Pacific Northwest. Much has been learned in recent years about the life history for lamprey but significant gaps remain. A general summary of the information on Pacific Lamprey life stages and primary potential factors affecting viability is presented here.

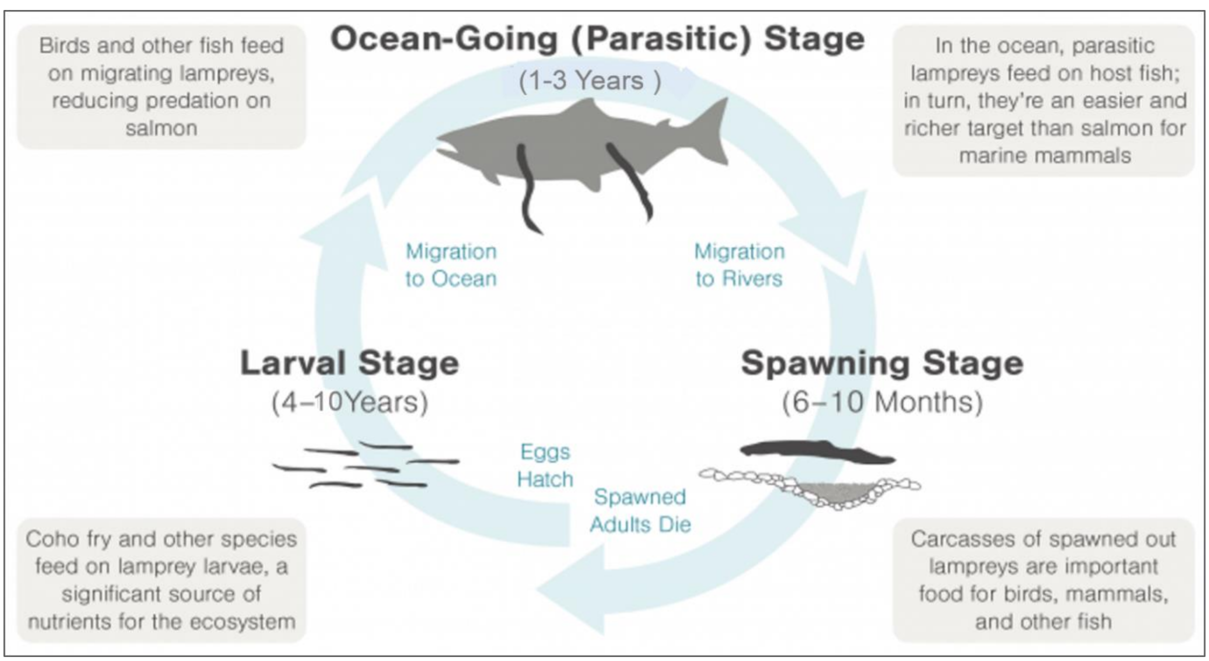

Figure 2-1. Life cycle of Pacific Lamprey (Illustration by Mark Garrison, Hakai Magazine, July 13, 2015).

2.1 Oceanic Life

Unlike salmonids, Pacific Lamprey are nearly panmictic; they do not appear to home to their natal streams, and show very low levels of geographic genetic structuring (Lin et al. 2008; Hatch and Whitaker 2009; Spice et al. 2012; Hess et al. 2012; Hess et al. 2014). Juvenile Pacific Lamprey have been collected off the Pacific Coast of North America from California to as far north as the Bering Sea (Sviridov et al. 2007; Orlov et al. 2008). During the 1-4 years spent in marine habitats (reviewed in Clemens et al. 2010a), individual fish grow from 2-5 g outmigrants (Mesa et al. 2012) to 165-800 g returning adults (Close et al. 2003a; Clemens 2011). Pacific Lamprey are opportunistic feeders, but host species include Pacific Hake *Merluccius productus*, Pacific Cod *Gadus macrocephalus*, Walleye Pollack *Theragra chalcogramma*, Pacific Halibut *Hippoglossus stenolepis*, Greenland Halibut *Reinhardtius hippoglossoides*, Pacific Herring *Clupea pallasii*, and Pacific salmonids *Oncorhynchus spp.* (reviewed in Murauskas et al. 2013). Murauskas et al. (2013) found that annual returns of adult Pacific Lamprey at Bonneville Dam on the Columbia River were most closely correlated with abundance indices for Walleye Pollock, Pacific Cod, Chinook Salmon *Oncorhynchus tshawytscha*, Pacific Herring, and Pacific Hake, and suggested that these indices were strong predictors of adult Pacific Lamprey abundance. However, additional insights into the marine ecology of Pacific Lamprey are needed to better understand this critical life phase.

The physiological mechanisms that signal adults to cease feeding and initiate freshwater migration are not well understood (or are unknown), but it has been suggested that they coincide (Beamish 1980). Research on European lampreys *Lampetra fluviatilus* suggested that freshwater discharge pulses might function to initiate migration (Abou-Seedo and Potter 1979). In the Columbia River estuary, returning adults are present January-March, and are generally captured in pelagic habitats (L. Weitkamp, NOAA, personal communication), which suggests ocean maturation might be triggered by physiological condition (size or age) combined with environmental cues associated with winter conditions (increasing day length). Telemetry data from Sea Lamprey *Petromyzon marinus* suggest that returning adults use both extensive and intensive search fields through the water column to locate river plumes with larval pheromone concentrations. They apparently use these pheromone cues to locate spawning locations (Meckley et al. 2014). Adults likely exploit tidal hydrology during upstream migration to facilitate migration efficiency once they enter estuarine habitats (Peterson Lewis 2009). Clemens et al. (2013) identified two different maturation types in the Willamette River: an 'ocean maturing' type that spawns quickly after entering freshwater that made up ~10-20% of all fish sampled, and a 'stream maturing' type that holds for a year or longer prior to maturing and spawning. Gonadal maturation may therefore be initiated during the freshwater transition, or may be delayed until the spring following freshwater entry.

2.2 Run Timing

Most of the information about run timing within the CRB has been inferred from passage facilities at Columbia River mainstem dams (Fish Passage Center, www.fpc.org), Willamette Falls (Baker at al. 2014), and the Clackamas River (PGE 2011a). In the Clackamas River, fish ladder adult trapping begins in mid-June and continues through August, peaking in late June and early July (PGE 2011b). Passage at Willamette Falls (located at roughly the head of the tidal influence) appears to be somewhat earlier, with peak counts occurring in June, but high numbers sometimes recorded into August. Together with

the Columbia River Estuary collection data (Weitkamp et al. 2015), this run timing information suggests that adults spend multiple months in estuaries before moving into freshwater habitats. This behavior is similar to that observed for the European River Lamprey *Lampetra fluviatilis* (Moser et al. 2015a).

Adult Pacific Lamprey passage at Bonneville Dam usually occurs between May and late August (Keefer et al. 2013a). Daily passage rates peak in July, but relatively high numbers may pass into September. Moving up the river system, peak passage at McNary Dam generally occurs in late July, and peak passage at each of the Snake River dams takes place a week later, with the few that pass Lower Granite Dam doing so in late August (McIlraith et al. 2015). Run timing appears to be delayed in the Columbia River upstream of McNary Dam relative to the Snake River (Fish Passage Center, www.fpc.org). Peak passage is generally in mid-August at Priest Rapids Dam, late August at Rock Island Dam, and what few remain pass Wells Dam into September. From these data, it appears that most lamprey take about two months to migrate upstream through the Columbia River system. Overwintering of many Pacific Lamprey in the mainstem Columbia River can prolong the period of migration. Within interior Columbia River tributaries, Pacific Lamprey are quite active and can migrate great distances during the spring (March – July) after overwintering and prior to spawning (Lampman et al. 2017a). At some tributary dams, such as Prosser Dam on the Yakima River, spring migration counts are typically higher than fall migration counts.

2.3 Adult Passage

Pacific Lamprey returning to the Columbia River encounter several substantial anthropogenic migration obstacles including numerous mainstem dams on the Columbia and Snake rivers and their tributaries. These include large hydropower dams, natural obstacles that have been retrofitted for hydropower generation, and low-head dams and irrigation diversions. Although adult Pacific Lamprey historically ascended the bedrock portion of Willamette Falls, OR, tagging studies have revealed that, under current conditions, the majority now pass through the fishway, and that passage rates are generally low, ranging from 22-34% (Mesa et al. 2010; Clemens et al. 2012a). However, passage rates at other dams in the Willamette System appear to be considerably higher (e.g., > 80% at River Mill Dam on the Clackamas River; N. Ackerman, PGE, personal communication). The relatively low passage efficiency at Willamette Falls has been specifically targeted in management actions including the development of multiple lamprey-specific passage routes.

The Columbia River hydropower system has been well studied and numerous operational changes have been implemented to aid lamprey passage. Roughly half the migrating lamprey in the Lower Columbia River that attempt to pass the lower mainstem dams are unsuccessful (~50% at Bonneville and John Day dams, ~65% at The Dalles Dam; Moser et al. 2002a, 2002b; Keefer et al. 2012a). Passage rates for individual passage attempts are substantially lower (14-34% per attempt, Keefer et al. 2013a). Dam passage at McNary Dam ranged from 65-75%, and more fish moved into the Columbia River rather than the Snake River following passage (Keefer et al. 2013b). Passage at Snake River dams ranged from 41-65% (Stevens et al. 2016). Passage efficiency at Mid- and Upper Columbia and Snake river dams is generally higher than at Lower Columbia Dams. Passage at Priest Rapids and Wanapum dams ranged

from 60-75% in most years (Le et al. 2015), but with ongoing fishway improvements passage efficiency has recently been measured at 70-75% (Le et al. 2016).

At low-head dams and diversions, passage efficiency has ranged from 0-82%. In the Yakima River, passage efficiency for five irrigation diversion dams ranged from 0% at Roza Dam to 75% at Wapato Dam with a mean of 55% (Johnsen et al. 2011; Johnsen et al. 2013; Grote et al. 2014; Grote et al. 2016; Lampman et al. 2016a). In the Umatilla River, passage efficiencies improved after the implementation of fish passage improvements. After Boyd's Diversion was breached, passage increased from 32% to 82% while at Three Mile Falls, flow was augmented in 2007 and passage efficiency increased from 17% to 50% in 2008 (Jackson and Moser 2013). Two other diversions in the Umatilla River (e.g. Brownell Dam and Dillon Dam) are scheduled for removal in 2017-2018. Despite these improvements, passage by Pacific Lamprey at irrigation dams and diversions remains low and the cumulative effects of multiple dams can result in low overall escapement into the upper reaches of spawning tributaries. Jackson and Moser (2013) estimated that out of every 100 lampreys that entered the Umatilla River in 2005 and 2006, only two would be able to pass the fourth dam on the river.

Passage efficiency for lamprey is in stark contrast to salmonid passage efficiency which generally exceeds 95% at each project within the mainstem. Throughout the numerous fishways in the CRB, passage structure designs have several limitations that impede adult lamprey. At lower Columbia River dams, passage efficiency was generally lowest during high discharge. Certain fishway segments, notably the lower elevation fishways and the serpentine weir sections, were especially problematic for lamprey to pass (Keefer et al. 2013a). Areas with high velocities and right angle vertical steps were also likely to impede lamprey migration (Keefer et al. 2010). In general, passage by adults through mainstem dams appears to select for larger individual fish, which has been confirmed by radiotelemetry and genetic studies (Keefer et al. 2009; Hess et al. 2014).

2.4 Movement within the Columbia River and Tributaries

Movement of adult Pacific Lamprey within the Willamette River Subbasin has been extensively described by Clemens (2011), and provides an excellent example of how lamprey complete their freshwater migration. Upstream migration by adult lamprey may be influenced by an unknown combination of environmental variables (e.g. temperature and discharge) and chemical cues (e.g. pheromones) (Moser et al. 2015a). Following passage of Willamette Falls, migrating adults distributed relatively evenly throughout the subbasin, migration distance was unrelated to total length, and individual fish traveled between 1.6 and 18.6 $km \cdot day^{-1}$. The timing of migration appeared to be temperature dependent, with a cessation of migration when river temperatures exceed ~24°C (Clemens et al. 2012b). Clemens et al. (2009) also found that water temperature helped to trigger final maturation of reproductive organs. Following initiation of these holding periods, most (~70%) migrating adults overwintered in the mainstem Willamette River. Overwintering locations typically were in deep pools with rock cover such as revetments and riprap areas (Clemens et al. 2012b). Movement resumed in the spring to final spawning locations. These migration patterns are like those that have been observed in other systems with Pacific Lamprey. In the Smith River, in the Oregon Coast Range, Starcevich et al. (2013) found that fish moved primarily at night, initiated holding concomitantly with baseflow and

maximum summer stream temperatures, and held in glides with boulder cover. Similar migration and survival patterns have also been observed in the North Umpqua River (Lampman 2011), and the Deschutes River (Baker et al. 2012). During migration, lamprey are also subjected to predation by birds (Roby et al. 2003), sturgeon, and sea lions *Zalophus californianus* (Wright et al. 2014), but the population level impacts of predation is probably negligible. At Willamette Falls, Pacific Lamprey predation by sea lions was estimated to be ~500 individuals (Wright et al. 2014), which is a very small fraction of the total run available (~250,000 individuals; Baker et al. 2014). Sea lions also actively fish near Bonneville Dam, but the impacts on adult lamprey returns are currently not quantified. Just the presence of predators may deter Pacific Lamprey migration and passage (Keefer et al. 2012a).

In the Columbia River system, adult lamprey appear to move through reservoirs very quickly (i.e., up to 50 km/day, Noyes et al. 2012). However, passage through John Day Reservoir appears low (i.e., 34%) compared to the Bonneville and The Dalles pools (i.e., 60%, Keefer et al 2012a), and larger fish are more likely to migrate farther upstream (Hess et al. 2014). Presumably, some fish initiate holding in mainstem dams as well; they are frequently not detected at subsequent dam structures (Keefer et al. 2013a). Robinson and Bayer (2005) tracked Pacific Lamprey in the John Day River, and found that individual fish migrated 1-20.9 km·day^{-1} (exclusively at night); holding was initiated coincident with high water temperature and occurred in boulder cover and movement resumed in the spring. Moser et al. (2013) detected individual temperature effects on the rate of migration through reservoirs.

In the Snake River Basin upstream of the four passable mainstem dams, adult lamprey generally moved 1-20 km·day^{-1} (up to 35 km·day^{-1}), moved primarily at night and appeared to select for the Clearwater River over other Snake River tributaries (McIlraith et al. 2015). In this study, individual fish were detected as high as the Lochsa and Selway Rivers as well as much of the Salmon River Subbasin. Fish also appeared to demonstrate over-winter holding, but movements generally resumed in February and March with the farthest upstream detections occurring after this holding period (McIlraith et al. 2015). Despite the relatively high apparent survival and fast travel time through the system, it is estimated that less than 25% of the original run at Bonneville Dam migrates past Ice Harbor or Priest Rapids dams, greatly limiting potential production in the upper Basin (Fish Passage Center, www.fpc.org).

2.5 Spawning

Following overwinter holding, Pacific Lamprey undergo a short migration to ultimate spawning locations (Robinson and Bayer 2005; Starcevich et al. 2013). Spawning in tributaries to the Willamette River usually takes place between mid-April and June when water temperature is increasing (10-15°C) and discharge is decreasing, and can occur in a variety of stream sizes, and possibly even mainstem rivers (e.g., Willamette River, Mayfield et al. 2014a; Schultz et al. 2014a). Spawning surveys for steelhead *Oncorhynchus mykiss* frequently detect Pacific Lamprey redds in the Clackamas River Subbasin, and the Oregon and Washington coasts (E. Brown, ODFW, unpublished data), but surveys generally end before peak Pacific Lamprey activity (Mayfield et al. 2014a). Spawning surveys in the Umatilla River drainage have been conducted in June and July (Ward et al. 2012), presumably because that was when water temperature was suitable in those snowmelt dominated systems. Adults usually spawn in pairs or aggregations of multiple individuals (Wyss et al. 2013) and utilize reach-scale habitat features that are

similar to those used by salmonids (e.g., pool tailouts, riffles, runs; Mayfield et al. 2014a). These spawning habitat patterns have been observed in other river basins including the Smith River (Gunckel et al. 2009) and Coquille River (Brumo et al. 2009). Others (i.e., Russel et al. 1987) have also reported Pacific Lamprey spawning in lentic systems in British Columbia, but this appears to be relatively uncommon in the published literature.

Across the entire Willamette Subbasin, spawning adults tended to select areas composed of alluvial underlying geology. However, within individual tributaries, habitat selection among types of underlying geology was neutral (Mayfield et al. 2014a). These patterns suggest that Pacific Lamprey exhibit a 'periodic generalist' life history strategy (Clemens et al. 2012a). Underlying geology also influenced the spatial distribution of redds; in areas with mostly alluvial underlying geology, redds were fairly evenly distributed across survey segments (Mayfield et al. 2014a, 2014b). The clustering of redds is particularly important in the context of designing surveys for monitoring spawning Pacific Lamprey (Mayfield et al. 2014b). Although redd counts can present data interpretation issues, work in the Willamette River Subbasin and elsewhere has demonstrated the utility of spawning survey data (Brumo et al. 2009; Gunckel et al. 2009; Mayfield et al. 2014a, 2014b; Whitlock et al. 2017).

2.6 Larval Life History

Eggs deposited during spawning remain in the gravel for 10-14 days before hatching (Yamazaki et al. 2003; Lampman et al. 2016c). Large cobble substrates are believed to be important habitat for newly emerged larval lamprey prior to drifting downstream to suitable burrowing sediments for the 3-10 year larval phase (Aronsuu and Virkkala 2013). Sampling in the Willamette and Klickitat rivers suggests that larvae grow to 12-30 mm in their first year (Wyss et al. 2013; Luke 2010), and seldom exceed 150 mm prior to metamorphosis in these systems (Luke 2010; Jolley et al. 2012; Schultz et al. 2014a). In contrast, larval Pacific Lamprey frequently exceed 180 mm in the middle- and upper- CRB (R. Lampman, Yakama Nation, personal communication) and up to 171 mm in the Snake River Basin (Cochnauer and Claire 2009). Pacific Lamprey appear to initiate metamorphosis in mid-August and appear to be fully transformed within 2-4 weeks (Wyss et al. 2013), which has also been observed in the Frazer River (Beamish 1980). Brook lamprey *Lampetra* spp. appear to transform later in the year than Pacific Lamprey (L. Schultz, OSU, unpublished data). Using a combination of existing age data (i.e., Meeuwig and Bayer 2005) and length frequency distribution information, Schultz et al. (2014a) estimated that larval Pacific Lamprey survival rates were very high (74-81%) relative to other fish populations. However, analyses were restricted to larvae >60 mm because suitable keys for smaller lamprey have not been developed for use in the field (Goodman et al. 2009). Larval Pacific Lamprey are widespread throughout wadeable habitats in the Willamette Subbasin (Schultz et al. 2014b), and larvae have also been detected in the lower Willamette River near Portland (Jolley et al. 2012). One of the primary factors limiting the distribution of Pacific Lamprey in the CRB appears to be the presence of natural, and, particularly, anthropogenic migration barriers (Luzier et al. 2011; Jackson and Moser 2012; Schultz et al. 2014b). Chemical barriers might also impede passage of adult Pacific Lampreys in some subbasins. Across the CRB, larval Pacific Lampreys are found in habitats typical of other lamprey species; catch rates were highest in areas with accumulated deep, fine substrates (Torgersen and Close 2004; Stone and Barndt 2005; Clemens et al. 2017). In particular, off channel habitats (e.g., side channels, backwaters) contained

10 to 40 times as many larvae as did pools and riffles, respectively (Schultz et al. 2014b). Catch rates and site occupancy of larval Pacific Lamprey in the Willamette River Subbasin appears to be much higher than other areas in the CRB upstream of Bonneville Dam (Schultz et al. 2014a).

Work in Idaho confirmed that Pacific Lamprey have been extirpated from habitats above Dworshak Dam on the North Fork Clearwater River, along with all other anadromous fishes (Cochnauer and Claire 2009). Lampman et al. (2014) found relatively few larval Pacific Lamprey on the Ceded Lands of the Yakama Nation and suggested that lamprey are severely depleted in the Yakima River, especially in the upper portions of the subbasin (prior to seeing the increased recruitment from adult translocation efforts in 2014-2016). The extremely low counts at Wells and Lower Granite dams (< 50 annually in many years) further suggest that few adult lamprey are entering the upstream reaches of the CRB (Cochnauer and Claire 2009; Yakama Nation and GeoEngineers 2012). Statler (2014) found that larval lamprey in the Snake River Basin were collected primarily from streams where translocations had occurred, and the length frequency of lamprey suggested an absence of natural recruitment for multiple years in the early 2000s (Cochnauer and Claire 2009). Not all rivers in the interior CRB are in this dire of condition. For instance, Pacific Lamprey were found up to 85 km up the Selway and Lochsa rivers in Idaho as recently as 2015 (USFWS, unpublished data), supporting the hypothesis that the Clearwater River is an important location for lamprey as was suggested by McIlraith et al. (2015). Lower in the CRB, Pacific Lamprey populations appear to be maintaining a more consistent presence. Larvae were present in the lower portions of Hood River and most of Fifteenmile Creek. The distribution is expected to expand in the Hood River with the recent removal of Powerdale Dam (CTWSRO 2014).

Stream dewatering due to hydropower and irrigation operations might be an important limiting factor for Pacific Lamprey larvae throughout the CRB. Dewatering due to normal operation may leave suitable habitats without water, and larvae that cannot move to watered habitats are likely to perish. Work in Bonneville Reservoir modeled potential reservoir levels on the inundation of inter-reservoir delta habitats and found water levels in those habitats could fluctuate up to 1.2 m in a roughly five-hour period (Mueller et al. 2015). Follow-up studies are currently being conducted to understand the physiological implications of dewatering to individual fish, and the occurrence of larvae in habitats most likely to be impacted by water lever fluctuations (Leidtke et al. 2015; R. Meuller, PNNL, personal communication). Major dam operation issues (e.g., dam repair needs) can also quickly dewater reservoir habitats and strand larval lamprey rearing in these habitats (e.g., Lampman 2011; Le et al. 2015). Several reservoirs in the CRB have utilized drawdowns in the fall to flush sediments and operate reservoirs similar to natural hydrographs (e.g., Keefer et al 2012a). The implications of these drawdowns to lamprey have not been evaluated though larval lamprey that are embedded in substrate may be stranded in dewatered habitat.

Finally, larval and juvenile entrainment into irrigation canals can be an additional threat to lamprey. Many fish are eventually lost in irrigation canals because of dewatering of these otherwise suitable habitats (Lampman et al. 2013a, 2014, 2015a, and 2016a). Screening of irrigation diversions can help reduce the risk of entrainment to larvae and metamorphosed lamprey (Moser et al. 2015b); however, screening is not effective for lamprey < 50 mm in length (Rose and Mesa 2012; Lampman et al. 2014).

Due to the difficulty in preventing larval and juvenile lamprey from accessing habitat behind irrigation canals, a variety of alternative, preventative measures are being tested.

2.7 Juvenile Outmigration

Metamorphosed lampreys appear to utilize slightly different habitats than larvae, including slightly faster water and larger substrate; this behavior has been observed in Pacific Lamprey (Wyss et al. 2012) and Sea Lamprey (Gritsenko 1968, cited in Potter 1980). Outmigrants are believed to move primarily at night and utilize spates and other high discharge events to facilitate downstream movement during the late fall and winter (Beamish 1980; van De Wetering 1998; Goodman and Reid 2015a, 2015b, 2015c, 2015d; Mesa et al. 2015). Outmigrating lampreys are frequently caught in screw traps (Beamish 1980; Close et al. 2009; Goodman and Reid 2015a), and they are currently enumerated at several CRB mainstem dams (Mesa et al. 2015). Collections at Bonneville Dam indicate large winter (January-March) peaks in outmigrants, a slightly smaller spring peak (~June; Fish Passage Center, www.fpc.org), with significantly fewer fish seen in July and August (Moser et al. 2015a). Metamorphosed lampreys have been collected in the Columbia River Estuary from January to March, commonly in benthic habitats (L. Weitkamp, NOAA, personal communication), but entry into saltwater may extend into June in other areas (Frazer River, Beamish 1980). Diets of Caspian terns *Sterna caspia* and other seabirds have included lampreys during June and July (Roby et al. 2003), so it is possible that some outmigrants either spend a substantial amount of time in estuarine habitats or migrate periodically through other times of the year.

Numerous anthropogenic factors can influence mortality, timing, and migration efficiency of Pacific Lamprey. Laboratory work has suggested that passage through dam turbines may not be as harmful to Pacific Lamprey as other fishes, probably because they lack swim bladders (Colotelo et al. 2012) though lamprey are still susceptible to abrasion, indirect strike, and predation (Mesa et al. 2015). However, downstream migrating juveniles and drifting larvae are susceptible to impingement in water diversions or turbine screens, and entrainment in diversion canals (Moursund et al. 2001; Dauble et al. 2006; Moser et al. 2015b). Laboratory experiments suggest that wire cloth screen materials are especially likely to cause entrainment and impingement, while perforated plate designs were most suitable for preventing impingement (Rose and Mesa 2012).

During downstream migration, metamorphosed lampreys also appear to be particularly vulnerable to predators. In the Umpqua River, (Schultz et al. 2017) estimated that ~600 smallmouth bass *Micropterus dolomieu* in a single pool consumed ~10,000 larval lamprey in a two-month period. Although their estimates were based on large extrapolation, at a minimum these findings indicate the order of magnitude of predation that this non-native fish could have on larval and metamorphosed lamprey. Smallmouth bass, walleye *Sander vitreus,* and Northern Pikeminnow *Ptychocheilus oregonensis* (native) are prevalent in the Columbia River and prey on native fishes (Zimmerman 1999; Fritts and Pearsons 2004). A laboratory study using native and non-native predators from the Yakima Subbasin showed that Common Carp *Cyprinus carpio*, White Sturgeon *Acipenser transmontanus*, Yellow Bullhead *Ameiurus natalis*, Smallmouth Bass, and Northern Pikeminnow consumed the highest percentages of larval lamprey (Arakawa and Lampman 2017). Some species, such as Smallmouth Bass and sculpin could eat

larval lamprey close to 100% of their own body length as well as consume >25% of their starting body mass feeding only on lamprey. Although predation was limited when fine sediment was present during the short-term study (two days), bottom feeding predators, such as White Sturgeon and Common Carp, were able to consume considerably more lamprey when the study period was extended to four days (62% and 17%, respectively) (Arakawa and Lampman 2017). Although no predation studies have been conducted in the Willamette River, the recent increase in smallmouth bass populations in the Lower and Middle Willamette River (S. Gregory and R. Wildman, OSU, unpublished data) may pose a threat to outmigrants. Other areas might also see increases in non-native species due to climate change (see Section 2.9).

2.8 Contaminants

Pacific Lamprey are in contact with stream sediments throughout their ontogeny and sediment contaminants have the potential to influence individual physiological processes and population dynamics at multiple life history stages. The implications of contemporary and legacy contaminants have been demonstrated in several studies in the CRB. Larval Pacific Lamprey grew very poorly and exhibited impaired burrowing performance in sediments collected from the Portland Harbor Superfund site relative to native river sediments; in many cases, individual fish did not even attempt to burrow into contaminated sediments (Unrein et al. 2016). Jolley et al. (2012) conducted deep water electrofishing surveys within Portland Harbor Superfund site and observed lower occupancy rates of larval lampreys there, relative to other benthic sites in the Willamette River. Nilsen et al. (2015) screened Pacific Lamprey tissues from throughout the CRB and observed concentrations of contaminants (pesticides, flame retardants, mercury, and DDT) that were high enough to be detrimental to individual organisms. Larval contaminant levels appeared to be particularly high in the Yakima, Umatilla, and Pudding (Willamette) river subbasins. Linley et al. (2016) analyzed mercury (Hg) concentrations within the fine sediment and larval lamprey tissues and when compared with other species where Hg effects have been well studied, the concentrations in larvae from Lower Columbia River tributary mouths suggest that many of these fish may have experienced and/or continue to experience lethal and sub-lethal adverse effects from Hg that constrain population recruitment. Numerous contaminants, including PCBs, have been observed within adult lamprey collected at Willamette Falls and John Day Dam (Nilsen et al. 2015). Together these studies suggest that contaminants likely negatively impact Pacific Lamprey and might be involved in the decline (Nilsen et al. 2015).

Contaminants may also impair the pheromone perception of adult Pacific Lamprey. In the CRB, atrazine is a commonly used pesticide in commercial timberlands and agricultural landscapes, and is a notable surface water contaminant. Smith (2012) tested the effects of environmentally-relevant concentrations of atrazine on the behavior of adult Pacific Lamprey and found that these chemicals may alter perceptions of larval pheromones and may potentially disrupt migration behavior. Following this work, Schultz et al. (2014b) suggested that water quality issues may impede passage of adult lamprey into the Tualatin River, because Pacific Lamprey were present in relatively low numbers despite favorable habitat conditions for spawning and rearing. Tribal harvesters have voiced concerns over the potential health implications of contaminant accumulations in harvested adult lamprey (Sheoships 2014).

2.9 Climate Change

Discussions about projected climate change effects on freshwater ecosystems have recently begun to include Pacific Lamprey (CRITFC 2011), but the precise effects to the species are unclear. Altered hydrologic regimes in the Willamette River Subbasin are projected to include lower September streamflow and higher incidence of spring floods (Jung and Chang 2012). In the Yakima River, existing thermal barriers during peak lamprey migrations may be exasperated by high spring and summer temperatures (R. Lampman, Yakama Nation, personal communication). In the mid-and upper-CRB, most climate projections predict that stream systems will switch from being snowmelt dominated systems to rainwater dominated systems, with increased pressure for limited stream discharge (Panye et al. 2004). Although the thermal tolerance of Pacific Lamprey adults or larvae is unknown, evidence from multiple lampreys suggests that early ontogeny may be influenced by water temperature. Meeuwig et al. (2005b) found that survival of larval Pacific Lamprey was significantly lower at 22°C than at lower rearing temperatures, and increased abnormalities were observed with higher rearing temperature. Similarly, Sea Lamprey hatch success and survival is negatively related to incubation temperature (Rodríguez-Muñoz et al. 2001), with a precipitous drop in post-burrowing survival above 23°C. Elevated temperature may also inhibit metamorphosis in Sea Lamprey (Holmes and Youson 1997, 1998). Although these studies indicate potential threats to larvae, climate change could also influence phenology of lamprey spawning, with spawning occurring earlier in warmer stream systems (*sensu* Mayfield et al. 2014a; Schultz et al. 2014a). Adult lamprey frequently utilize the mainstem Willamette River all summer (Clemens et al. 2012a) suggesting that mainstem water temperatures might not be a substantial limiting factor for adults.

Increased water temperatures might not affect lamprey directly, but indirect effects of reduced streamflow, increased concentration of contaminants, water withdrawal pressures, changes to marine food web dynamics, and interactions with non-native fishes might pose threats to Pacific Lamprey at multiple life history stages (CRITFC 2011). As stream discharge is reduced by diminishing natural streamflow and the increased pressure from water withdrawals, larvae will be subjected to increasing concentrations of stream contaminants (e.g., Littlewood 1992). Increased water withdrawal may also lead to entrainment and loss associated with water delivery systems (Moser et al. 2015b). Introduced fishes may cause impacts across increasing ecological scales including genetic, individual, population, community, and ecosystem levels (Cucherousset and Olden 2011). The deleterious effects of non-native fishes will likely be worsened with climate change, because habitat conditions will favor warmwater species (e.g., smallmouth bass, Sharma et al. 2007). Finally, climate change will likely influence marine productivity across multiple spatial scales and trophic levels, and changes in production might influence the marine life history stage of Pacific Lamprey (e.g., Brander 2007; Murauskas et al. 2013).

3 EXISTING COLUMBIA RIVER BASIN GUIDING DOCUMENTS AND EFFORTS FOR PACIFIC LAMPREY

A variety of existing documents and ongoing efforts are aimed at restoring and conserving Pacific Lamprey within the CRB. The primary objectives of these efforts range from identifying threats and critical uncertainties (CRBLTWG 2005), to ranking regionally evaluated threats throughout the range of

Pacific Lamprey (Luzier et al. 2011), to providing guidance for regional lamprey restoration (CRITFC 2011), and to identifying needs and implementing actions for specific threats (USACE 2008, 2014). During initial lamprey restoration efforts (1995-2004) primary impediments included lack of awareness, understanding, and prioritization for Pacific Lamprey declines and restoration actions. Since 2004, awareness of Pacific Lamprey declines and their important cultural and ecological roles within the CRB has improved significantly. Currently, a variety of tribes, federal agencies, states, NGO's, universities, and public utility districts, throughout the range of Pacific Lamprey, have an increasing, committed interest in restoring and conserving lamprey (USFWS 2012).

3.1 1995, 2004, and 2015 – Columbia River Basin Lamprey Technical Working Group

As part of a 1995 NPCC action, the CRBLTWG was established to serve and guide coordination activities for new and existing lamprey projects funded, or proposed for funding, through the Bonneville Power Administration (BPA). In 2004, the purpose of the CRBLTWG was modified to provide technical review, guidance, and recommendations for activities related to lamprey conservation and restoration as a subcommittee of the Anadromous Fish Committee of the CBFWA. The CRBLTWG aimed to accomplish this by:

1. Identifying and prioritizing critical uncertainties regarding lamprey conservation.
2. Providing a forum for discussion regarding lamprey-related concerns.
3. Disseminating technical information.

In 2015, the CRBLTWG was re-formed to work on range-wide lamprey issues as a component of the Lamprey Conservation Agreement (Agreement; USFWS 2012). The new Workgroup acts as an advisory group to the Agreement (see Section 3.13). It receives technical questions and is assigned special topic questions such as monitoring and research guidance and assessing climate change impacts. The Workgroup also provides the Regional Management Units (RMUs; see Section 3.6) with technical support as requested. The Workgroup may also respond to requests for technical input and expertise from outside entities. Subgroups within the Workgroup work on specific topics (e.g., dredging, passage metrics, tagging, engineering criteria, genetics, ocean phase, juvenile entrainment, critical uncertainties, and climate change) and/or geography (RMUs) when necessary to evaluate an issue.

3.2 1999 – Restoration Plan for Pacific Lampreys (Lampetra tridentata) in the Umatilla River, Oregon

In 1999, the CTUIR developed a Restoration Plan for Pacific Lampreys (*Lampetra tridentata*) in the Umatilla River, Oregon (Close 1999). The goal of the CTUIR lamprey plan was to restore the natural production of Pacific Lampreys in the Umatilla River to self-sustaining and harvestable levels. The CTUIR lamprey plan was based on a conceptual foundation that states that (1) the Umatilla River is a natural, cultural system, (2) lamprey productivity requires a network of complex interconnected habitats, (3) plasticity in lamprey life history has allowed adaptation to diverse habitat conditions allowing for evolutionary success, and (4) restoration of lampreys in the Umatilla River will depend on removal of constraints within and outside of the Umatilla River Subbasin. The goal of the CTUIR lamprey plan was to be achieved by addressing four objectives (Close. 1999):

Objective 1: Estimate lamprey abundance before and after out planting adults in the Umatilla River.

Objective 2: Increase larval abundance in the Umatilla River.

Objective 3: Determine reproductive success of adult outplants.

Objective 4: Estimate adult lamprey abundance in the Columbia River at the John Day Dam.

Objective 5: Assess artificial propagation using Pacific Lampreys.

3.3 2004 and 2008 – Lamprey Summits I and II

The first Lamprey Summit (i.e. Lamprey Summit I) was held in 2004 to provide a forum for Tribal, State, and Federal executives, managers, and biologists to discuss the main threats to lamprey and to begin to explore how best to address these threats and build momentum toward long-term restoration. Lamprey Summit I brought executives and agency heads together to discuss the various actions that needed to be completed including prioritization of conservation actions. Lamprey Summit I also provided an opportunity to celebrate Pacific Lamprey and their value to the Tribes. Building on the Lamprey Summit I and subsequent actions basinwide, Lamprey Summit II (2008) was characterized by the presentation of components of the CRITFC's draft Tribal Pacific Lamprey Restoration Plan. The draft TPLRP identified specific actions in which the tribes sought regional partnerships, funding, and commitments. Lamprey Summit II was a stronger call for actions which was highlighted by a tribal elder's panel as well as CRITFC and its member tribes calling for specific recovery measures and goals.

3.4 2005 – Critical Uncertainties for Lamprey in the Columbia River Basin: Results from a Strategic Planning Retreat of the Columbia River Lamprey Technical Workgroup

The purpose of the Critical Uncertainties for Lamprey in the Columbia River Basin (Critical Uncertainties; CRBLTWG 2005) document was to report the results of a process used by the CRBLTWG to determine and prioritize the critical uncertainties for CRB lamprey species. The Critical Uncertainties document described the methods used to generate and prioritize a list of critical uncertainties for lamprey and provides recommendations for how the results should be used. This document was intended to guide lamprey conservation, management, research, and funding decisions in the CRB. The CRBLTWG provided technical recommendations regarding the information and actions needed to conserve CRB lamprey in a prioritized and consistent manner and supported using the methods described within the Critical Uncertainties document to prioritize any new actions in the CRB.

The CRBLTWG (2005) generated a prioritized list of critical uncertainties for anadromous lamprey species (Pacific Lamprey and River Lamprey *Lampetra ayresii*). The CRBLTWG sorted prioritized lists of critical uncertainties by their expected biological benefit and relied on best professional judgment of participants to place uncertainties into four priority categories: Imminent, Highly Important, Important, and Needed (Table 3-1

Table 3-1).

Table 3-1. Prioritized critical uncertainties for anadromous lamprey in the CRB.

Ranking	Critical Uncertainty	Category
1	Lamprey Status	Imminent
2	Passage	Imminent
3	Population Delineation	Highly Important
4	Limiting Factor Analysis	Highly Important
5	Restoration Activities	Important
6	Biology/Ecology	Important
7	Population Dynamics (Predictive Analyses)	Needed

3.5 2006 and 2009 – Mid-Columbia Public Utility District Pacific Lamprey Management Plans

The Grant County (Grant PUD), Chelan County (Chelan PUD), and Douglas County (Douglas PUD) Public Utility Districts own and operate five hydroelectric dams on the Columbia River (Grant PUD – Wanapum and Priest Rapids; Chelan PUD – Rock Island and Rocky Reach; Wells PUD – Wells). In accordance with Federal Energy Regulatory Commission (FERC) licensing and 401 Water Quality Certification (WQC) requirements for these projects, the PUDs are required to develop and implement, in consultation with various stakeholders and partners, their respective Pacific Lamprey Management Plans (PLMPs).

The goal of the Grant PUD PLMP (Grant PUD 2009) is to identify ongoing Project-related impacts on Pacific Lamprey, implement reasonable and feasible measures to reduce or eliminate such impacts, and implement on-site or off-site measures to address unavoidable impacts in an effort to achieve No Net Impact (NNI). Objectives of the Grant PUD PLMP include: (1) No Net Impact (NNI) - Identify, address, and fully mitigate Project effects to the extent reasonable and feasible, (2) Provide safe, effective, and timely volitional passage for adult upstream and downstream migration, (3) Provide safe, effective, and timely volitional passage for juvenile downstream migration, and (4) Avoid and mitigate Project impacts on rearing habitat. The annual Pacific Lamprey Management Plan Comprehensive Annual Report describes updated Pacific lamprey passage, behavioral, and survival investigations and measures undertaken in the CRB (Le et al. 2017, Table 5 – Included here as Appendix A).

The goal of the Chelan PUD PLMP (Chelan PUD 2006) is to provide safe, timely, and effective passage for adult and juvenile Pacific Lamprey; and where unavoidable Project impacts are measured, then provide appropriate and reasonable Protection, Mitigation, and Enhancement measures (PMEs) that achieve an overall No Net Impact (NNI) on this population. Objectives of the Chelan PUD PLMP are to address (1) potential ongoing Project impacts on upstream passage of adult Pacific Lamprey, (2) potential ongoing Project impacts on downstream passage of juvenile Pacific Lamprey, (3) potential ongoing Project impacts on the existing reservoir habitat used currently by juvenile Pacific Lamprey, and (4) any unavoidable impacts by identifying and implementing measures to achieve No Net Impact (NNI).

The goal of the Douglas PUD PLMP (Douglas PUD 2009) is to implement measures to monitor and address impacts, if any, on Pacific Lamprey (Lampetra tridentata) resulting from the Douglas PUD's Projects. Objectives of the Douglas PUD PLMP are to (1) Identify and address any adverse Project-

related impacts on passage of adult Pacific Lamprey, (2) Identify and address any Project-related impacts on downstream passage and survival and rearing of juvenile Pacific Lamprey and (3) Participate in the development of regional Pacific Lamprey conservation activities.

3.6 2007 – U.S. Fish and Wildlife Service Pacific Lamprey Conservation Initiative

The Pacific Lamprey Conservation Initiative (Initiative) is the USFWS' strategy to improve the status of Pacific Lamprey throughout their range by helping implement research and conservation actions. The Pacific Lamprey was historically widespread along the West Coast of the United States but populations have declined in abundance and become restricted in distribution throughout California, Oregon, Washington, and Idaho. Threats to Pacific Lamprey occur in much of the range of the species and include restricted mainstem and tributary passage, reduced flows and dewatering of streams, stream and floodplain degradation, degraded water quality, and changing marine and climate conditions. The USFWS is working collaboratively with tribes and Federal, State, and local agencies to conserve and restore Pacific Lamprey to achieve long term persistence and support traditional tribal cultural use. The three components of the Initiative are the Pacific Lamprey Assessment and Template for Conservation Measures (Luzier et al. 2011; Goodman and Reid 2012), the Conservation Agreement for Pacific Lamprey in the States of Alaska, Oregon, Idaho, and California (USFWS 2012), and Regional Implementation Plans for Pacific Lamprey RMUs (https://www.fws.gov/pacificlamprey/PlansMainpage.cfm).

3.7 2008 – Columbia Basin Fish Accords

The Columbia Basin Fish Accords (Accords) were signed by the CTUIR, CTWSRO, YN, Colville Tribe, the CRITFC and the United States represented by the Bureau of Reclamation (Reclamation), the Army Corps of Engineers (USACE) and the BPA in May of 2008. The Accords are a series of policy and legal agreements in which the tribal governments and the CRITFC agreed not to litigate against hydropower and river operations conditions for a decade. In return, the federal government committed funding to high priority tribal fish recovery and habitat restoration projects that included harvest, passage, production, habitat, lamprey, and infrastructure and outreach projects. The Accords require adaptive management for dam operations to meet survival and passage needs of salmon. Specific to lamprey, Accord projects seek to halt the decline of the Pacific Lamprey, with the longer-term goal of restoration to levels supportive of their unique cultural and ecosystem values.

3.8 2009 – U.S. Army Corps of Engineers Passage Improvements Implementation Plan: 2008-2018

The USACE Pacific Lamprey Passage Improvements Implementation Plan: 2008-2018 (Passage Improvement Plan, USACE 2008) was developed as part of the Accords. The Accords required collaboration with the tribes and USFWS to develop a 10-year plan, included a funding commitment of approximately $50 million over the ten-year period, and identified specific actions to be considered to improve lamprey passage and survival. The goal was to develop a 10-year lamprey plan to improve adult and juvenile passage and survival through the Federal Columbia River Power System, to be achieved through adaptive management strategies, scientific research, adult and juvenile monitoring, and modifications at hydropower facilities to improve passage. Further, the Passage Improvement Plan aimed to quickly and substantially contribute towards rebuilding depressed populations to sustainable,

harvestable levels throughout their historic range. The Passage Improvement Plan included a preliminary prioritization approach based on two factors: (1) where passage efficiency is the poorest, and (2) where the affected numbers of Pacific Lamprey are the highest. Improvements at Bonneville, John Day, and McNary dams were considered the highest priorities. Although no specific performance targets or goals for lamprey passage currently exist, the USACE is working to improve passage at dams by at least 10% through operational and structural modifications. The plan was updated in 2014 (USACE 2014) to reflect lessons learned and project actions to be completed by the end of the Accords period (2018).

3.9 2011 – Pacific Lamprey (Entosphenus tridentatus) Assessment and Template for Conservation Measures

The Pacific Lamprey Assessment and Template for Conservation Measures (Assessment) developed by the USFWS (Luzier et al. 2011; Goodman and Reid 2012) identifies critical uncertainties regarding Pacific Lamprey life history and improves the scientific understanding regarding the importance of Pacific Lamprey. The Assessment tracks the current knowledge of Pacific Lamprey habitat requirements, abundance, and historic and current distribution; describes threats and factors for decline; and identifies conservation actions and research, monitoring, and evaluation needs. The Assessment's approach is to be inclusive of other conservation measures with the objective of yielding coordinated efforts throughout the range of Pacific Lamprey. The Assessment notes that needed actions and research identified in the TPLRP are applicable throughout the Columbia and Snake River regions. The Assessment recognizes and is inclusive of efforts such as the Critical Uncertainties document (CRBLTWG 2005), which included a recommendation to develop, implement, and monitor reintroduction methods (e.g., transplantation, hatchery production).

3.10 2011 – Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin

The Columbia River Treaty Tribes developed the TPLRP for the restoration of Pacific Lamprey in the CRB to numbers adequate for the basin's ecological health and tribal cultural use (CRITFC 2011). The TPLRP is a comprehensive plan and restoration guide containing restoration goals and objectives, cultural context, lamprey life history, abundance and status, critical uncertainties and limiting factors, and prioritized project actions. The tribes believe aggressive action must be taken now, despite information gaps about the species' life history and population dynamics. The goals of the TPLRP are to immediately halt the decline of Pacific Lamprey and ultimately restore them throughout their historic range in numbers that provide for ecological integrity and sustainable tribal harvest. The objectives of the TPLRP include improving lamprey mainstem passage, survival and habitat (Objective 1), improving tributary passage and identify, protect, and restore tributary habitat (Objective 2), supplementing/augmenting interior lamprey populations by reintroduction and translocation of adults and juveniles into areas where they are severely depressed or extirpated (Objective 3), evaluating and reducing contaminant accumulation and improving water quality for lamprey in all life stages (Objective 4), and establishing and implementing a coordinated regional lamprey outreach and education program within the region (Objective 5).

The TPLRP is a collaborative effort between the CRITFC and its member tribes. The TPLRP addresses lamprey issues at the CRB scale, generally focused on the mainstem Columbia and Willamette rivers and the issues affecting lamprey at these locations. Included in the TPLRP are Tribal Ceded Area Action Plans that were designed to (1) summarize proposed lamprey actions by CRITFC member tribes and (2) link CRITFC member tribe lamprey projects in the tributaries with mainstem actions (e.g. adult tagging at Bonneville Dam with tributary entrance at Fifteenmile Creek).

3.11 2012 – Assessment of U.S. Bureau of Reclamation Projects in the Columbia River Basin: Effects on Pacific Lamprey (Lampetra tridentata) and Reclamation Lamprey Plan

In the Accords, Reclamation agreed to (1) conduct a study, in consultation with the Tribes, to identify all Reclamation projects in the Columbia Basin that may affect lamprey as well as (2) jointly develop a lamprey implementation plan for Reclamation projects as informed by the 1st Accord commitment, the tribal draft restoration plan, and other available information.

The Assessment of U.S. Bureau of Reclamation Projects in the Columbia River Basin: Effects on Pacific Lamprey (*Lampetra tridentata*) (USBR 2012; USBR Assessment) documents the activities undertaken to satisfy the 1st Accord commitment. The USBR Assessment provided the basis to inform the development of the 2nd Accord commitment – Lamprey Implementation Plan for Reclamation Projects (Reclamation Lamprey Plan). The USBR Assessment serves to document Reclamation's assessment of projects in the CRB that may affect Pacific Lamprey, with a focus on the Yakima and Umatilla subbasins, which is accomplished by tables summarizing all dams and diversions in these basins as well as recommendations for either further study or actions that may be taken to address effects on Pacific Lamprey in these subbasins.

The Reclamation Lamprey Plan (USBR 2012) outlines a collaborative strategy with the CTUIR, the YN, and other partners to implement recommendations from the USBR Assessment for further study or actions that may be taken to reduce effects to Pacific Lamprey. Further studies, as described in the Pacific Lamprey 2011 Annual Report and Reclamation Lamprey Plan (USBR 2012), are in progress to better understand the effects of Reclamation projects on lamprey. As these studies increase knowledge of Pacific Lamprey in and around low-head dams and diversions in the Yakima and Umatilla Rivers, projects have been implemented, monitored, and adapted to address effects, and studies are refined to continue to meet objectives. Study and implementation plans are updated through collaboration with partners as described in the Reclamation Lamprey Plan (USBR 2012) and documented in periodic updates (USBR 2013, 2016).

3.12 2012 – Lamprey Summit III

Recognizing the cultural significance of lamprey to the tribes, their biological significance to the river systems of the West Coast, and the continued declines in numbers and distribution of Pacific Lamprey throughout their entire geographic range, the CRITFC and the USFWS co-sponsored Lamprey Summit III to solidify regional and range wide commitments to lamprey conservation actions. Lamprey Summit III consisted of a broad overview of Pacific Lamprey conservation from a policy, management and scientific

perspective as well as the development of strategies for implementing lamprey conservation actions at the regional level. The Conservation Agreement for Pacific Lamprey in the States of Alaska, Oregon, Idaho, and California (USFWS 2012; see Section 3.13) was signed by many tribes, states and agencies at Lamprey Summit III.

3.13 2012 – Conservation Agreement for Pacific Lamprey (Entosphenus tridentatus) in the States of Alaska, Oregon, Idaho, and California

The Conservation Agreement (USFWS 2012) is a voluntary commitment by interested parties – signed by 11 tribal and 24 non-tribal groups – to collaborate on efforts that reduce or eliminate threats to Pacific Lamprey to the greatest extent possible. The goal of the Agreement is to achieve long-term persistence of Pacific Lamprey and support traditional tribal cultural use of Pacific Lamprey throughout their historical range in the United States. The intent of the parties is to achieve this goal by maintaining viable populations in areas where they exist currently, restoring populations where they are extirpated or at risk of extirpation, and doing so in a manner that addresses the importance of lamprey to tribal peoples. The Agreement parties envision a future where threats to Pacific Lamprey are reduced, historic geographic range and ecological role are re-established and traditional tribal harvest and cultural practices are restored. The Agreement provides a mechanism for interested parties to collaborate and pool available resources to expeditiously and effectively implement conservation actions. Cooperative efforts through the Agreement intend to: a) develop regional implementation plans (RIPs) derived from existing information and plans; b) implement conservation actions; c) promote scientific research; and d) monitor and evaluate the effectiveness of those actions. Objectives of the Agreement include: 1) Evaluating Pacific Lamprey population substructure; 2) identifying global issues that are impacting Pacific Lamprey; 3) developing and implementing public outreach; 4) continuing to build and maintain data sharing; 5) identifying and characterizing Pacific Lamprey for the RMUs; 6) identifying, securing and enhancing watershed conditions contained in the RMUs; and 7) restoring Pacific Lamprey of the RMUs.

3.14 2014 – Pacific Lamprey Passage Improvements Implementation Plan: 2008 – 2018 (2014 Revision)

An updated version of the Passage Improvement Plan, developed by the USACE and its partners to improve lamprey passage within the mainstem environment, was finalized in December 2014 (USACE 2014). The update includes specific revisions to the Passage Improvement Plan (USACE 2008) given a better understanding of lamprey life history and the USACE's ability to implement passage improvements. From 2009 through 2012, the primary focus of USACE lamprey passage efforts was on design, construction, and initial evaluations of relatively large-scale adult fishway entrance modifications. Based on lessons learned and progress made since 2009, the USACE proposed to continue a prioritized strategy (e.g. where passage effectiveness is poorest and where the potential for adverse effects on lamprey are the highest), with a few notable diversions that can be summarized as follows:

1. Increased focus on addressing adult lamprey passage bottlenecks in fishway sections that are upstream of entrances (i.e. transition pools, serpentine weirs). Post-hoc evaluation of historic telemetry data suggests this will enhance likelihood of improving overall dam passage efficiency and conversion to upriver dams (Keefer et al. 2013a).

2. Based on success of Bonneville Dam Cascades Island Ladder entrance Lamprey Passage Structure and preliminary success at John Day North Ladder, and apparent benign effects on salmonids, install similar systems elsewhere at ladder bottlenecks (Corbett et al. 2013).
3. Accelerate implementation of small-scale modifications at Lower Columbia dams (Bonneville, The Dalles, and John Day).
4. Consider alternative approaches to inform management decisions regarding juvenile lamprey passage improvements, other than the current strategy of developing juvenile lamprey acoustic transmitter. Managers should consider technological feasibility, schedule, cost, and ESA obligations.

Given the ongoing need to improve adult Pacific Lamprey passage, the USACE intends to generally prioritize adult lamprey passage efforts over juvenile lamprey efforts until appropriate tools are developed for evaluating juvenile lamprey passage. In doing this, the USACE assumes that restoring migration corridors for adult lamprey is the critical first step – as was the case with salmon restoration efforts in the basin – in restoring Pacific Lamprey in the CRB.

3.15 2014 – Columbia Basin Fish and Wildlife Program

The NPCC, as directed by the Northwest Power Act, developed the Program to "protect, mitigate, and enhance fish and wildlife, including related spawning grounds and habitat, on the Columbia River and its tributaries … affected by the development, operation, and management of [hydroelectric projects] while assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply." The Program includes a set of strategies that provide specific guidance for topics that address policy needs. These consist of guidance for anadromous fish mitigation in blocked areas, wildlife mitigation, resident fish mitigation, sturgeon, and lamprey. The Program was revised in 2014 with added guidance on implementing actions that result in increased abundance and survival for Pacific Lamprey, including habitat actions, dam operations and passage, monitoring populations, and research to improve understanding of how the development and operation of the Federal Columbia River Power System affects migration success, survival and growth of lamprey.

Within the 2014 Program revision, the NPCC recognizes and supports efforts to restore Pacific Lamprey consistent with The Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin and The Agreement. Guiding principles of the 2014 revision include (1) juvenile and adult lamprey should be able to safely pass dams in the basin, (2) the population size, distribution, and other limiting factors for lamprey related to the hydropower system need improved understanding, and (3) lamprey throughout their historic range should be self-sustaining and harvestable.

3.16 2015 – Regional Implementation Plans for Pacific Lamprey Regional Management Units

Through the Agreement, conservation aims to be advanced by the development of RIPs that will prioritize implementation of conservation actions and evaluate action effectiveness. The RIPs will build upon existing restoration plans that include conservation actions such as: modifying fish ladders and entranceways at dams, constructing lamprey passage structures at tributary barriers, restoring lamprey habitat, and considering lamprey during in-stream work. However, gaps in addressing threats to Pacific

Lamprey remain. The RIPs will identify additional conservation actions needed at the watershed scale to address threats and issues identified by local experts.

Regional Management Unit groups develop a RIP that includes a list of prioritized actions and a 3-5-year implementation strategy. The RIPS consist of project spreadsheets for each 4th Field hydrologic unit code (HUC) or watershed in the RMU and a summary of how the actions and research needs in the spreadsheets will address overall RMU threats. Each RIP identifies: 1) threats that affect lamprey; 2) existing restoration and conservation efforts; 3) conservation actions and research needs to address those threats; 4) high priority projects; and 5) potential funding for high priority projects in their RMU. The RMU project summaries spreadsheets contain actions and research categorized by threat for each HUC. Efforts are made to include additional information including scope, benefit, feasibility, partner participation, cost, implementing entity, and potential funding source for each need.

3.17 2017 – Conservation Challenges and Research Needs for Pacific Lamprey in the Columbia River Basin

In October 2013, experts from throughout the range of Pacific Lamprey met to identify emerging links and unknowns in the biology, research and management of lampreys of the West Coast of North America. This was accomplished by utilizing four facilitated working groups that focused on evolution and dispersal, ocean biology, freshwater biology, and passage. The workshop generated a publication (Clemens et al. 2017) that provided an up-to-date summary of tribal, federal, and local plans for managing, conserving, and restoring Pacific Lamprey in the CRB, (2) synthesized important and current limiting factors, and (3) identified important research, monitoring, and evaluation needs of lamprey in freshwater. Limiting factors in freshwater were identified as barriers to passage (e.g. dams, culverts, and screens), habitat, dredging and excavation, dewatering, perturbations to water quantity and quality, lack of awareness, and established protocols.

Clemens et al. (2017) effectively summarized and updated critical uncertainties for CRB and West Coast Pacific Lamprey in which key research needs were identified as collecting accurate and fine-scale knowledge of distribution and occupancy, estimating relative abundance and estimating survival at each life stage, assessing limiting factors and the effectiveness of creative and applied solutions, and characterizing genetic population structure(s) of the species. Clemens et al. (2017) identifies six conservation and restoration actions that can greatly benefit Pacific Lamprey as (1) removing passage barriers or providing adequate passage for Pacific Lamprey, (2) modifying diversion screens and facilities to deter impingement and entrainment of larval and juvenile lamprey, (3) restoring and managing river habitats to promote the dynamic equilibria of natural, free-flowing river ecosystems, (4) minimizing losses due to dredging and dewatering, (5) educating citizens about the importance of lamprey, and (6) implementing best management practices to include lamprey in planning and implementation for instream work.

4 SUMMARY OF BONNEVILLE POWER ADMINISTRATION'S FISH & WILDLIFE PROGRAM-FUNDED PROJECTS

4.1 Summary Tables

The ISAB (2012) recommended that the Synopsis be revised to include tabular summaries by topic. Below is a series of tables that summarize Program funded tribal lamprey projects within the CRB over the past 20 years[a]. The tables include seven subject headings that are defined specifically below.

- Critical Uncertainty – A description of which critical uncertainty (or uncertainties) are being (or were) addressed per the definitions defined in CRBLTWG (2005); see Section 3.4. The critical uncertainties identified within CRBLTWG (2005) were Lamprey Status, Biology/Ecology, Population Delineation, Passage, Population Dynamics, Limiting Factor Analysis, and Restoration Activities.
- Threat – A description of which threats are being or were addressed by this project per the definitions defined in Luzier et al. (2011); see Section 3.9. The threats identified within Luzier et al. (2011) were Passage, Dewatering and Flow Management, Stream and Floodplain Degradation, Water Quality, Harvest/Overutilization, Predation, Disease, Small Effective Population Size, Lack of Awareness, Ocean Conditions, Climate Change, and Other.
- Project Name/Title and Number (BPA or USBR project number).
- Duration – Estimated project duration by calendar year.
- Geographic Area – Approximate location of the project by 4th Field Hydraulic Unit Code.
- General Conclusions – Modified summary of general conclusions originating from the specific project or project objectives.
- References – Citation of relevant documents (project reports and/or peer reviewed journal articles) found in the Reference list (see Section 7). When possible, citations are direct links to electronic copies.

4.1.1 Yakama Nation Lamprey Projects

The long-term goal of the YN is to restore natural production of Pacific Lamprey to a level that will provide robust species abundance, significant ecological contributions and meaningful harvest throughout the Yakama Nations Ceded Lands and in the Usual and Accustomed areas. The purpose of the Yakama Nation Pacific Lamprey Project (YNPLP), developed through the Yakama Nation Ceded Lands Lamprey Evaluation and Restoration project (2008-47-000), is to restore natural production of Pacific Lamprey in the Yakama Nation Ceded Lands, specifically, the Yakima, Wenatchee, Entiat, Methow, Klickitat, White Salmon, Little White Salmon, Wind, and Rock Creek subbasins. The stated objectives of this project are to (1) collect and report critical information to evaluate status, trends and other biological characteristics, (2) identify known and potential limiting factors for Pacific Lamprey within Columbia River tributaries, and (3) develop, implement and evaluate the effects of Pacific Lamprey restoration actions within the Yakama Nation Ceded Lands. To accomplish these objectives, the YNPLP

[a] The 2016 Pacific Lamprey Management Plan Comprehensive Annual Report, completed annually by Grant PUD, in accordance to their PLMP (Section 3.5), describes updated Pacific lamprey passage, behavioral, and survival investigations and measures undertaken in the Columbia River basin (Le et al. 2017, Table 5 – Included here as Appendix A).

has focused activities on five broad themes including, (1) providing regional leadership in promoting lamprey restoration and awareness, (2) implementing reintroduction and supplementation projects, (3) supporting development and management actions associated with adult and juvenile productivity, (4) exploring critical uncertainties that are known or likely to limit productivity, and (5) actively pursuing a strong outreach and education program.

Since initiation in 2008, the YNPLP has gained a better understanding of program development and prioritizing action plans. In particular, the YNPLP has worked to reestablish and supplement lamprey in Ceded Area tributaries through adult translocation (>3,000 adults between 2012-2017 in Yakima, Wenatchee, and Methow), developed the best management practices and protocols for the artificial propagation of Pacific Lamprey, obtained a better understanding of adult, larval, and juvenile passage issues and solutions in various subbasins, studied and assessed larval/juvenile entrainment issues, completed extensive status, trend, and exploratory surveys for larval and juvenile lamprey, collected extensive genetics data on Pacific Lamprey and *Lampetra* species, developed and enhanced larval lamprey identification guides and tagging methods, and established a strong Pacific Lamprey outreach and education program through various activities (Table 4-1):

1) Improve mainstem adult lamprey passage which will be critical to allowing migration throughout the CRB, in particular to upstream locations;
2) Improve passage within the tributary environment which will continue to allow limiting factors to be identified;
3) Develop and improve alternative passage routes and strategies, such as adult translocation, to maintain the presence of lamprey in upstream locations while mainstem limiting factors are being developed;
4) Continue to understand primary limiting factors at the local level which requires the presence of lamprey;
5) Develop, improve, and implement supplementation and restoration research activities such as artificial propagation and aquaculture to determine if feasible for future use;
6) Strengthen lamprey outreach and education at the local, regional, and national levels;
7) Continue to identify, evaluate, and monitor status, trends, and distribution of lamprey within the upper reaches of their historic distribution.

Table 4-1. Summary of Program funded and other lamprey projects conducted by the Yakama Nation.

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Biology/Ecology	Lack of Awareness	Pacific Lamprey vs. Western Brook (or River) Lamprey Larvae Identification Guides (2008-470-00)	2013, 2014	Columbia Basin	1) The new identification guide displays the differences in tail features between Pacific Lamprey and Western Brook Lamprey larvae (1 and a 2 page versions). A collection of close up photos that show the lamprey tail for Pacific Lamprey and Western Brook Lamprey sorted by sizes were summarized in another document. Lastly, a Western River Lamprey was found in Lower Yakima River and identifying features were shown and listed in another document.	Lampman et al. 2014a (Appendices K2, K3) Lampman et al. 2015a (Appendices G1, G2)
Biology/Ecology	Predation	Yakima River Species Interaction Studies (1995-063-25)	2002	Upper Yakima; Lower Yakima	1) Documents the hypothetical monitoring of lamprey in the upper Yakima River basin to detect potential impacts from hatchery supplementation. 2) The release of large numbers of hatchery raised salmon are suspected to have benign effects on lamprey abundance.	Pearsons et al. 2003
Biology/Ecology	Small Effective Population Size	Trapping Adult Pacific Lamprey in the Yakima River (2008-470-00)	2012	Lower Yakima	1) Specially designed lamprey traps (PVC tube and bicycle wheel traps) were set in Lower Yakima River confluence with the Columbia River between August 9 and 29, 2012. No lamprey were collected during this period. 2) Trapping below Horn Rapids and Prosser dams is recommended in the future.	Hoffarth 2013
Biology/Ecology	Small Effective Population Size	The Role of Pacific Lamprey in Yakima River Tributary Food Webs (2008-470-00)	2014-2016	Lower Yakima; Upper Yakima	1) In 2014, we evaluated retention rates of adult lamprey carcasses in a stream channel. The carcasses placed in the channel margins remained in place at a higher rate in the short-term but were detected less frequently in the long-term compared to those placed in the middle of the channel, indicating potential predation by mammalian species. 2) In 2015, we assessed the effects of spawning lamprey through a) the use of a mechanism-based model of stream primary production in response to simulated lamprey spawning; b) an experiment to assess juvenile salmonid growth in response to artificially added lamprey carcass material; and c) an observational study of post-spawn carcass fate of adult lamprey translocated into a tributary of the lower Yakima River. We found evidence that lamprey-derived nutrient subsidies may play a significant role in reach-scale primary production under certain conditions and that under all conditions they may represent a 'hot spot' for	Lampman et al. 2016a (Appendix G6, G7) Lampman et al. 2017a (Appendix L4)

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					trophic activity by higher trophic level consumers (i.e., fish) in streams. 3) In the 2016 study, carcasses lost ~75% of their original wet weight during the four-week study. Particularly strong responses were seen in the families Chironomidae and Baetidae, which comprised >85% of samples by lamprey carcasses and showed significant differences due to accessibility treatments.	
Biology/Ecology	Other	Evaluating Persistence of Visibility with Visible Implant Elastomer Tags on Assorted Sizes of Larval and Transformer Western Brook lamprey Over a Five Month Period: Preliminary Report (2008-470-00)	2013	Laboratory	1) VIE tags can be inserted just underneath the translucent skin tissue in up to six locations on an individual juvenile/larva, with best visibility observed in the center point between the last gill pore and first dorsal insertion area. 2) None of the visibility ratings changed for larvae with or without the use of the black light during the course of the study (48 and 154 days); those tags rated as "highly visible" at the beginning remained "highly visible" and those tags rated as "visible" at the beginning remained "visible" till the end of the study.	Lampman et al. 2014a (Appendix K1)
Lamprey Status	Lack of Awareness	Consolidated and Summarized Cultural Oral Interviews on Lamprey Eels (2008-470-00)	2012, 2014-2016	Columbia Basin	1) Elder fishers and families were interviewed with questions related to the biography, harvest and abundance, biology and ecology, culture, and human impacts surrounding Pacific Lamprey. Interview answers have been analyzed over time.	Lampman et al. 2013a (Appendix D1) Lampman et al. 2015a (Appendix B1) Lampman et al. 2016a (Appendix L1) Lampman et al. 2017a (Appendix L1)
Lamprey Status	Lack of Awareness	2014 Yakama Nation Pacific Lamprey Project Outreach and Education (2008-470-00)	2014-2016	Lower Yakima	1) Technical representatives of the Yakama Nation Pacific Lamprey project are actively involved in providing presentations at professional meetings, local schools, and organizations. 2) The report outlines the dates, events, location, presenter, audiences and estimate number of people reached throughout the calendar year (reaching half a million in 2016).	Lampman et al. 2015a (Appendix I1) Lampman et al. 2016a (Appendix I1) Lampman et al. 2017a (Appendix E1)

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Lamprey Status	Small Effective Population Size	Larval Lamprey Survey Reports (2008-470-00)	2010-2016	Lower Yakima; Upper Yakima; Naches; Methow; Wenatchee; Entiat; Klickitat; White Salmon; Columbia Basin	1) Yakima – Pacific Lamprey were virtually absent in most of the Yakima Subbasin in 2010-2012, but by 2017, after years of translocation, they are now found throughout the Yakima Subbasin, including Lower Yakima tribs, Upper Yakima tribs in lower reaches, and mainstem Naches and Yakima from lower to upper reaches. 2) Methow – Pacific Lamprey distribution and relative abundance were on a sharp decline in 2012-2015, but after translocation began, their distribution has increased to upper and lower reaches of Methow and Chewuch rivers. 3) Wenatchee – Pacific Lamprey were readily found downstream of Tumwater Dam but no lamprey were found upstream of the Dam in 2012-2015. However, after translocation, they are found in both lower and upper reaches of Wenatchee. 4) Entiat - Pacific Lamprey have been found in the mainstem from lower to upper reaches (no major passage barrier exists, so no translocation has occurred here). 5) Klickitat – Pacific Lamprey were readily found up to Klickitat Hatchery weir dam, but very few Pacific Lamprey are found upstream (indicating this to be at least a partial barrier to adult Pacific Lamprey). 5) White Salmon – Pacific Lamprey were found upstream of the old Condit Dam site since the removal; however, they have not been found too far upstream from the site. 6) Distribution and occupancy within all Yakama Nation Ceded Lands using 2009-2015 data are summarized in the 2016 Appendix G1 Report.	Luke 2011 Luke 2012a Lampman et al. 2013a (Appendices B1-B3, G1) Lampman et al. 2014a (Appendices D1-D6) Lampman et al. 2015a (Appendices D1-D4, G6) Lampman et al. 2016a (Appendices C1-C6, G1) Lampman et al. 2017a (Appendices C1-C7)
Lamprey Status	Small Effective Population Size	Larval Lamprey Assessment Using a Deepwater Electrofishing Platform	2015	Lower Yakima; Upper Yakima	1) In 2015, a new modified deepwater electrofishing platform (DEP) system was developed by PNNL which, when deployed, from a small boat which has the capability of surveying in small water bodies that are inaccessible by motorboats. 2) In 2015, Pacific Northwest National Laboratory 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. 3) Results from surveys indicated that very few larval	Lampman et al. 2016a (Appendix G4) Lampman et al. 2017a (Appendices L2)

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					lamprey are inhabiting regions just upstream of the Roza Diversion facility although suitable substrates are present and abundant. 4) 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.	
Lamprey Status	Various	Yakama Nation Pacific Lamprey Project Annual Progress Reports (2008-470-00)	2009-2016	Lower Yakima; Upper Yakima; Naches; Wenatchee; Entiat; Methow; Klickitat; White Salmon; Columbia	1) Summarizes activities related to adult Pacific Lamprey trapping and collection, larval surveys, larval/juvenile salvage in diversions, entrainment studies, contaminant level concentrations in larval tissue and fine sediment, species ID guide, larval outplanting plans, translocation releases and migration data, larval/juvenile PIT tagging studies, state of art on artificial propagation and larval rearing, and cultural interviews.	Luke 2010 Luke 2011 Luke 2012a Lampman et al. 2013a Lampman et al. 2014a Lampman et al. 2015a Lampman et al. 2016a Lampman et al. 2017a
Lamprey Status	Various	Evaluation and Coordination of Pacific Lamprey Activities in the Yakima River Basin (2014-2015) (R11AC10069)	2012-2016	Lower Yakima; Upper Yakima; Naches	1) The reports summarize activities related to adult lamprey collection in the Columbia and Yakima Rivers, development and installation of adult holding facilities, adult passage designs, adult passage studies, larval sampling and salvage in irrigation canals, entrainment studies, larval / juvenile lamprey research, artificial propagation, evaluation of water quality / toxicants effects, and regional coordination in association with the Cooperative Agreement between the Bureau of Reclamation and Yakama Nation.	Luke 2012b Lampman et al. 2013b Lampman et al. 2014b Lampman et al. 2015b Lampman et al. 2016b Lampman et al. 2017b
Limiting Factors	Dewatering & Stream Flow Management	Assessment of Larval/Juvenile Lamprey Entrainment in Irrigation Diversions within the Yakima and Wenatchee Subbasins (2008-470-00)	2011-2016	Lower Yakima; Upper Yakima; Naches; Wenatchee	1) Irrigation diversions are serving as refuge habitat for larval/juvenile lamprey. The amount of habitat available is strongly linked to the number of larval/juvenile lamprey present. 2) The results showed differential rates of entrainment based on lamprey size classes. Most of the desiccated larvae were small, potentially indicating that small larvae are more susceptible to dewatering. 3) Although even the smallest mesh size (such as 1.75 mm) cannot effectively prevent small larval lamprey from passing through the screens, the	Luke 2012a (Appendix A) Lampman et al. 2013a (Appendices G2, G3) Lampman et al. 2014a (Appendix F1) Lampman et al. 2015a (Appendices F1, F2, G8)

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					diversion sites with finer mesh screens appeared to be more effective in reducing at least some of the medium sized larvae from moving downstream (i.e. mesh size does matter). 4) The vast majority of lampreys were found in two large scale diversions: Wapato Diversion (upstream of fish screens) and Sunnyside Diversion (downstream of fish screens). 5) Mark recapture studies concluded that potentially between 19-45%of the lamprey present in a given area were observed during a single pass survey, resulting in at least 7,200 larvae at Wapato Diversion and 11,667 larvae at Sunnyside Diversion. In 2016, over 24,000 larvae were salvaged from Wapato Diversion. 6) A large area of larval lamprey habitat was identified in the reservoir above Roza Dam. The area of larval habitat in the reservoir decreased dramatically when the reservoir was at its lowest level (drying up much of the larval habitat). 7) Dryden Diversion on Wenatchee River is another canal that holds a lot of Pacific Lamprey (including lots of macrophthalmia). Approximately 10,000 larvae have been found salvaged each year during dewatering as well as dredging activities.	Lampman et al. 2016a (Appendices F1, G2, G8) Lampman et al. 2017a (Appendices D1-D3)
Limiting Factors	Water Quality	Reconnaissance of contaminants in larval Pacific lamprey (Entosphenus tridentatus) tissues and habitats in the Columbia river basin, Oregon and Washington, USA (2008-470-00)	2012-2014	Columbia Basin	1) A wide range of contaminants were measured in sediments and tissues at across a large geographic area of diverse land use. Of which, four are within the Yakima River Basin. 2) This is the largest dataset of contaminants in habitats and tissues of Pacific Lamprey in North America and the first study to compare contaminant bioaccumulation during the larval life stage and the anadromous, adult portion of the life cycle. 3) Based on available data, contaminants are accumulating in larval Pacific Lamprey at levels that are likely detrimental to organism health and may be contributing to the decline of the species.	Lampman et al. 2014a (Appendix F5) Nilsen et al. 2015
Limiting Factors	Water Quality	Effects of Water Quality on Pacific Lamprey in the Yakima River Basin (2008-470-00)	2012	Lower Yakima; Upper Yakima; Naches	1) This literature review of Yakima River water quality studies suggests levels of contaminants (pesticides, insecticides, herbicides or eutrophication) are higher in agricultural tributaries and lower reaches of Yakima River and summarizes recommended actions to further investigate impacts of water quality and contaminants on lamprey.	Lampman et al. 2013a (Appendix D5)

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					2) Peak concentrations of contaminants coincide with spawning timing.	
Limiting Factors	Various	Yakima Basin Pacific Lamprey Action Plan and Table (2008-470-00)	2011-2013	Lower Yakima; Upper Yakima; Naches	1) The Action Plan presents information on Pacific Lamprey recovery specific to the Yakima River Subbasin. The overarching purpose of the Action Plan is to define near- and long-term actions that should be implemented towards the goal of recovering lamprey and identify the schedule and entity(s) responsible for implementation. 2) The Action Table lists out threats and recommended actions related to: adult migration, downstream passage and entrainment, stream and floodplain degradation, water quality and quantity, predation, disease, harvest, and small effective population.	Luke 2012a (Appendix B) Lampman et al. 2013a (Appendices D2, D3) Lampman et al. 2014a (Appendix G3)
Limiting Factors	Dewatering & Stream Flow Management	Evaluation of the Potential Impacts of "Flip Flop" on Larval Lamprey in the Upper Yakima River Using Photo Documentation and Habitat Assessment: Summer 2012 (2008-470-00)	2012	Upper Yakima	1) Nine sites throughout the upper Yakima River between Cle Elum and Roza Dam (rkm 300.9 to rkm 214.9) were sampled, attempting to assess the potential effects of "Flip Flop" flow management on larval lamprey habitat. 2) During the course of the Flip Flop period, we observed 40-100% loss of larval lamprey habitat (average of 67%) in these nine sites. 3) Reduced peak high flow during spring and late summer flow attenuation can negatively impact adult spawning migration and behavior.	Lampman et al. 2013a (Appendix D4)
Limiting Factors	Passage	Monitoring of Juvenile/Larval Lamprey Passage in Diversions (2008-470-00)	2013-2016	Lower Yakima; Naches	1) Larvae were released in Congdon Diversion to evaluate a) how lamprey of various size interact with the fish screens using video analysis, b) how many will move through the fish screens vs. bypass, and c) how many will remain in the diversion at the time of dewatering. 2) Forty-three PIT tagged larval/juvenile Pacific Lamprey were released upstream of the Chandler Diversion fish bypass (Prosser, WA) in April 2014. Although all juvenile PIT tagged fish migrating downstream through the bypass channel are supposed to be detected at the pit tag arrays, only 12.5% of the juvenile and 2.9% of the larval lamprey were detected. 3) Thirty-three PIT tagged larval/juvenile Pacific Lamprey were released upstream in the Chandler Diversion in May 2015. Only 3.0% were detected at the bypass PIT array. 4) Chandler Diversion bypass channel was explored	Lampman et al. 2014a (Appendices F2-F4) Lampman et al. 2015a (Appendix G7) Lampman et al. 2016a (Appendices E2, G3) Lampman et al. 2017a (Appendices H1, H2)

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					extensively during the dewatering period to evaluate any potential gaps or holes that may pass juvenile and larval lamprey. Holes in the range of 3.5-4.5 mm were found in many places, but larger holes (>4.5 mm) were sealed successfully. 5) Seventy-three PIT tagged juvenile/larval lamprey were released near the bypass entrances at Chandler Diversion to enhance our understanding of detection rates within the bypass channel. Detection rates were high for Pacific Lamprey (>80%), but were low for Western Brook Lamprey (52%).	
Limiting Factors	Predation	The Predation Potential of Pacific Lamprey and Western Brook Lamprey Ammocoetes by Various Native and Non-Native Species	2015-2016	Laboratory	1) We conducted two confined, experimental feeding studies (short-and long-term) to estimate the predation potential of Pacific Lamprey ammocoetes by various native and non-native fishes collected from the Yakima River Subbasin. 2) Predator fishes preyed heavily on ammocoetes when fine sediment was absent (ave. predation rate of 47%) as opposed to present (ave. predation rate of 5%). 3) Small ammocoetes (YOY and small) were preyed primarily when fine sediment was present while wider range of ammocoetes length was preyed when fine sediment was absent. 4) Smallmouth Bass was capable of consuming ammocoetes that was at least 97% of its fork length. Similarly, sculpin and Yellow Bullhead consumed ammocoetes that were at least 91% and 77% of their length, respectfully. 5) The predation rates with fine sediment present increased considerably for White Sturgeon and Common Carp in the long-term study compared to the short-term study.	Lampman et al. 2017a (Appendix L1)
Limiting Factors	Water Quality	Lower Columbia River Tributaries Larval Lamprey Survey Reports (for Mercury Concentration Assessment) (2008-470-00)	2013, 2014, 2016	Columbia Basin	1) Three of the lower Columbia River tributary mouths (Klickitat, Fifteenmile, and Wind) were sampled to collect larval/juvenile Pacific Lamprey and fine sediment they rear in for a mercury concentration analysis by Pacific Northwest National Laboratory. 2) A wide variation in methyl mercury (Hg) concentrations were found in larvae and adult lamprey in the Klicktat River, Wind River, and Fifteenmile Creek. 3) When compared with other species where Hg effects have been well studied, the concentrations in	Lampman et al. 2014a (Appendices D5, F6) Lampman et al. 2015a (Appendices D4, G10) Lampman et al. 2017a (Appendix L3) Linley et al. 2016

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					larvae from the Klickitat River, Fifteenmile, and the Wind River suggest that many of these fish may have experienced and/or continue to experience lethal and sub-lethal adverse effects from Hg that constrain population recruitment. 4) 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. Total Hg concentrations from two females collected at Bonneville and John Day dams and held at the Prosser Hatchery until ripe and their eggs also showed evidence of generational Hg transmission. For the larger (530 mm) adult female collected at Bonneville Dam, the 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. For the 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.	
Passage	Passage	Adult Pacific Lamprey Passage (2008-470-00)	2011-2014	Lower Yakima; Upper Yakima; Naches	1) Pacific Lamprey collected at lower Columbia River dams were radio-tagged and released downstream and upstream of major Yakima and Naches River dams between 2011 and 2014. 2) Reduced fall passage at the lower river dams (Wannawish and Prosser) may decrease the number of lampreys available to pass the upper river dams (Sunnyside and Wapato) in the fall when passage success at these facilities is highest. 3) Passage at Roza Dam was 0%, indicating issues within the fish ladder as well as at the uppermost collection pool.	Johnsen et al. 2013 Grote et al. 2014 Lampman et al. 2014a (Appendices G1, G2) Grote et al. 2016
Restoration	Small Effective Population Size	Adult Pacific Lamprey Collection in the Columbia River Basin (2008-470-00)	2011-2012, 2014-2016	Lower Columbia	1) The report summarizes the results and general guidelines for trapping and transporting of adult Pacific Lamprey from Lower Columbia River hydroelectric dams to decrease mortality while increasing efficiency.	Luke 2012a Lampman et al. 2013a (Appendix A1) Lampman et al. 2015a (Appendix E1) Lampman et al. 2016a (Appendix D1) Lampman et al. 2017a (Appendix K1)

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Restorations	Small Effective Population Size	Translocation of Adult Pacific Lamprey within the Yakama Nation Ceded Lands (2008-470-00)	2012-2016	Lower Yakima; Upper Yakima; Methow; Wenatchee	1) Yakima - adults have been translocated into Satus, Toppenish, and Ahtanum creeks since 2012-2013. Some adults have been released in Upper Yakima (2015) and Lower Yakima (2013-2016). Results from PIT tag data show that they move upstream in search of spawning habitat in most cases (with increasing propensity each year), but certain dams are inhibiting the passage of adults (such as Prosser, Roza and Unit 2 [Toppenish] dams). Adults have shown to use Teanaway and Swaulk creeks in upper Yakima. Larvae recruitment from translocation have been confirmed in all translocation streams as well as mainstem Yakima. 2) Methow – adults have been translocated into Methow (lower and upper), Chewuch, and Twisp rivers since 2015. Results to date indicate that a large number of adults move into Chewuch River for spawning during the fall and spring migration season. Spring migration appears to be just as important as fall migration in migrating to spawning habitat. Currently, only a limited number of adults have been documented to move into Twisp and Upper Methow rivers. Larvae recruitment from translocation have been confirmed in Chewuch and Methow rivers. 3) Wenatchee – adults have been translocated into lower and upper Wenatchee (including within Tumwater Dam) as well as Icicle Creek. Results to date indicate that adults struggle to pass Tumwater Dam during both fall and spring migration. However, adults released upstream of Tumwater Dam have occupied a wide range of habitat including White River (past Lake Wenatchee) and Nason Creek. Larvae recruitment from translocation have been confirmed in both lower and upper Wenatchee.	Lampman et al. 2015a (Appendices G3-G5) Lampman et al. 2016a (Appendix E1) Lampman et al. 2017a (Appendices G1-G3)
Restorations	Small Effective Population Size	Developing Techniques for Artificial Propagation and Early Rearing of Pacific Lamprey (Entosphenus tridentatus) for Species Recovery and Restoration (2008-470-00)	2012, 2015, 2016	Laboratory	1) This laboratory work provides the best management practices on the culturing of Pacific Lamprey from adult holding to larval rearing. 2) It also provides important insights into lamprey early life history. The transition from prolarvae to burrowing and first-feeding lamprey larvae appears to be a survival bottleneck, with high mortality of early life stages in hatchery settings, indicating that early survival bottlenecks may occur in nature as well. 3) There is enough knowledge in the Pacific	Lampman et al. 2013b (Appendix 5) Lampman et al. 2015a (Appendix J1) Lampman et al. 2016a (Appendix J1) Lampman et al. 2016c

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					Northwest region to begin a supplementation program to reintroduce and supplement locally extinct and functionally extinct populations.	
Restorations	Small Effective Population Size	Assessment of Release Sites for Larval Pacific Lamprey Outplanting (2008-470-00)	2014	Naches; Upper Yakima	1) The Eschbach Park Site (Naches River), lower reach of Wenas Creek, the Holmes Acclimation site (outlet to the Yakima River), and the Cle Elum Hatchery side channel were evaluated for potential larval lamprey outplanting. 2) Larval lamprey habitat appeared to be abundant, with overall carrying capacity estimated to be 197,636, 49,475, 149,600, and 286,978 larvae respectively.	Lampman et al. 2015a (Appendices C2-C5)

4.1.2 Confederated Tribes of the Umatilla Indian Reservation Lamprey Projects

The goal of the CTUIR is to protect, restore and enhance the First Foods – water, salmon, deer, cous and huckleberry – for the perpetual cultural, economic and sovereign benefit of the CTUIR utilizing traditional ecological and cultural knowledge and science to inform: 1) population and habitat management goals and actions; and 2) natural resource policies and regulatory mechanisms. The CTUIR, through its Pacific Lamprey Research and Restoration Project (Close 1999; Jackson et al. 2011), intends to provide the critical information to restore Pacific Lamprey in the Umatilla, Grande Ronde, Walla Walla, Tucannon, John Day and Imnaha subbasins (Phelps 2004). Restoration of Pacific Lamprey will eventually provide harvest opportunities and will recover the ecosystem functions that lamprey provide.

Since initiation of lamprey restoration efforts by CTUIR in 1995, the project has gained a better understanding of program development as well as prioritizing restoration actions based upon the CTUIR lamprey restoration plan (Close et al. 1999). In particular, the CTUIR lamprey project (1994-026-00) has translocated ~6700 adult lamprey into high-value spawning habitat in the Umatilla and Grande Ronde rivers, monitored the increased distribution of larval lamprey and outmigration of juvenile lamprey in the Umatilla River, identified and monitored adult passage barriers and obstacles within the Umatilla River, designed and implemented adult lamprey passage structures in the Umatilla River, and helped develop artificial propagation and rearing techniques for Pacific Lamprey (Table 4-2). Based on regional and project specific results, the CTUIR aims to prioritize the following objectives:

1) Improve mainstem adult lamprey passage which will be critical to allowing migration throughout the CRB, in particular to upstream locations;

2) Improve passage within the tributary environment which will continue to allow limiting factors to be identified;

3) Develop and improve alternative passage routes and strategies, such as adult translocation, to maintain the presence of lamprey in upstream locations while mainstem limiting factors are being developed;

4) Continue to understand primary limiting factors at the local level which requires the presence of lamprey;

5) Develop, improve, and implement supplementation and restoration research activities such as artificial propagation and aquaculture to determine if feasible for future use;

6) Strengthen lamprey outreach and education at the local, regional, and national levels;

7) Continue to identify, evaluate, and monitor status, trends, and distribution of lamprey within the upper reaches of their historic distribution.

Table 4-2. Summary of Program funded lamprey projects conducted by the CTUIR

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Biology/Ecology	Disease	Prevalence of Pathogens in Pacific Lamprey of the Pacific Northwest (1994-026-00, R12AC10024)	2016-17	Range-wide	1) Assembled regional fish health data for Pacific Lamprey 2) *Aeromonas salmonicida* is the most prevalent pathogen in samples examined 3) Provides data gaps and research needs regarding disease issues in Pacific Lamprey	Jackson et al. (*In review*)
Biology/Ecology	Lack of Awareness	Habitat suitability criteria for larval Pacific Lamprey (1994-026-00)	2002	Middle Fork John Day	1) Larvae lamprey distribution is positively associated with fine substrate (silt or sand), slow water velocity (0 to 9 cm/s), and depth of organic material (>30mm).	Aronsuu et al. 2003 (Chapter 4 in Close et al. 2003b)
Biology/Ecology	Lack of Awareness	The Ecological and Cultural Importance of a Species at Risk of Extinction, Pacific Lamprey (1994-026-00)	2002	Columbia River Basin	1) Lamprey are culturally significant to the tribes; however, cultural biases toward lamprey have affected management policies in the past. Lamprey may have acted as a buffer for salmon from predators.	Close et al. 2002
Biology/Ecology	Lack of Awareness	Suspended matter processing by larval Pacific Lamprey (1994-026-00)	2008	Laboratory	1) Clearance rates for seston from the water column of lamprey averaged 2.6 L/h*g dry weight under the best simulated natural conditions in the laboratory, which is comparable to other suspension-clearance invertebrates including bivalves mollusks and zooplankton.	Kreeger 2007. (Chapter 5 in Howard et al. 2007).
Biology/Ecology	Passage	Effects of passive integrated transponder (PIT) implantation on Pacific Lamprey ammocoetes	2015-2017	Laboratory	1) Develop tagging methodology for larval Pacific Lamprey 2) Evaluate the healing rate, tag retention, swimming performance, growth and survival of Pacific Lamprey ammocoetes	Moser et al. 2017
Biology/Ecology	Stream and Floodplain Degradation	Spawning habitat selection of Pacific Lamprey in a tributary of the Umatilla River, Oregon (1994-026-00)	2003	Umatilla Subbasin	1) Pacific Lamprey typically spawn in run/glide habitat with shallow water (between 20 and 40 cm deep) with larger rock (128-256 mm) and water velocity less than 30 cm/s (at 5 cm above substrate).	Aronsuu et al. 2003. (Chapter 2 in Howard, and Close 2005)
Biology/Ecology	Small Effective Populations Size	Identification of putative migratory pheromones from Pacific Lamprey (*Lampetra tridentata*) (1994-026-00)	2011-12	Laboratory	1) Migratory adult lamprey are attracted to odors emanating from larval lamprey which functions as chemical communication system that guides adults to spawning habitat.	Yun et al. 2011 Robinson et al. 2003. (Chapter 2 in Close et al. 2003b) Yun et al. 2003. (Chapter 3 in Close et al. 2003b) Robinson et al. 2002. (Chapter 2 in Close 2002b).

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Biology/Ecology; Passage	Various	Behavior and Potential Threats to survival of migrating lamprey ammocoetes and macrophthalmia (1994-026-00)	2015	Rangewide	1) The very structures designed to protect migrating juvenile salmonids can be harmful to juvenile lamprey. Yet at turbine intakes and spillways, lampreys, which have no swim bladder, can withstand changes in pressure and shear stress large enough to injure or kill most teleosts. 2) Provisions for safe passage of juvenile lamprey are being considered at dams and water diversions in North America and Europe.	Moser et al. 2015b
Lamprey Status and Biology/Ecology	Various	Pacific Lamprey Evaluation and Coordination Activities in the Umatilla River Basin (R12AC10024)	2013-2017	Lower Umatilla and Laboratory	1) This report summarizes activites related to adult passage designs, adult passage studies, larval sampling and salvage in irrigation canals, entrainment studies, larval / juvenile lamprey research, artificial propagation, and regional coordination.	Jackson and Moser 2014 Jackson and Moser 2015 Jackson and Moser 2016 Jackson and Moser 2017
Lamprey Status	Lack of Awareness	Traditional Ecological Knowledge of Pacific Lamprey (Entosphenus tridentata) in Northeastern Oregon and Southeastern Washington from Indigenous Peoples of the Confederated Tribes of the Umatilla Indian Reservation (1994-026-00)	2004	Northeastern Oregon and Southeastern Washington	1) This report documents the historical presence, use, and cultural importance of Pacific Lamprey to people of the Confederated Tribes of the Umatilla Indian Reservation.	Close et al. 2004.
Lamprey Status	Various	Assessing Pacific Lamprey Status in the Columbia River (1994-026-00)	2003	Columbia River Basin	1) Adult lamprey counts at hydropower dams underestimated losses between some dams and overestimated passage times through reservoirs 2) Count data were not correlated with trap captures of adults conducted in the same area and at the same time, likely due to lamprey-specific behaviors that result in inaccurate counts. 3) Salmonid-based sampling for juvenile lamprey is inadequate the need is highlighted for standardized larval lamprey monitoring that provides both abundance and size distributions.	Moser and Close 2003
Lamprey Status	Various	Lessons from the Reintroduction of a non-charismatic migratory fish: Pacific Lamprey in the upper Umatilla River, Oregon (1994-026-00)	2009	Umatilla Subbasin	1) Successful reintroduction of lamprey to a region requires a multidisciplinary scientific approach involving fisheries and wildlife managers, ecologists, physiologists, and geneticists. 2) Designing reintroduction projects with multifaceted information in mind, both biological and non-biological, is necessary to monitor success as well as developing models and alternative management scenarios for reintroduction efficiency.	Close et al. 2009

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Lamprey Status	Various	Status Report of the Pacific Lamprey (Lampetra tridentata) (1994-026-00)	1995	Columbia River Basin	1) Pacific Lamprey have been extirpated from many subbasins in the interior CRB 2) Lamprey were historically important to indigenous peoples	Close et al. 1995.
Passage	Passage	Effect of surgically-implanted radio transmitters on the climbing ability of adult Pacific Lamprey (1994-026-00)	2007	Laboratory	1) Laboratory study found no differences in lamprey climbing ability between tagged and untagged fish.	Moser et al. 2008. (Chapter 4 in Close et al. 2008).
Passage	Passage	Identification of Low Elevation Impediments to Adult Pacific Lamprey (Lampetra tridentata) Migration in the Umatilla River Oregon and Installation of a Lamprey Passage Structure at One of Them: Three Mile Falls Dam (1994-026-00)	2007-2009	Umatilla Subbasin	1) Radio telemetry was used to assess lamprey passage efficiency at seven dams located within the lowest 55-km reach of the Umatilla River. 2) During the study, one dam was breached, after which passage efficiency there immediately improved from 32% to 81%. 3) Water augmentation actions at Three Mile Falls Dam apparently contributed to improved mean passage efficiency of migratory-phase fish (from 17% to 50%).	Jackson and Moser, (*In Review*) Jackson and Moser 2012 Moser and Jackson 2010. (Chapter 2 in Jackson and Moser 2013). Moser and Jackson 2007. (Chapter 2 in Close et al. 2008).
Population Delineation	Small Effective Populations Size	Amplified Fragment Length Polymorphism Assessment of Genetic Diversity of Pacific Lamprey (1994-026-00)	2008	Laboratory	1) Genetic study of Pacific Lamprey from Japan, Alaska, and Pacific Northwest showed a high proportion of shared bands, which indicated significant levels of historic gene flow across the range of species. 2) Genetic diversity within the Pacific Northwest was not significant as to delineate stocks, populations, or evolutionarily significant units.	Lin et al. 2008.
Restoration	Dewatering and Flow Management Stream and Floodplain Degradation	Influence of habitat heterogeneity on the distribution of larval Pacific Lamprey (Lampetra tridentata) at two spatial scales (1994-026-00)	2003	John Day Subbasin	1) Spatial patterns in channel morphology and substratum composition were analyzed to determine the influence of habitat heterogeneity on the distribution and abundance of larval lamprey. 2) Habitat variables explained variation in larval abundance at large and small scales, but locational factors, such as longitudinal position (river km) and sample location within the channel unit, explained additional variation	Torgersen and Close 2004.
Restoration	Passage	Long Term Monitoring of the Reintroduction of Pacific Lamprey in the Upper Umatilla River, Oregon (1994-026-00)	1999-2009	Umatilla Subasin	1) Over 10 years, CTUIR translocated over 3,000 adult lamprey to the upper Umatilla River. 2) Following relocation, mean density of larvae in survey plots increased over time from 0.08 to 8.22 larvae/m^2. 3) Downstream migration by larvae may be hindered by irrigation withdrawals. Summer	Jackson et al. 1996 Aronsuu et al. 2003 (Chapter 1 in Close et al. 2003b) Close 2002a Close 2002b

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					enhanced flows of the Umatilla Basin Project are a major benefit for larval rearing.	Howard and Close. 2005 Howard et al. 2005 Close et al. 2008 Jackson et al. 2011 Jackson and Moser 2013
Restoration	Various	Restoration Plan for Pacific Lamprey (Lampetra tridentata) in the Umatilla River, Oregon (1994-026-00)	1999	Umatilla Subbasin	1) The CTUIR developed and began implementing a restoration plan for Pacific Lamprey 2) The plan included translocation of adult lamprey	Close 1999.

4.1.3 Confederated Tribes of Warms Springs Reservation of Oregon Lamprey Projects

The CTWSRO Natural Resources Fisheries Program has been conducting research on Pacific Lamprey since 2003 (BPA Projects 2002-016-00, 2007-007-00, 2008-308-00, and 2011-014-00). These studies and others (e.g. Portland General Electric Company 2011a;) were aimed at establishing population status and trends and documenting distribution in the Deschutes River, Fifteenmile Creek, and the Willamette River, monitoring recolonization of lamprey into Hood River after dam removal, investigating the potential for reestablishment upstream of Pelton-Round Butte Hydrological Complex, characterizing larval rearing habitats, identifying overwinter and spawning habitats, relating patterns of migration to environmental variables, and estimating harvest at Sherars Falls on the Deschutes River, Cushing Falls on Fifteenmile Creek, and Willamette Falls on the Willamette River.

Since initiation in 2003, the CTWSRO lamprey program has gained a better understanding of Pacific Lamprey life history and limiting factors within CTWSRO Ceded Area streams. In particular, the CTWSRO lamprey program has provided abundance and escapement estimates at Willamette Falls (Willamette River) and Sherars Falls (Deschutes River), estimated adult abundance and spawning habitat in the lower Deschutes River, evaluated status and trends and distributions of lamprey in CTWSRO Ceded Area streams (e.g. Deschutes River, Fifteenmile Creek, Warm Springs River, and Shitike Creek), and refined larval sampling and habitat identification methods and techniques (Table 4-3).

In 2016, the CTWSRO completed a “Synthesis of Pacific Lamprey studies by the Confederated Tribes of the Warm Springs Reservation of Oregon, 2003 to 2013” (Baker 2016) which synthesizes results from CTWSRO lamprey projects monitoring population status and trends and documenting distribution in the Deschutes River, Fifteenmile Creek, and the Willamette River, monitoring recolonization of lamprey into Hood River after dam removal, investigating the potential for reestablishment of lamprey upstream of Pelton-Round Butte Hydrological Complex, characterizing larval rearing habitats, identifying overwinter and spawning habitats, relating patterns of migration to environmental variables, and estimating harvest at Sherars Falls on the Deschutes River, Cushing Falls on Fifteenmile Creek, and Willamette Falls on the Willamette River.

Based on regional and project specific results (Baker 2016), the CTWSRO recommends prioritizing the following objectives:

1) Continue to estimate abundance of adult lamprey at existing harvest locations within the CRB (e.g. Sherars, Willamette Falls, and Cushing Falls) as well as expand at other potential locations (e.g. Warm Springs River, John Day River, Hood River, Clear Creek – Clackamas Subbasin);
2) Continue to evaluate, and monitor status, trends, and distribution of lamprey at all life history stages across CTWSRO ceded lands (e.g. Deschutes River, Fifteenmile Creek, and Hood River);
3) As habitat restoration continues in Reservation streams and ceded lands by CTWSRO Habitat Program, continue to evaluate and monitor lamprey response to restoration activities at new sites;

4) Continue to employ updated methods of genetic analysis, within existing lamprey projects, to help evaluate larval age at outmigration, to compare effective population size with estimated abundance, and to identify successful family groups employing parentage analysis in addition to searching for genetic markers that indicate adaptive traits that may have geographic significance;

5) Improve passage within the tributary environment, by identifying and modifying and/or removing (e.g. Powerdale dam) all potential passage barriers, which will continue to allow limiting factors to be identified;

6) Develop and improve alternative passage routes and restoration strategies to maintain the presence of lamprey in upstream locations while mainstem limiting factors are being developed;

7) Continue to understand primary and emerging (e.g. poor water quality, contaminants) limiting factors at the local level.

Table 4-3. Summary of Program funded lamprey projects conducted by the CTWSRO

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Lamprey Status	Passage	Willamette Falls Lamprey Escapement Estimate (2008-308-00)	2010-2014	Lower Willamette	1) A mark and recapture study was used to estimate lamprey escapement at Willamette Falls 2010-2014. 2) It is believed that most lamprey pass over Willamette Falls using the fish ladder. Lamprey behavior below falls is unpredictable. Less than 50% of lamprey pass the falls with the remaining either congregating at the base of the falls or moving downstream to other tributaries.	Baker and Graham 2011 Baker and Graham 2012 Baker et al. 2014 Baker and McVay 2015
Lamprey Status	Passage	Willamette Falls Lamprey Escapement Estimate (2008-308-00)	2010	Lower Willamette	1) 2010 was the first year lamprey were estimated at Willamette Falls. Escapement through the fish ladder was 89,668.	Baker and Graham 2011
Lamprey Status	Passage	Willamette Falls Lamprey Escapement Estimate (2008-308-00)	2011	Lower Willamette	1) In 2011, estimated escapement of lamprey through the fish ladder at Willamette Falls was 49,072. 2) Given the proportion of marked lamprey that failed to return to the ladder (54.3%) and escapement, the estimated abundance of lamprey in the horseshoe area below the falls was 58,217.	Baker and Graham 2012
Lamprey Status	Passage	Willamette Falls Lamprey Escapement Estimate (2008-308-00)	2012-13	Lower Willamette	1) In 2012 and 2013, estimated escapement of lamprey through the fish ladder at Willamette Falls was 109,320 and 55,460, respectively. 2) Total abundance in 2012 and 2013, including lamprey below the falls that failed to go through the fish ladder, was 245,325 and 173,792, respectively.	Baker et al. 2014
Lamprey Status	Passage	Willamette Falls Lamprey Escapement Estimate (2008-308-00)	2014	Lower Willamette	1) In 2014, estimated escapement of lamprey through the fish ladder at Willamette Falls? was 125,778. Lamprey present at the falls that failed to ascend was estimated to be 210,527 for a total abundance estimated at 336,305.	Baker et al. 2014
Lamprey Status	Passage	Adult Pacific Lamprey Escapement at Sherars Falls on the Deschutes River (2011-014-00)	2004-20124	Lower Deschutes; Middle Columbia-Hood	1) Estimated abundance of lamprey at Sherars Falls in 2013 was 11,455; escapement was 9,658. The 2013 estimate was 56% above the 2004 - 2012 average of 5,130 lamprey. 2) Between July 28 and October 1, 2013, 48 lamprey PIT tagged at Sherars Falls entered Warm Springs River (32 of 48) and Shitike Creek (16 of 48). Of the 48 lamprey, eight had overwintered in 2012 before entry into the tributaries.	Graham et al. 2013. (Chapter 1 in Baker and Graham 2013).
Lamprey Status	Passage	Adult Pacific Lamprey Escapement at Sherars Falls on the Deschutes River (2011-014-00)	2004-2013	Lower Deschutes; Middle Columbia-Hood	1) Estimated lamprey abundance, exploitation rates, and escape estimates for the lower Deschutes River have been calculated from 2004 to 2013. 2) The Project objectives were to: continue a mark-recapture study to estimate adult Pacific Lamprey	Baker et al. 2015b

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
					escapement over Sherars Falls and monitor tribal harvest at Sherars Falls; and monitor entrance timing of half-duplexed Pacific Lamprey into Warm Spring River and Shitike Creek.	
Lamprey Status	Passage	Adult Pacific Lamprey Escapement at Sherars Falls on the Deschutes River (2011-014-00)	2013-2014	Lower Deschutes; Middle Columbia-Hood	1) In 2013, the estimated abundance of lamprey in Fifteenmile Creek was 1,928; 33% lower than in 2012. 2) Distribution in Fifteenmile Creek and Eightmile Creek were 60.8 and 40.1, respectively. Lamprey distribution in Mill Creek was up to rkm 9.6. In Hood River, the upper extent of lamprey distribution was rkm 5.6 in the East Fork of Hood River.	CTWSRO Fisheries Research 2014
Lamprey Status	Passage	Adult Pacific Lamprey Escapement at Sherars Falls on the Deschutes River	2014	Lower Deschutes; Middle Columbia-Hood	1) The estimated abundance of lamprey at Sherars Falls in 2014 was 16,713; escapement was 15,050. 2) The 2014 abundance estimate was 2.9 times the 2004 - 2013 average of 5,789 lamprey. 3) In 2014, antenna arrays detected 13 Pacific Lamprey in Warm Springs River and two in Shitike Creek.	Baker et al. 2015b
Lamprey Status	Passage	Adult Pacific Lamprey Escapement at Sherars Falls on the Deschutes River	2015	Lower Deschutes; Middle Columbia-Hood		Baker 2015
Lamprey Status	Passage	Pacific Lamprey Status in Fifteenmile Creek and Hood River Subbasins (2011-014-00)	2011-2012	Middle Columbia-Hood	1) Lamprey abundance in Fifteenmile Creek was estimated to be 1,504 and 2,708 in 2011 and 2012, respectively. 2) Distribution was established at rkm 58 in Fifteenmile Creek and rkm 30 in Eightmile Creek. 3) In both 2011 and 2012, high summer water temperatures in Fifteenmile Creek may have caused lamprey to suspend migration to upper reaches. 4) In 2012, Lamprey distribution increased in the upper Hood River following the removal of Powerdale Dam in 2010 up to rkm 3.6 in East Fork Hood River.	Fox and Wildbill 2013. (Chapter 3 in Baker and Graham 2013).
Lamprey Status	Passage	Pacific Lamprey Status in Fifteenmile Creek and Hood River Subbasins (2011-014-00)	2014	Middle Columbia-Hood	1) In 2014, the estimated abundance of lamprey in Fifteenmile Creek was 3,238; 70% greater than the 2013 estimate. 2) Lamprey distribution in Fifteenmile and Eightmile creeks were similar to the previous two years, at 56 km and 37 km, respectively. 3) Lamprey in Hood River had extended an additional 5.8 rkm upstream in East Fork Hood River (to rkm 11.4).	Baker et al. 2015b.

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Lamprey Status	Stream and Floodplain Degradation	Determining Adult Pacific Lamprey Abundance and Spawning Habitat in the Lower Deschutes River Subbasin (2002-016-00)	2002-2010	Lower Deschutes	1) The abundance and harvest of adult Pacific Lamprey in the Deschutes River was estimated yearly at Shears Falls from 2004 to 2010. 2) Lamprey populations in the lower Deschutes are relatively stable but declining slightly over time. 3) A high percentage (60%) of spawning occurs in Deschutes River main stem rather than tributaries. No Western Brook or River lamprey have been positively identified within the Deschutes Subbasin. 4) Larval presence is highly correlated to habitats containing woody debris and soft substrate	Fox et al. 2010 Graham and Brun 2007
Restoration	Stream and Floodplain Degradation	Pacific Lamprey ammocoete densities in Reservation streams: A comparison between Warm Springs River and Shitike Creek and relationships between environmental variables and habitat restoration (2011-014-00)	2012-2013	Lower Deschutes	1) Larva had recolonized stream restoration area but mean densities were lower in the restoration area than the undisturbed control reach in Shitike Creek. 2) Maximum sediment depth was found to be a main predictor of larval abundance.	Baker 2013. (Chapter 2 in Baker and Graham 2013).
Restoration	Stream and Floodplain Degradation	Pacific Lamprey ammocoete densities in Reservation streams: A comparison between Warm Springs River and Shitike Creek and relationships between environmental variables and habitat restoration (2011-014-00)	2013	Lower Deschutes	1) In 2013, mean larval densities of lamprey in a salmonid-restoration reach in Shitike Creek was lower than pre-project densities in 2009 and in the undisturbed control reach in 2013.	CTWSRO Fisheries Research 2014
Restoration	Stream and Floodplain Degradation	Pacific Lamprey ammocoete densities in Reservation streams: A comparison between Warm Springs River and Shitike Creek and relationships between environmental variables and habitat restoration (2011-014-00)	2014	Lower Deschutes		Baker et al. 2015b

4.1.4 Columbia River Inter-Tribal Fish Commission Lamprey Projects

The CRITFC, through the Implement the Tribal Pacific Lamprey Restoration Plan project (2008-524-00), is directed towards implementing the six objectives contained within the Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin that was finalized by CRITFC and its member tribes (CRITFC 2011). This project is closely administered and coordinated with the Accord Lamprey Projects by the YN, CTUIR, and CTWSRO, and by the Nez Perce Tribal lamprey restoration project. Project objectives include (1) improving lamprey mainstem passage, survival and habitat, (2) improving tributary passage and identifying, protecting, and restoring tributary habitat, (3) supplementing interior lamprey populations by reintroducing and translocating adults and juveniles into areas where they are severely depressed or extirpated, (4) evaluating and reducing contaminant accumulation and improving water quality for lamprey in all life stages, (5) establishing and implementing a coordinated regional lamprey outreach and education program within the region, and (6) conducting research, monitoring and evaluation of lamprey at all life history stages.

Since initiation of the CRITFC lamprey project, a better understanding has been gained regarding the prioritizing of restoration actions based upon the TPLRP. In particular, the CRITFC lamprey project has improved the understanding of migration characteristics, passage issues, and distribution/occupancy patterns of Pacific Lamprey in the Willamette River Subbasin, contributed to significant improvements in understanding lamprey genetics and population substructure of local, regional, and range-wide population segments, developed an improved baseline for water quality and contaminant accumulation in CRB lamprey, improved local and regional perceptions of Pacific Lamprey, and provided leadership in the development and implementation of alternative forms of restoration (e.g. translocation and artificial propagation) (Table 4-4). Based on regional and project specific results (see sections 5 and 6), the CRITFC aims to prioritize the following objectives:

1) Improve mainstem adult lamprey passage which will be critical to allowing migration throughout the CRB, in particular to upstream locations;
2) Improve passage within the tributary environment which will continue to allow limiting factors to be identified;
3) Develop and improve alternative passage routes and strategies, such as adult translocation, to maintain the presence of lamprey in upstream locations while mainstem limiting factors are being developed;
4) Continue to understand primary limiting factors at the local level which requires the presence of lamprey;
5) Develop, improve, and implement supplementation and restoration research activities such as artificial propagation and aquaculture to determine if feasible for future use;
6) Strengthen lamprey outreach and education at the local, regional, and national levels;
7) Continue to identify, evaluate, and monitor status, trends, and distribution of lamprey within the upper reaches of their historic distribution.

Table 4-4. Summary of Program funded lamprey projects conducted by the CRITFC.

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Biology/Ecology	Passage	Migration Characteristics and Habitat Use of the Imperiled Adult Pacific Lamprey in the Willamette Basin: Prelude to Estimating Requirements for Persistence (2008-524-00)	2009-2012	Lower Willamette; Middle Willamette	1) Radio telemetry was used to investigate the migration characteristics and distribution of adult Pacific Lamprey in the Willamette Basin, and to identify potential barriers to the migration of these fish. 2) Most adults held in one location during the late summer (August through September), and moved to spawning locations during periods higher flows with cooler water temperature. Mainstem holding location occurred in most available habitat type and was not associated with cold-water refugia. 3) Thirty-one dams were identified as potential barriers to lamprey in the Willamette Basin.	Clemens et al. 2010 (Appendix A in Heinith and McIlraith 2011) Clemens et al. 2012b Courter et al. 2012
Biology/Ecology	Other	Relative roles of Pacific Lamprey marine-derived nutrients in freshwater food webs (2008-524-00)	2015-2016	Lower Yakima; Upper Yakima; Naches; Umatilla	1) Quantitative analysis of the factors that influence lamprey carcass deposition. Suggests historic food web subsidies were variable in form, fate, and phenology. 2) Restoration and marine derived nutrient supplementation programs should attempt to mimic historic subsidy diversity and timing to represent the diversity of anadromous species and life histories which fertilized spawning streams.	Dunkle and Caudill 2016 (Appendix C in McIlraith 2016))
Lamprey Status	Lack of Awareness	The Lost Fish-The Struggle to Save Pacific Lamprey (2008-524-00)	2013-2015	Columbia River Basin	1) Outreach and education video package that describes the plight of Pacific Lamprey within the Columbia River Basin through a tribal voice.	The Lost Fish
Lamprey Status	Passage	Determining the presence/absence of Pacific Lamprey in the Snake River Basin (2008-524-00)	2013-2016	Clearwater; Lower Snake-Asotin	1) Pacific Lamprey larval surveys were conducted in all seven of the adult translocation streams: Asotin Creek, Big Canyon Creek, Orofino Creek, Lolo Creek, Newsome Creek, Wallowa River and the South Fork Salmon River. 2) Lamprey larvae and juveniles were detected in all translocation streams but not control streams suggesting increased lamprey recruitment and distribution due to translocation efforts.	McIlraith 2013 Statler 2014 (Appendix D in McIlraith 2014) Statler 2015 (Appendix D in McIlraith 2015) McIlraith 2016
Lamprey Status	Passage	Monitoring the relative abundance of ammocoetes in the Willamette River Basin (2008-524-00)	2011-2014	Lower Willamette; Middle Willamette	1) Spawning surveys were conducted in three Willamette River tributaries. Redd counts ranged from 17 redds/km to 165 redds/km). 2) Larval Pacific Lamprey were positively associated with depositional areas containing deep, fine substrates, and particularly off-channel habitats (e.g., side channels, backwaters). 3) Fish passage barriers limit access to lamprey spawning areas in the Willamette River Basin.	Wyss et al. 2013 (Appendix A in McIlraith 2013) Schultz et al. 2014a (Appendix C in McIlraith 2014)

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Lamprey Status	Stream and Floodplain Degradation	Microsatellite analysis on Pacific Lamprey from Willamette Basin (2008-524-00)	2012	Lower Willamette; Middle Willamette	1) Data indicate a lack of reproductive isolation among the different migratory clusters of Pacific Lamprey in the Willamette River, OR suggesting some plasticity in migratory behavior. 2) Different migratory behaviors were not correlated with any genetic differences.	Docker 2013 (Appendix B in McIlraith 2013)
Lamprey Status	Stream and Floodplain Degradation	Investigations into Pacific Lamprey spawning ecology and larval distribution in the Willamette River Basin, Oregon	2012-2015	Lower Willamette; Middle Willamette	1) Adults spawned in a relatively small portion of the spawning redds that were excavated and a large proportion of adults from both sexes deposited gametes in multiple depressions. 2) Genetic pedigree reconstruction provided an estimate of the effective number of lamprey spawners-per-redd, a rate that can be used to index lamprey escapement in other locations where these surveys are performed. 3) Development and evaluation of a lamprey growth model provided a means by which to estimate larval lamprey mortality, which can potentially be used to inform life history models for Pacific Lamprey. 4) Lamprey abundance and distribution was predicted in the Luckiamute River Basin using a model fitted to existing field survey data from the lower Santiam River Basin, and those predictions were ground-truthed by sampling within the Luckiamute River Basin.	Schulz et al. 2015 (Appendix B in McIlraith 2015) Whitlock et al. 2016 (Appendix B in McIlraith 2016)
Limiting Factors	Water Quality	Emerging and Legacy Contaminants in Larval Pacific Lamprey in the Columbia River Basin (2008-524-00)	2011-2014	Lower Willamette; Middle Willamette; Middle Columbia-Hood; Lower Deschutes; Umatilla	1) Pollution from anthropogenic sources is widespread in the Columbia River Basin with higher concentrations of contaminates typically found in the lower portions of sub basins. Halogenated compounds bioaccumulate in lamprey tissues and found to be much higher in tissue than surrounding sediment. 2) The most prevalent contaminants in larval lamprey tissues were organochlorine pesticides and PBDE flame retardants. 3) In sediments, the most prevalent contaminants were PAHs, sterols, fragrances, and a chemical solvent.	Nilsen and Temple 2012 (Appendix B in McIlraith 2012) Nilsen and Temple 2013 (Appendix C) in McIlraith 2013) Nilsen et al. 2014 (Appendix B in McIlraith 2014) Nilsen et al. 2015
Limiting Factors	Lack of Awareness	Implement Tribal Pacific Lamprey Restoration Plan (2008-524-00)	2009-2016	Columbia River Basin	1) Work elements for outreach and education, tribal and regional coordination, genetic and contaminant analysis, and lamprey passage and distribution studies are ongoing.	Heinith and McIlraith 2011 McIlraith 2012 McIlraith 2013 McIlraith 2014 McIlraith 2015 McIlraith 2016

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Passage	Passage	Assess the impact of irrigation diversion screens on juvenile lamprey in the Columbia River Basin (2008-524-00)	2010-2014	Laboratory	1) Lamprey ammocoetes were analyzed for entrainment and impingement on a variety of screen panels in a recirculating flume: interlock, perforated plates, vertical bars, 14-guage wire cloth, and 12 gauge wire cloth. 2) Entrainment and impingement varied between the different screen panels as well as the size of the ammocoetes. 3) Results indicate that wire cloth screens should be replaced, where practical, with perforated plate, vertical bar, or interlocking bar screens to reduce lamprey entrainment at water diversions.	Rose and Mesa 2012 (Mesa 2014 (Appendix E in McIlraith 2014)
Passage	Passage	Willamette River lamprey research synthesis, spawning biology assessment, and putative barriers (2008-524-00)	2014-2015	Lower Willamette; Middle Willamette	1) Efforts to improve the passage of adult lamprey at Willamette Falls should continue, because slight improvements are likely to dramatically increase larval recruitment throughout the Basin. 2) There is substantial evidence that barriers are a primary factor influencing the distribution and abundance of Pacific Lamprey in the Willamette Basin. Barriers downstream of larger and more productive habitat patches should be given greater priority. 3) Studies of Pacific Lamprey ecology in the Willamette River Basin show very similar findings as those that have been conducted in other locations. Because Pacific Lamprey of various life history stages are relatively abundant in the Willamette River, it can serve as an important testing ground for hypotheses about the ecology and management of the species.	Schultz et al. 2015 (Appendix C in McIlraith 2015)
Passage	Passage	Monitoring streams downstream of Willamette Falls for PIT tagged Pacific Lamprey (2008-524-00)	2014	Lower Willamette; Middle Willamette	1) A small percentage (1% in 2014; 12% in 2015) of adult lamprey collected and tagged at Willamette Falls, were detected in downstream tributaries (e.g. Abernethy Creek) suggesting that adult lamprey migration behavior is flexible. Information generated from this project pinpointed the fate of PIT tagged adult lamprey that did not attempt to pass fish ladders at Willamette Falls and contributed to abundance and escapement estimates.	McIlraith 2016
Population Delineation	Small Effective Populations Size	Population genomics of Pacific Lamprey: adaptive variation in a highly dispersive species (2008-524-00)	2013	Columbia River Basin	1) Pacific Lamprey exhibit minimal population structure, but may have some adaptive genetic variation. 2) Reconciles previous findings of population genetic heterogeneity within a species that displays extensive gene flow.	Hess et al. 2012

Critical Uncertainty	Threat	Project Name (Number)	Duration	Geographic Area	General Conclusions	References
Population Delineation	Other	Genetic monitoring using Single Nucleotide Polymorphism (SNP) genetic markers for Columbia River Basin lamprey species (2008-524-00)	2012-2016	Laboratory	1) 96 high-throughput single nucleotide polymorphisms (SNP) assays were developed from a total of 4,439 SNPs identified via a previous genomic study of Pacific Lamprey in order to address four disparate objectives: parentage analysis, species identification, and characterization of neutral and adaptive variation. 2) Identified SNP markers provide an important resource to address critical uncertainties associated with the conservation and recovery of this imperiled species.	Hess et al. 2012 McIlraith 2013 Hess 2014 (Appendix A in McIlraith 2014) Hess and McIlraith 2015 (Appendix A in McIlraith 2015) Hess and McIlraith 2016 (Appendix A in McIlraith 2016)
Restoration	Small Effective Populations Size	First International Forum on the Recovery and Propagation of Lamprey (2008-524-00)	2011	Columbia River Basin	1) Through discussions with regional and international experts, it was determined that artificial propagation for Pacific Lamprey is possible, that there are appropriate existing facilities and resources in the Columbia Basin, and that development of the knowledge base for an artificial propagation and translocation plan in the Columbia Basin needs to continue.	Greig and Hall 2011
Restoration	Small Effective Populations Size	Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin (2008-524-00)	2015	Columbia River Basin	(1) Developed to initiate a regionally coordinated and long-term RM&E plan directed towards the implementation of supplementation and recovery actions for Pacific Lamprey within the Columbia River Basin. (2) The Framework intends to standardize key elements of supplementation RM&E so that findings associated with status and trends and other important objectives can be reported in a common and consistent format. (3) Finally, the Framework provides specific guidance for the development of subbasin supplementation research plans	CRITFC 2014
Restoration	Small Effective Populations Size	Master Plan for Pacific Lamprey (Entosphenus tridentatus) Supplementation, Restoration, and Research (2008-524-00)	2016	Columbia River Basin	(1) Goal is to evaluate the feasibility of using supplementation and aquaculture to better understand and ultimately restore Pacific Lamprey, with emphasis on the Columbia River Basin. (2) Provide artificially propagated larval and juvenile lamprey for research projects to evaluate critical uncertainties and limiting factors. (3) Obtain a better understanding of basic but important aspects of Pacific Lamprey biology and ecology through the scientific process. (4) Develop techniques, protocols, and equipment needs for a future conservation aquaculture facility.	-

4.2 Summary Maps

In its review summary, the ISAB (2012) recommended that the Synopsis be revised to include a figure showing project locations and their coverage with respect to the overall historical range of lamprey in the CRB, along with the conservation status for the areas assessed in the Assessment developed by the USFWS (Luzier et al. 2011). The maps below (Figure 4-1 and Figure 4-2) summarize Program funded tribal lamprey projects and their spatial distribution within the CRB over the past 20 years.

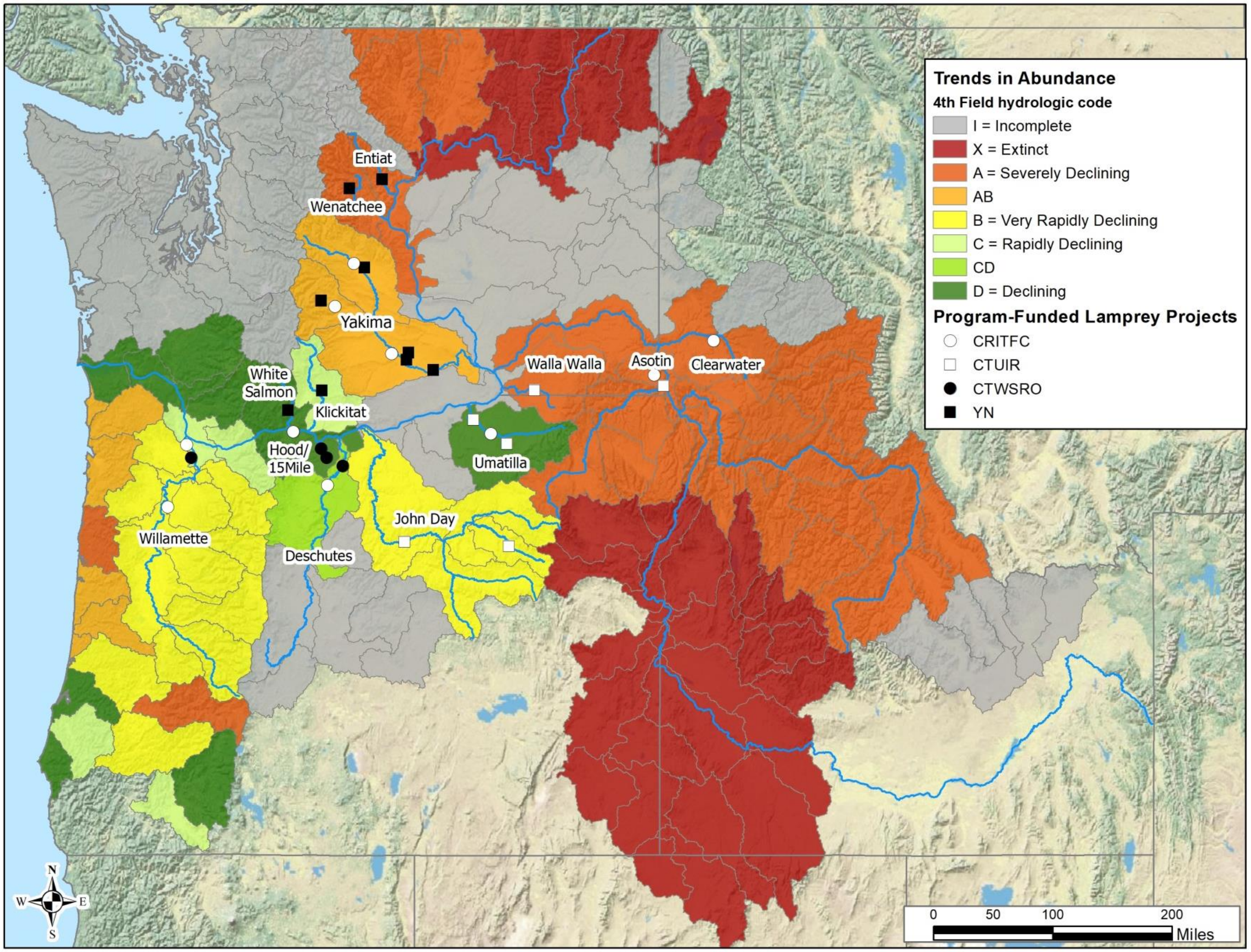

Figure 4-1. Project locations and their coverage with respect to abundance trends of Pacific Lamprey in the Columbia River Basin as assessed by Luzier et al. (2011).

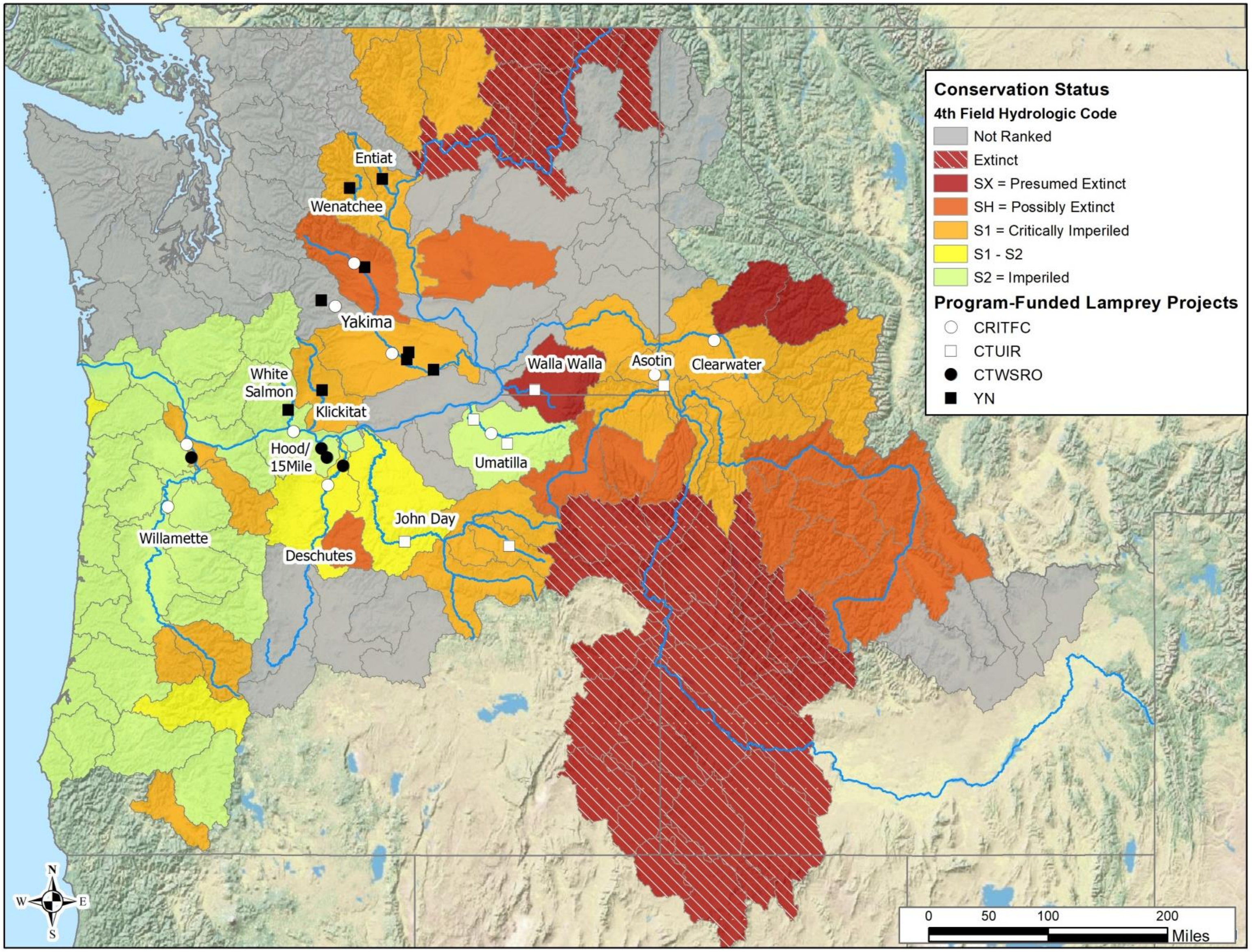

Figure 4-2. Project locations and their coverage with respect to conservation status of Pacific Lamprey in the Columbia River Basin as assessed by Luzier et al. (2011). Conservation status designations are defined in Figure 5-1.

5 SPECIFIC QUESTIONS FROM THE ISRP AND ISAB REVIEWS

5.1 **Question 4.1 – What are the General Conclusions of the Studies to Date?** Are lamprey recovering in the basin?

Summary – Pacific Lamprey do not appear to be recovering in the Columbia River basin. A risk assessment showed that Pacific Lamprey distribution and abundance had decreased compared to historic levels and that many threats are still impacting Pacific Lamprey. Though some geographic population segments may be at relatively lower risk, all geographic population segments appear to be at risk of decline and extirpation.

As specified in the Synopsis (CRBLTWG and CBFWA 2012), results from the USFWS Assessment (Luzier et al. 2011) indicate that Pacific Lamprey do not appear to be recovering in the CRB. This assessment included updated information from all existing Program funded lamprey projects as well as numerous others. A risk assessment conducted at the 4^{th} Field HUC level showed that Pacific Lamprey distribution and abundance had decreased compared to historic levels and that many threats are impacting Pacific Lamprey throughout their range (Luzier et al. 2011).

Additional assessments from the subbasins where studies are taking place, and elsewhere in the CRB, also suggest that lamprey are not recovering. Research in the Yakima River Subbasin indicates that carrying capacity of lamprey is high in various watersheds, but that current abundance is low (Table 4-1). Adult passage in the subbasin is impaired by mainstem and tributary dams, and many larval and juvenile lamprey are entrained into irrigation canals. Pacific Lamprey recruitment in other subbasins surveyed by the YN is also severely reduced.

Research and restoration activities have been ongoing in the Umatilla River subbasin since 1995 (Table 4-2). These efforts to reintroduce, monitor, and restore lamprey are showing positive survival results across all life history stages. The summary of findings below is reported in Jackson and Moser (2013) and from continuing CTUIR studies since that time. In short, counts of adult returns, densities of larval Pacific Lamprey, and juvenile outmigration estimates have increased in recent years, but numbers are still far below historic levels.

The CTWSRO began research in the Deschutes River Subbasin in 2003, and has expanded efforts to include Fifteenmile Creek and Hood River subbasins, and estimates of escapement at Willamette Falls (Table 4-3). Pacific Lamprey in the Deschutes River subbasin appear to be slightly declining, but Pacific Lamprey re-colonized new areas of the Hood River after removal of Powerdale Dam. Abundance in Fifteenmile Creek does not appear to be increasing. Passage by Pacific Lamprey at Willamette Falls is likely below historic averages.

The Assessment (Luzier et al. 2011) indicates that Pacific Lamprey are at high risk throughout much of the CRB, particularly in the Snake River, the Mid-Columbia and the Upper Columbia Regions (Figure 5-1). Threats affecting these populations include barriers to mainstem and tributary passage, stream and floodplain degradation and small population effects. Lower Columbia and Willamette River Pacific

Lamprey population segments are also at risk. Tributary passage, water quality and stream and floodplain degradation are ongoing threats in these regions.

Table 5-1 through Table 5-4 outline the risk of extirpation as well as demographic and threat information for Pacific Lamprey in the CRB. The information is displayed by 4th Field HUC. The HUCs where the studies to date have taken place are highlighted in yellow. For easier reference, the table numbers from the Assessment (Luzier et al. 2011) are included in each table caption.

Pacific Lamprey distribution and abundance in the CRB appears to have decreased when compared to historic levels (Luzier et al. 2011). Unfortunately, restoration, recovery, and research actions targeted for Pacific Lamprey have only recently begun in the CRB (Close 2002a) therefore it is difficult to accurately determine whether lamprey are truly “recovering” as traditionally monitored by increasing adult returns at mainstem and tributary locations. Pacific Lamprey have a long and complex life history (~7-13 years) so it may take several generations to observe recovery within the CRB in relation to restoration actions implemented since 2000 as well as the Columbia Basin Fish Accords’ projects that began in 2008. That being said, daytime adult counts at Bonneville Dam and escapement estimates at Willamette Falls (Figure 1-1 and Figure 1-3) have shown an increasing trend increased since 2011 though indices of abundance are still well below recent and historical returns. Though these increases are encouraging, it remains unclear if they represent recovery, especially considering the long and relatively panmictic life history of lamprey, or if they are influenced by more global, unmeasured variables (e.g. marine prey species fluctuations or ocean conditions).

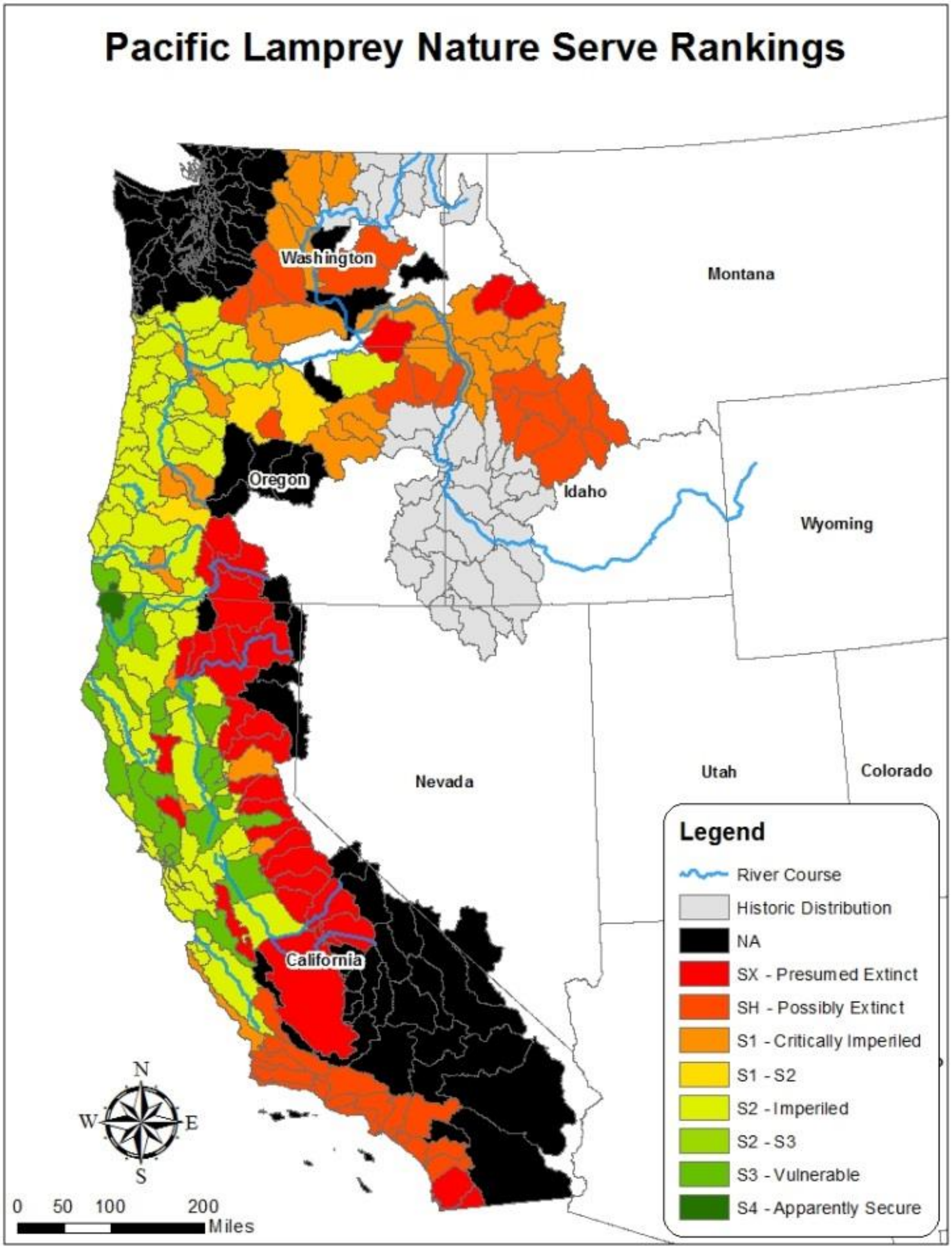

Figure 5-1. **Calculated NatureServe relative risk ranks for Pacific Lamprey.**

Table 5-1. (Assessment Table 4-1). Categorical rank inputs and resulting NatureServe ranks for Pacific Lamprey population groupings within the Lower Columbia River Region. Yellow highlighting indicates that lamprey studies have been conducted.

Watershed	HUC	Calculated Risk Rank[a]	Distribution: Historic (km²)	Distribution: Current (km²)	Ratio of Current to Historic Distribution	Population Size (#)[b]	Short Term Trend (% decline)	Threat: Scope	Threat: Severity
Lower Columbia-Sandy	17080002	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	C (30-50)	High	High
Lewis	17080003	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	D (10-30)	High	High
Lower Columbia-Clatskanie	17080004	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	D (10-30)	High	Moderate
Upper Cowlitz	17080005	SH	D (1,000-5,000)	Z (0)	Z (0.001)	U	NA	High	High
Lower Cowlitz	17080006	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	D (10-30)	High	High
Lower Columbia	17080007	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	D (10-30)	High	Moderate
Middle Fork Willamette	17090001	S1	D (1,000-5,000)	E (100-500)	B (0.10)	U	B (50-70)	High	High
Coast Fork Willamette	17090002	S1	D (1,000-5,000)	E (100-500)	B (0.10)	U	B (50-70)	High	Moderate
Upper Willamette	17090003	S2	D (1,000-5,000)	(2,000-20,000)		U	B (50-70)	High	High
Mckenzie	17090004	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	B (50-70)	High	Moderate
North Santiam	17090005	S2	C (250-1000)	E (100-500)	D (0.37)	U	B (50-70)	High	High
South Santiam	17090006	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	B (50-70)	High	High
Middle Willamette	17090007	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	B (50-70)	High	High
Yamhill	17090008	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	B (50-70)	High	High
Molalla-Pudding	17090009	S2	D (1,000-5,000)	(2,000-20,000)		U	B (50-70)	High	High

Watershed	HUC	Calculated Risk Rank[a]	Distribution: Historic (km^2)	Distribution: Current (km^2)	Ratio of Current to Historic Distribution	Population Size (#)[b]	Short Term Trend (% decline)	Threat: Scope	Threat: Severity
Tualatin	17090010	S2	D (1,000-5,000)	F (500-2,000)	E (0.5)	U	B (50-70)	High	High
Clackamas	17090011	S1	D (1,000-5,000)	E (100-500)	B (0.10)	U	B (50-70)	High	Moderate
Lower Willamette	17090012	S1	C 250-1000	E (100-500)	D (0.37)	U	B (50-70)	High	High

[a] SH = Possibly Extirpated; S1 = Critically Imperiled; S2 = Imperiled.
[b] U = Unknown

Table 5-2. (Assessment Table 4-2). Categorical rank inputs and resulting NatureServe ranks for Pacific Lamprey population groupings within the Mid-Columbia River Region. Yellow highlighting indicates that lamprey studies have been conducted.

			Distribution		Ratio of Current		Short Term	Threat	
Watershed	HUC	Calculated Risk Rank[a]	Historic (km^2)	Current (km^2)	to Historic Distribution	Population Size (#)	Trend (% decline)	Scope	Severity
Walla Walla	17070103	SX	D (1,000-5,000)	X (0)	Z (0.001)	ZA (0-50)	A (>70)	High	High
Umatilla	17070104	S2	C (250-1,000)	E (100-500)	E (0.5)	C (250-1,000)	D (10-30)	High	High
Willow	17070105	NA							
Mid-Columbia-Hood	17070106	S2	C (250-1,000)	E (100-500)	E (0.5)	C (250-1,000)	D (10-30)	High	High
Klickitat	17070107	S1	C (250-1,000)	E (100-500)	E (0.5)	B (50-250)	C (30-50)	High	High
Upper John Day	17070202	S1	CD (250-5,000)	CD (4-100)	A (0.05)	BC (50-1,000)	B (50-70)	High	High
North Fork John Day	17070203	S1	CD (250-5,000)	E (100-500)	C (0.25)	BC (50-1,000)	B (50-70)	High	High
Middle Fork John Day	17070204	S1	CD (250-5,000)	E (100-500)	C (0.25)	C (250-1,000)	B (50-70)	High	High
Lower John Day	17070205	S1S2	CD (250-5,000)	U	F (0.75)	BC (50-1,000)	B (50-70)	High	High
Upper Crooked	17070305	NA							
Lower Crooked	17070306	NA							
Lower Deschutes	17070307	S1S2	D (1,000-5,000)	E (100-500)	B (0.1)	E (2,500-10,000)	CD (10-50)	High	High
Trout	17070308	SH	U	Z (0)	Z (0)	Z (0)	U	High	High
Beaver S. Fork	17070304	NA							
Upper Deschutes	17070302	NA							
Little Deschutes	17070303	NA							

[a] SX = Presumed Extirpated; SH = Possibly Extirpated; S1 = Critically Imperiled; S1S2 = Imperiled to Critically Imperiled; S2 = Imperiled; NA = Not Assessed.

Table 5-3. (Assessment Table 4-3). Categorical rank inputs and resulting NatureServe ranks for Pacific Lamprey population groupings within the Upper Columbia River Region. Yellow highlighting indicates that lamprey studies have been conducted.

Watershed	HUC	Calculated Risk Rank[a]	Distribution: Historic (km²)[b]	Distribution: Current (km²)[b]	Ratio of Current to Historic Distribution	Population Size (#)[b]	Short Term Trend (% decline)	Threat: Scope	Threat: Severity
Crab Creek	17020013, 016	SH	U	U	A (0.05)	Z (0)	UE (U or +/- 10%)	High	High
Wenatchee	17020012	S1	D (1,000-5,000)	E (100-500)	B (0.1)	A (1-50)	A (>70)	High	High
Entiat	17020011	S1	D (1,000-5,000)	F (500-2,000)	E (0.5)	A (1-50)	A (>70)	High	High
Chelan	17020009	S1	U	U	A (0.05)	U	U	High	High
Methow	17020009	S1	D (1,000-5,000)	F (500-2,000)	E (0.5)	A (1-50)	A (>70)	High	High
Okanogan	17020007	S1	D (1,000-5,000)	F (500-2,000)	E (0.5)	A (1-50)	A (>70)	High	High
Smilkameen	17020008	S1	A (<100)	D (20-100)	A (0.05)	A (1-50)	A (>70)	High	High
Kettle, Colville, Sanpoil	17020002-005	SX		Z (0)	Z (0.001)	X (0)	NA		
Upper Yakima	17030002	SH	CD (250-5,000)	Z (0)	Z (0.001)	ZU (U-0)	AB (50->70)	High	High
Naches	17030003	SH	BC (100-1,000)	ZA (0-0.4)	Z (0.001)	AB (1-250)	AB (50->70)	High	High
Lower Yakima	17030004	S1	BC (100-1,000)	AB (>0-4)	A (0.05)	AU (U-50)	AB (50->70)	High	High

[a] SX = Presumed Extirpated; SH = Possibly Extirpated; S1 = Critically Imperiled.
[b] U = Unknown

Table 5-4. (Assessment Table 4-4). Categorical rank inputs and resulting NatureServe ranks for Pacific Lamprey populations within the Snake River Region. Yellow highlighting indicates that lamprey studies have been conducted.

Watershed	HUC	Calculated Risk Rank[a]	Distribution		Ratio of Current to Historic Distribution	Population Size (#)	Short Term Trend (% decline)	Threat	
			Historic (km^2)	Current (km^2)				Scope	Severity
Lower Clearwater	17060307	S1	E (5,000-20,000)	DE (20-500)	A (0.05)	A (1-50)	A (>70)	High	High
Lower North Fork Clearwater	17060309	SX	D (1,000-5,000)	X (0)	Z (0.001)	X (0)		High	High
Upper North Fork Clearwater	17060308	SX	D (1,000-5,000)	X (0)	Z (0.001)	X (0)		High	High
Middle Fork Clearwater	17060305	S1	C (1,000-5,000)	CD (4-100)	B (0.1)	A (1-50)	A (>70)	High	High
South Fork Clearwater	17060306	S1	D (1,000-5,000)	CD (4-100)	A (0.05)	A (1-50)	A (>70)	High	High
Lochsa	17060304	S1	D (1,000-5,000)	C (4-20)	A (0.05)	A (1-50)	A (>70)	High	High
Lower Selway	17060303	S1	D (1,000-5,000)	C (4-20)	A (0.05)	A (1-50)	A (>70)	High	High
Upper Selway	17060302	S1	D (1,000-5,000)	C (4-20)	A (0.05)	A (1-50)	A (>70)	High	High
Lower Snake-Asotin	17060104	S1	D (1,000-5,000)	CD (4-100)	A (0.05)	A (1-50)	A (>70)	High	High
Mainstem Snake River Hells Canyon	17060102	S1	BC (100-1,000)	AB (<0.4-4)	A (0.05)	A (1-50)	A (>70)	High	High
Above Hells Canyon		SX		E	Z	X			

[a] SX = Presumed Extirpated; SH = Possibly Extirpated; S1 = Critically Imperiled.

5.2 Question 4.2 – What Have Emerged as Primary Limiting Factors for Lamprey Basinwide?

Basinwide? The ISRP noted that lamprey are declining coast wide, suggesting that ocean factors may be affecting survival, but no studies are being conducted in the marine environment. Lampreys are also likely very susceptible to toxic contaminant effects but very limited work is being done on this issue. Most proponents are focusing on key limiting factors in tributary habitat but the ISRP, as well as ISAB (2009-3) has pointed out this approach is too restrictive for anadromous lamprey. A comparison of lamprey stocks in various rivers might be useful, including those outside the Columbia River Basin.

Summary – Pacific Lamprey face a multitude of threats. Within the USFWS Assessment, passage, dewatering and stream flow management, stream and floodplain degradation, small effective population, ocean conditions, climate change, water quality, harvest/overutilization, predation, disease, and lack of awareness were identified as threats. Within the Tribal Pacific Lamprey Restoration Plan, mainstem passage and habitat, tributary passage and habitat, supplementation/augmentation, contaminants and water quality, public outreach and education, and research, monitoring and evaluation were identified as objectives aimed at addressing priority threats. Passage, dewatering and stream flow management, stream and floodplain degradation and lack of awareness were all highly ranked within 4th level Hydrologic Unit Codes.

As summarized in the Synopsis (CRBLTWG and CBFWA 2012), Pacific Lamprey face a multitude of threats at various life history stages. Within the Assessment (Luzier et al. 2011), 11 regionally evaluated threats were identified and were subsequently summarized in the Synopsis. These threats are passage, dewatering and stream flow management, stream and floodplain degradation, small effective population, ocean conditions, climate change, water quality, harvest/overutilization, predation, disease, and lack of awareness. Within the TPLRP (CRITFC 2011), mainstem passage and habitat, tributary passage and habitat, supplementation/augmentation, contaminants and water quality, public outreach and education, and research, monitoring and evaluation were identified as objectives aimed at addressing priority threats. The Assessment identifies critical uncertainties regarding Pacific Lamprey life history and improves the scientific understanding regarding the importance of Pacific Lamprey.

The Assessment tracks the current knowledge of Pacific Lamprey habitat requirements, abundance, and historic and current distribution; describes threats and factors for decline; and identifies conservation actions and research, monitoring, and evaluation needs. Passage, dewatering and stream flow management, stream and floodplain degradation and lack of awareness were all highly ranked within 4th level Hydrologic Unit Codes (

Table 5-5). Primary threats have anecdotal as well as scientific support for their role in lamprey declines. Secondary threats, although likely important, have mostly anecdotal and speculative support for their role in lamprey declines. Tertiary threats have minimal anecdotal and speculative support for their role in lamprey declines. In addition, tertiary threats may be geographical limited or affecting lamprey at smaller spatial scales and as a result, are presumed to play a smaller role in lamprey declines.

Table 5-5. Regionally evaluated threats within the Pacific Lamprey Assessment and Template for Conservation Measures (Luzier et al. 2011) organized into three tiers of influence.

Primary	Secondary	Tertiary
Passage	Ocean conditions	Harvest/overutilization
Dewatering and stream flow management	Climate change	Disease
Stream and floodplain degradation	Water quality	--
Small effective population	Predation	--
Lack of awareness	--	--

The Synopsis indicated that threats vary in combinations and severities across the range of Pacific Lamprey. Though some geographic population segments may be at relatively lower risk when taking into account population demographics, local threats, and proximity to areas of difficult passage, all geographic population segments appear to be at risk of decline and extirpation. Although the Synopsis did not rank these threats at the basin level as suggested by the ISAB and ISRP (ISAB 2012), the scope and severity of threats were ranked by 4th Field HUCs for each RMU within the USFWS Assessment (Luzier et al. 2011). Table 5-6 through Table **5-10** show the ranking of threats by HUC for the CRB (Lower Columbia/Willamette, Mid-Columbia, Upper Columbia, Clearwater, Salmon, and Lower Snake, Mainstem Columbia and Snake River). For easy reference, the table numbers from the Assessment (Luzier et al. 2011) are included in each table caption.

At this point, no single threat can be pinpointed as the “primary limiting factor” in the observed decline of Pacific Lamprey in the CRB. However, passage, dewatering and stream flow management, stream and floodplain degradation and lack of awareness were all highly ranked within 4th Field HUCs (Luzier et al. 2011) indicating that these are likely the most important threats affecting Pacific Lamprey. Summaries of how these highly-ranked threats affect Pacific Lamprey in the CRB are provided below.

Table 5-6. (Assessment Table 11-3). Threats to Pacific Lamprey and their habitats within the Lower Columbia River, as identified and ranked by participants at regional meetings. H=4, M/H=3.5, M=3, L/M=2.5, L=2, I=1, U=No value

	Passage		Dewatering and Flow Management		Stream and Floodplain Degradation		Water Quality		Harvest		Predation	
Watershed	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Lower Columbia River												
Sandy	4	4	2	3	3	3	3	3	1	1	4	U
Lewis	3	3	4	4	3	3	3	3	1	1	4	U
Clatskanie	4	4	2	3	3	3	2	U	1	1	4	U
Upper Cowlitz	3	4	4	4	3	3	1	1	1	1	U	U
Lower Cowlitz	3	3	3	4	3	3	1	2	1	1	4	U
Lower Columbia	2	4	2	2	3	3	2	U	1	1	4	U
Mean	3.17	3.67	2.83	3.33	3.00	3.00	2.00	2.25	1	1	4	
Rank	M	H	M	M	M	M	L	L	I	I	H	
Mean Scope & Severity	3.42		3.08		3.00		2.13		1			
Drainage Rank	M		M		M		L		I			

Table5-6. (Assessment Table 11-3). Continued.

Watershed	Passage		Dewatering and Flow Management		Stream and Floodplain Degradation		Water Quality		Harvest		Predation	
	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Willamette River Basin												
Middle Fork	4	4	4	4	4	4	4	4	1	1	2	2
Coast Fork	4	3	3	3	4	3	3	3	1	1	U	U
Upper Willamette	3	3	3.5	3	4	4	4	3.5	U	U	3	3
Mckenzie	3	3	3	3	4	3	2	2	1	1	2	2
North Santiam	4	4	3	3	3.5	3	3	3	1	1	2	2
South Santiam	4	4	3	3	3.5	3	3	3	1	1	2	2
Middle Willamette	2	2	4	4	4	4	3	3	U	U	3	3
Yamhill	3	3	3	3	4	4	4	4	1	1	3	3
Molalla-Pudding	2.5	2.2	4	4	4	4	3	3	1	1	3	3
Tualatin	2.5	2.5	2.5	2.5	4	4	4	4	1	1	3	3
Clackamas	4	3	3	3	4	3	3	3	1	1	3	3
Lower Willamette	4	3	3	3	4	4	4	4	U	U	4	4
Mean	3.33	3.08	3.25	3.21	3.92	3.58	3.33	3.29	1/U	1/U	2.73	2.73
Rank	M	M	M	M	H	H	M	M	U	U	M	M
Mean Scope & Severity	3.21		3.23		3.75		3.1		1/U		2.73	
Drainage Rank	M		M		H		M		U		M	
Lower Columbia/Willamette Region												
Overall Rank												
Mean	3.31		3.16		3.38		2.62		1.0		3.3U	
Overall Threat	M		M		M		M		I		M/U	

Table 5-6. (Assessment Table 11-3). Continued.

	Translocation		Disease		Small Population Size		Lack of Awareness		Climate Change	
Watershed	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Lower Columbia River										
Sandy	NA	NA	U	U	U	U	4	U	4	U
Lewis	NA	NA	U	U	U	U	4	U	4	U
Clatskanie	NA	NA	U	U	U	U	4	U	4	U
Upper Cowlitz	NA	NA	U	U	4	U	4	U	4	U
Lower Cowlitz	NA	NA	U	U	U	U	4	U	4	U
Lower Columbia	NA	NA	U	U	U	U	4	U	4	U
Mean					4		4		4	
Rank					H		H		H	
Mean Scope & Severity										
Drainage Rank										

Table 5-6. (Assessment Table 11-3). Continued.

Watershed	Translocation		Disease		Small Population Size		Lack of Awareness		Climate Change	
	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Willamette River Basin										
Middle Fork Willamette	1	1	U	U	U	U	2	2	4	U
Coast Fork Willamette	NA	NA	U	U	U	U	2	2	U	U
Upper Willamette	NA	NA	U	U	U	U	4	4	U	U
Mckenzie	1	1	U	U	4	U	2	2	4	U
North Santiam	1	1	U	U	U	U	2	2	4	U
South Santiam	1	1	U	U	U	U	2	2	4	U
Middle Willamette	NA	NA	U	U	U	U	4	4	U	U
Yamhill	NA	NA	U	U	U	U	4	4	U	U
Molalla-Pudding	NA	NA	U	U	U	U	4	4	U	U
Tualatin	NA	NA	U	U	U	U	4	4	U	U
Clackamas	1.5	2	U	U	U	U	2	2	4	U
Lower Willamette	1	1	2	2	2	2	3	3	4	U
Mean					4		4		4	U
Rank	NA	NA	U	U	U	U	2.92	2.92	4	U
Mean Scope & Severity Drainage Rank	NA		U		U		M		4/U	
Lower Columbia/Willamette Region										
Overall Rank										
Mean Scope/Severity	NA		U		U		3.46/U		4/U	
Overall Threat Rank	NA		U		U		M/U		H/U	

Table 5-7. (Assessment Table 10-3). Threats to Pacific Lamprey and their habitats within the Mid-Columbia River Region, as identified and ranked at regional meetings. H=4, M/H=3.5, M=3, L/M=2.5, L=2, I=1, U=No value

	Passage		Dewatering and Flow Management		Stream and Floodplain Degradation		Water Quality		Harvest		Predation	
Watershed	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Walla Walla	3	3	3.5	3.5	3	2.5	3	3	1	1	2	2
Umatilla	4	3.5	3	3.5	4	4	3.5	3	1	1	2	2
Willow												
Mid. Columbia-Hood	3	3	4	4	4	4	4	3.5	U	U	1	1
Klickitat	1	1	1	1	2	2	2	3	2	2	2	2
Upper John Day	3.5	3.5	3.5	3.5	3.5	4	4	4	1	1	2	2
North Fork John Day	2	2	2.5	2.5	2.5	2.5	2	2.5	1	1	2	2.5
Mid. Fork John Day	2	2	2.5	2.5	3.5	3.5	3	3	1	1	1.5	1.5
Lower John Day	3	3	4	4	3.5	3.5	4	4	1.5	1.5	3	3
Lower Deschutes	2	2.5	2	2	2.5	2.5	2.5	2.5	2.5	2.5	1	1
Mean	2.61	2.61	2.89	2.94	3.17	3.17	3.11	3.17	1.38	1.38	1.83	1.89
Rank	M	M	M	M	M	M	M	M	I	I	L	L
Mean Scope & Severity	2.61		2.92		3.17		3.14		1.38		1.86	
Drainage Rank	M		M		M		M		I		L	

Table 5-7. (Assessment Table 10-3). Continued.

	Translocation		Disease		Small Population Size		Lack of Awareness		Climate Change		Mainstem Passage	
Watershed	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Walla Walla	1	1	U	U	4	4	3	3	3.5	3.5	4	4
Umatilla	1	1	U	U	3	3	2	2	3.5	3.5	4	4
Willow												
Mid. Columbia-Hood	1	1	U	U	2.5	2.5	3.5	3	4	4	4	4
Klickitat	1	1	U	U			3	3	3	3	4	4
Upper John Day	1	1	U	U	2	2	3	3	3.5	3.5	4	4
North Fork John Day	1	1	U	U	2	2	2	2	3.5	3.5	4	4
Mid. Fork John Day	1	1	U	U	2	2	2.5	2.5	3.5	3.5	4	4
Lower John Day	1	1	U	U	1	1	2.5	2.5	3.5	3.5	4	4
Lower Deschutes	1	1	U	U	2	2	2	2	3.5	3.5	4	4
Mean	1	1			2.31	2.31	2.61	2.56	3.5	3.5	4	4
Rank	I	I			L	L	M	M	H	H	H	H
Mean Scope & Severity	1				2.31		2.58		3.5		4	
Drainage Rank	I				L		M		H		H	

Table 5-8. (Assessment Table 9-3). Threats to Pacific Lamprey and their habitats in the Upper Columbia River Region, as identified and ranked by participants in regional meetings. H=4, M/H=3.5, M=3, L/M=2.5, L=2, I=1, U=No value

	Passage		Dewatering and Flow Management		Stream and Floodplain Degradation		Water Quality		Harvest		Predation	
Watershed	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Upper Columbia												
Crab Creek			2	2	3	3	4	4	1	1	1	1
Smaller Tributaries	1	1	3	2	1	2	1	2	1	1	1	1
Wenatchee	3	2	3	2	3	3	1	2	1	1	1	1
Entiat	1	1	2	2	3	3	1	1	1	1	1	1
Chelan				1	1	1	1	1	1	1	1	1
Methow	1	1	2.5	1	3	3	1	1	1	1	1	1
Okanogan	1	1	3	3	3	3	3	3	1	1	1	1
Mean	1.4	1.2	2.66	1.86	2.43	2.57	1.714	2	1	1	1	1
Rank	I	I	M	L	L	M	L	L	I	I	I	I
Mean Scope & Severity	1.30		2.22		2.50		1.86		1.00		1.00	
Drainage Rank	I		L		M		M		I		I	
Yakima Drainage												
Upper Yakima	4	4	4	4	2	2	1	1	1	1	1	1
Naches	3	3	3	3	2	2	2	2	1	1	1	1
Lower Yakima	3	4	4	4	2	2	4	4	1	1	2	4
Mean	3.33	3.67	3.67	3.67	2	2	2.33	2.33	1	1	1.33	2
Rank	M	H	H	H	L	L	L	L	I	I	I	L
Mean Scope & Severity	3.50		3.67		2.00		2.33		1.00		1.67	
Drainage Rank	H		H		L		L		I		L	
Upper Columbia Region Overall Rank	2.13	2.13	2.94	2.40	2.30	2.40	1.90	2.10	1.00	1.00	1.10	1.30
Mean Scope & Severity	2.13		2.67		2.35		2.00		1.00		1.20	
Overall Threat Rank	L		M		L		L		I		I	

Table 5-8. (Assessment Table 9-3). Continued.

	Translocation		Disease		Small Population Size		Mainstem Passage		Climate Change	
Watershed	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Upper Columbia	1	1	1	1			4	4		
Crab Creek	1	1					4	4		
Smaller Tributaries							4	4		
Wenatchee							4	4		
Entiat							4	4		
Chelan							4	4		
Methow							4	4		
Okanogan							4	4		
Mean	1	1	1	1			4	4		
Rank	I	I	I	I			H	H		
Mean Scope & Severity	1.00		1.00				4.00			
Drainage Rank	I		I				H			
Yakima Drainage										
Upper Yakima	1	1	1	1	4	4	4	4		
Naches	1	1	1	1	4	4	4	4	3	4
Lower Yakima	1	1	1	1	4	4	4	4	3	4
Mean	1	1	1	1	4	4	4	4	3	4
Rank	I	I	I	I	H	H	H	H	M	H
Mean Scope & Severity	1.00		1.00		4.00		4.00		3.50	
Drainage Rank	I		I		H		H		H	
Upper Columbia Region										
Overall Rank	1.00	1.00	1.00	1.00	4.00	4.00	4.00	4.00	3.00	4.00
Mean Scope & Severity	1.00		1.00		4.00		4.00		3.50	
Overall Threat Rank	I		I		H		H		H	

Table 5-9. (Assessment Table. 8-3). Threats to Pacific Lamprey and their habitats within the Clearwater, Salmon, and Lower Snake River drainages, as identified and ranked by participants at regional meetings. H=4, M/H=3.5, M=3, L/M=2.5, L=2, I=1, U=No value

	Passage		Dewatering and Flow Management		Stream and Floodplain Degradation		Water Quality		Harvest		Predation	
Watershed	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Clearwater Drainage												
Lower Clearwater	2.5	2.5	2.5	2.5	3	3.5	3	3.5	1	1	2	2.5
Middle Fork Clearwater	2	2	2	2	2.5	3	2	2.5	1	1	2	2
South Fork Clearwater	3	2.5	1.5	1.5	3.5	3.5	3	2.5	1	1	2	2.5
Lochsa	2	2	1	1	2	2	1	1	1	1	1	1
Lower Selway	1	1	1	1	2	2	1	1	1	1	1	1
Upper Selway	1	1	1	1	1	1	1	1	1	1	1	1
Mean	1.92	1.83	1.5	1.5	2.33	2.5	1.83	1.92	1	1	1.5	1.67
Rank	L	L	L	L	L	M	L	L	I	I	L	L
Mean Scope & Severity	1.88		1.50		2.42		1.88		1.00		1.58	
Drainage Rank	L		L		M		L		I		L	
Salmon Drainage												
Lower Salmon	2	2	2	2	2	2	2	2.5	1	1	2	2
Little Salmon	2	2.5	2.5	2.5	2.5	2.5	3	3	1	1	2	2
South Fork Salmon	2	2	1	1	2.5	2.5	2.5	2.5	1	1	2	2
Mid. Salmon-Chamberlain	1	1	1	1	2	2	2	2.5	1	1	2	2
Low. Middle Fk. Salmon	1	1	1	1	1	1	1	1	1	1	1	1
Up. Middle Fk. Salmon	1	1	1	1	1	1	1	1	1	1	1	1
Middle Salmon-Panther	3	3	3	4	3	3	3	2	1	1	2	1
Lemhi	3.5	4	4	4	3	3	3	2	1	1	2	1
Pahsimeroi	3.5	4	4	4	4	3	3	2	1	1	2	1
Upper Salmon	3	2	3	2	3	3	2	2	1	1	2	1
Mean	2.2	2.25	2.25	2.25	2.4	2.3	2.25	2.05	1	1	1.8	1.4
Rank	L	L	L	L	L	L	L	L	I	I	L	I
Mean Scope & Severity	2.23		2.25		2.35		2.15		1.00		1.60	
Drainage Rank	L		L		L		L		I		L	

Table 5-9. (Assessment Table. 8-3). Continued.

Watershed	Passage Scope	Passage Severity	Dewatering and Flow Management Scope	Dewatering and Flow Management Severity	Stream and Floodplain Degradation Scope	Stream and Floodplain Degradation Severity	Water Quality Scope	Water Quality Severity	Harvest Scope	Harvest Severity	Predation Scope	Predation Severity
Lower Snake												
Lower Snake-Asotin	2	1.5	1.5	1.5	3	3.5	2.5	2.5	1	1	3	3
Lower Grande Ronde	2	2	1	1	2	2	2	2.5	1	1	2	2.5
Upper Grande Ronde	2	3	3	3.5	3.5	3.5	3	3.5	1	1	2.5	3
Imnaha	2	3.5	2	3	2	2.5	2	2	1	1	1	1
Wallowa	2	3.5	3	3.5	3	3.5	2	3.5	1	1	2.5	3
Lower Snake-Hells Canyon	2	4	4	4	2	3	1	1	1	1	1	2
Lower Snake-Tucannon	2	4	1	2	3	3	3	2	1	1	2	2
Mean	2	3.07	2.21	2.64	2.64	3	2.21	2.43	1	1	2	2.36
Rank	L	M	L	M	M	M	L	M	I	I	L	L
Mean Scope & Severity	2.54		2.43		2.82		2.32		1.00		2.18	
Drainage Rank	M		L		M		L		I		L	
Upper Snake Region												
Overall Rank	2.07	2.39	2.04	2.17	2.46	2.57	2.13	2.13	1.00	1.00	1.78	1.76
Mean Scope & Severity	2.23		2.11		2.51		2.13		1.00		1.77	
Overall Threat Rank	L		L		M		L		I		L	

Table 5-9. (Assessment Table. 8-3). Continued.

Watershed	Translocation Scope	Translocation Severity	Disease Scope	Disease Severity	Small Population Size Scope	Small Population Size Severity	Lack of Awareness Scope	Lack of Awareness Severity	Climate Change Scope	Climate Change Severity	Mainstem Passage Scope	Mainstem Passage Severity
Clearwater Drainage												
Lower Clearwater	1	1	1	2	4	4	3	3	3	3.5	4	4
Middle Fork Clearwater	1	1	1	1	4	4	3	3	2.5	2.5	4	4
South Fork Clearwater	1	1	1	1	4	4	3	3	2.5	2.5	4	4
Lochsa	1	1	1	1	4	4	1	1	1	1	4	4
Lower Selway	1	1	1	1	4	4	1	1	1	1	4	4
Upper Selway	1	1	1	1	4	4	1	1	1	1	4	4
Mean	1	1	1	1.17	4	4	2	2	1.83	1.92	4	4
Rank	I	I	I	I	H	H	L	L	L	L	H	H
Mean Scope & Severity	1.00		1.08		4		2.00		1.88		4	
Drainage Rank	I		I		H		L		L		H	
Salmon Drainage												
Lower Salmon	1	1	1	2	4	4	3	3	3	3.5	4	4
Little Salmon	1	1	1	2	4	4	3	3	3	3.5	4	4
South Fork Salmon	1	1	1	2	4	4	3	3	3	3.5	4	4
Mid. Salmon-Chamberlain	1	1	1	2	4	4	3	3	3	3.5	4	4
Low. Middle Fk. Salmon	1	1	1	2	4	4	1	1	2	2	4	4
Up. Middle Fk. Salmon	1	1	1	2	4	4	1	1	2	2	4	4
Middle Salmon-Panther	1	1	1	2	4	4	3	3	3	3.5	4	4
Lemhi	1	1	1	2	4	4	3	3	3	3.5	4	4
Pahsimeroi	1	1	1	2	4	4	3	3	3	3.5	4	4
Upper Salmon	1	1	1	2	4	4	3	3	3	3.5	4	4
Mean	1	1	1	2	4	4	2.6	2.6	2.8	3.2	4	4
Rank	I	I	I	L	H	H	M	M	M	M	H	H
Mean Scope & Severity	1.00		1.50		4.00		2.60		3.00		4.00	
Drainage Rank	I		L		H		M		M		H	

Table 5-9. (Assessment Table. 8-3). Continued.

Watershed	Translocation		Disease		Small Population Size		Lack of Awareness		Climate Change		Mainstem Passage	
	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Lower Snake												
Lower Snake-Asotin	1	1	1	1	4	4	3.5	3.5	2.5	2.5	4	4
Lower Grande Ronde	1	1	1	1	4	4	4	4	4	4	4	4
Upper Grande Ronde	1	1	1	1	4	4	4	4	3	3	4	4
Imnaha	1	1	1	1	4	4	4	4	3	3	4	4
Wallowa	1	1	1	1	4	4	4	4	4	4	4	4
Lower Snake-Hells Canyon	1	1	1	1	4	4	4	4	3	3	4	4
Lower Snake-Tucannon	1	1	1	1	4	4	3	3	U	U	4	4
Mean	1	1	1	1	4	4	3.79	3.79	3.25	3.25	4	4
Rank	I	I	I	I	H	H	H	H	M	M	H	H
Mean Scope & Severity	1.00		1.00		4.00		3.79		3.25		4.00	
Drainage Rank	I		I		H		H		M		H	
Upper Snake Region												
Overall Rank	1.00	1.00	1.00	1.48	4.00	4.00	2.80	2.80	2.66	2.86	4.00	4.00
Mean Scope & Severity	1.00		1.24		4.00		2.80		2.76		4.00	
Overall Threat Rank	I		I		H		M		M		H	

Table 5-10. (Assessment Table. 7-1). Threats to Pacific Lamprey and their habitats within the Mainstem Columbia River and Snake River Region.

Watershed	Passage		Dewatering and Flow Management		Stream and Floodplain Degradation		Water Quality		Predation	
	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Snake Basin	4	4	2	3.5		4	4		4	4
Upper Columbia – Above Priest	4	4	2	3.5		4	4		4	4
Mid Columbia – Bonneville to Priest	4	4	2	3.5		4	4		4	4
Mean	4	4	2	3.5		4	4		4	4
Rank[a]	H	H	L	H		H	H		H	H
Mean Scope and Severity	4		2.75						4	
Drainage Rank	H		M		H		H		H	

[a] H (High) = 4, M/H (Moderate/High) = 3.5, M (Moderate) =3, L/M (Low/Moderate) = 2.5, L (Low) = 2, I (Insignificant) = 1, U = No value

5.2.1 Passage

As reviewed in Section 2.3, in the Synopsis (CRBLTWG and CBFWA 2012), and specifically for mainstem Columbia River projects (Keefer et al. 2012a), Pacific Lamprey returning to the CRB encounter a variety of migration obstacles at mainstem dams and at low-head dams and diversions. Artificial barriers impact distribution and abundance of Pacific Lamprey by impeding upstream and downstream movement by lamprey at all life stages (Close et al. 1995; Vella et al. 1999; Ocker et al. 2001; Lucas et al. 2009). Upstream adult migrations are blocked or hindered by dams without suitable passage alternatives or attraction to fish ladder entrances (Moser et al. 2002a). Fish ladders and culverts designed to pass salmonids can block or delay lamprey passage, particularly if they have sharp angles and vertical steps to which lamprey cannot attach (Keefer et al. 2012a), have confusing flows and high water velocities (Moser et al. 2002a; Mesa et al. 2003, Keefer et al. 2012a), or adversely expose lamprey to predators (Luzier et al. 2011). Culverts and other low-head structures that have a drop at the outlet are impassable for a variety of reasons including high velocities or distance, insufficient resting areas, and lack of suitable attachment substrate (CRBLTWG 2004; Streif 2009; USFWS 2010).

Downstream migrating larval and juvenile lamprey are often entrained in water diversions or turbine intakes (Moursund et al. 2001; Dauble et al. 2006). Due to their size and weak swimming ability (Sutphin and Hueth 2010), larval and juvenile lamprey can be impinged on turbine screens (Moursund et al. 2001) and irrigation screens (Ostrand 2004), resulting in injury or death. Juveniles have shown high survival through the juvenile salmonid bypass systems at Columbia River mainstem dams (Moursund et al. 2001), but are often inadvertently collected and transported downstream in barges or trucks with salmonid smolts.

Many of these challenging passage environments have been well studied and numerous operational and structural changes have been implemented to improve lamprey passage (Keefer et al. 2012a; USACE 2014). Lamprey Passage Structures (LPSs) have been installed at the Cascades Island entrance, within the Washington Shore Auxiliary water supply channels, and at the Washington Shore ladder at Bonneville Dam as well as at the John Day Dam north fish ladder entrance (USACE 2014). LPSs are known to be effective routes of passage once lamprey approach these structures (Corbett et al. 2013). Once inside LPSs, adults can successfully pass dams within hours rather than days (Corbett et al. 2015). Passage through LPSs accounted for approximately 35% of tagged fish released below Bonneville Dam in 2014 (Corbett et al. 2015). Modifications to fishway entrances, such as the installation of keyhole entrances at Bonneville and John Day dams (USACE 2014) and variable width weirs at Priest Rapids Dam, have improved entrance efficiencies for lamprey as well as other migratory species (Clabough et al. 2011; Corbett et al. 2013). Other "minor" structural changes within fishways, such as providing alternative routes of passage (e.g. raised picketed leads, orifice installation at weirs), installing lamprey rest boxes, and eliminating potential, small-scale passage barriers (e.g. rounding corners, ramping steps, providing attachment points at high velocity areas, reducing grating widths), have been implemented to cumulatively improve the passage environment for adult lamprey.

Regardless of these changes, ~22-65% of the migrating lamprey in the Lower Columbia and Willamette rivers that attempt to pass dams are unsuccessful (Moser et al. 2002a, 2002b; Mesa et al. 2010; Keefer

et al. 2012b; Clemens et al. 2012a) with slightly higher passage rates (65-75%) in the Mid- and Upper Columbia and Snake rivers (Keefer et al. 2013b; Le et al. 2015). At low-head dams and diversions, passage efficiency has ranged from 17-81% (Jackson and Moser 2013; Lampman et al. 2014). The higher end of this passage range has been observed at newly installed LPSs at low-head dams in the Umatilla River (Jackson and Moser 2013). Passage efficiency for lamprey is in stark contrast to salmonid passage efficiency which generally exceeds 95% at each project within the mainstem (NOAA Fisheries 2008).

As described in Section 3, evaluating and improving passage throughout the CRB has been identified as a high priority for restoring Pacific Lamprey. The Critical Uncertainties document (Section 3.4), the USACE Passage Improvements Implementation Plan (Section 3.8) and revision (Section 3.14), the USFWS Pacific Lamprey Assessment and Template for Conservation Measures (Section 3.9), the tribal Pacific Lamprey Restoration Plan for the Columbia River Basin (Section 3.10), and the regional implementation plans for Pacific Lamprey regional management units (Section 3.16) all stress the importance of improve passage for lampreys.

5.2.2 Dewatering and Stream Flow Management

As mentioned in the Synopsis (CRBLTWG and CBFWA 2012), rapid and unnatural fluctuations in reservoir and stream water levels from irrigation diversions, power hydropeaking, and instream channel activities can temporarily or permanently isolate lamprey from flowing water leading to stranding, desiccation, or predation (Kostow 2002; Streif 2009; USFWS 2010; Maitland et al. 2015; Lampman et al. 2015a, 2016a). Suitable habitats for larval and juvenile lamprey are often the first areas dewatered when stream flow declines. Low stream flows during summer and fall can also impede adult lamprey migration timing and overwintering success of adults, and desiccate nests by restricting flow into an exposed, shallow river channel or by creating thermal passage barriers (Maitland et al. 2015; Clemens et al. 2017). Gradual dewatering events can be conducive to larval and juvenile lamprey, as in receding flood waters (Kostow 2002). Streif (2009), USFWS (2010), and Clemens et al. (2017) suggested three options to conserve lamprey during instream work including (1) identification of key instream work periods when few lamprey may be encountered, (2) collection (via netting and electrofishing) and transport of lamprey out of exposed areas, and (3) allowing lamprey to volitionally escape from the dewatered areas back into areas not being dewatered.

5.2.3 Stream and Floodplain Degradation

As mentioned in the Synopsis (CRBLTWG and CBFWA 2012), lamprey spawn (Pletcher 1963; Kan 1975) and rear (Pletcher 1963; Potter 1980; Richards 1980; Torgersen and Close 2004; Graham and Brun 2007) in low gradient stream reaches with complex channel structure, pools, and riffles, and adjacent stream margins and side channels with finer sediment and detritus. These features are frequently found in low gradient areas with wide floodplains, which are popular for development. The loss of these habitats reduces areas for spawning and rearing. Riparian vegetation is an important component of larval rearing areas. Pirtle et al. (2003) found that larvae were collected where canopy cover was 71.8% on average; however, they were observed over a wide range of cover from 7.5% to 100%. In Idaho, the amount of riparian vegetation and shading was positively correlated with larval abundance (Claire 2004) and loss of these features would likely negatively impact lamprey. Eggs and larvae from many lamprey species that

rear in stream substrates have been impacted by activities that remove silt and fine substrate from the stream such as excavation, mining, or dredging activities (Beamish and Yousan 1987).

Graham and Brun (2007) found that larval presence is highly correlated to habitats containing woody debris and soft substrate. Baker and Graham (2013) found that although larvae had recolonized a stream restoration area, density was lower in the restoration area than in an undisturbed control reach. Maximum sediment depth was found to be a main predictor of larval abundance. Larval density was lower in a salmonid-restoration reach than it was before the project, and was lower than in the undisturbed control reach (CTWSRO 2014).

5.2.4 Lack of Awareness

During initial lamprey restoration efforts (1995-2004) primary impediments to restoration included lack of awareness, understanding, and prioritization for Pacific Lamprey declines and restoration actions. Since 2004, awareness of Pacific Lamprey declines and their important cultural and ecological roles within the CRB has improved dramatically. Currently, a variety of tribes, federal agencies, states, NGO's, universities, and public utility districts, throughout the range of Pacific Lamprey, have an increasing, committed interest in restoring and conserving lamprey (USFWS 2012). Though the lamprey restoration paradigm has shifted in a positive direction within the CRB, in particular with Agreement signatories and supporters, significant work remains. Many people are not aware that Pacific Lamprey exist within the CRB. If they are aware, these fish are negatively associated with the invasive and nuisance Sea Lamprey of the Laurentian Great Lakes. Restoration projects that have highlighted lamprey decline, as well as reestablished cultural and ecological connections (e.g. adult translocation), have helped to elevate regional awareness (Crandall and Wittenbach 2015). Increased awareness and implementation of active outreach and education programs (CRITFC 2011; Lampman et al. 2017a) will be critical to advancing regional and range-wide restoration efforts. The Initiative and the TPLRP aim to foster coordination and implementation of lamprey research and restoration projects (CRITFC 2011; Luzier et al. 2011; USFWS 2012).

5.2.5 Oceanic Life

Numerous efforts have highlighted that a more thorough understanding of lamprey life history will be critical to their ultimate restoration. Recent efforts have been focused on improving passage, understanding habitat requirements, raising awareness for lamprey, their declines, and their cultural importance—with limited resources and growing awareness, and prioritizing efforts on known (relatively understood) issues. Though Pacific Lamprey spend a minority of their life cycle in the marine environment, it is generally understood that this life history component may be very important to the overall health of West Coast lamprey populations (See Section 2.1). Pacific Lamprey spend 1-4 years in the marine environment parasitizing a wide variety ocean prey (Clemens et al. 2017). The prey in turn may be affected by a variety of changing environmental conditions within the ocean environment. Murauskas et al. (2013) hypothesized that lamprey returns to the CRB may be affected by fluctuating levels of prey in the ocean.

The CRBLTWG, under the guidance of the Agreement, has created an ocean life stage subgroup. The ocean life stage subgroup of the Workgroup is currently in the process of outlining a path forward for a more thorough evaluation of the marine life history of Pacific Lamprey. This path may include, among other things, the development of an updated literature review of Pacific Lamprey marine life history as well as the identification of existing marine and estuarine projects, personnel, and datasets that may support a more complete understanding of Pacific Lamprey marine life history, and the creation of a formal research and monitoring plan to address marine life history data gaps and critical uncertainties. The subgroup has included this information in a RIP Progress made within the ocean life stage subgroup will be reported to the Workgroup on a semi-annual basis.

5.2.6 Contaminants

The CRITFC lamprey project includes an evaluation of contaminant and water quality issues for Pacific Lamprey in the CRB, which includes both legacy and emerging contaminants (Table 4-4). In general, work on the effects of contaminants and water quality for Pacific Lamprey has been limited (see Section 2.8), though there is concern that lampreys bioaccumulate contaminants at dangerous levels (Bettaso and Goodman 2010; Maitland et al. 2015; Nilsen et al. 2015), that Pacific Lamprey larvae may avoid toxin-laden sediments (Unrein et al. 2016), and that protracted freshwater life histories may increase exposure to contaminants (Bettaso and Goodman 2008). To begin addressing this work element, the CRITFC, in collaboration with its member tribes, partnered with the U.S. Geological Survey to provide reconnaissance-based information about multiple classes of contaminants of concern in larval Pacific Lampreys and their habitats. The project initially focused on the health of Pacific Lamprey during the sensitive life stage before their transformation to adults, existing data from adult life stages, as well as possible human health implications. Nilsen et al. (2015) compared contaminant bioburden during different life stages of Pacific Lampreys and established that bioaccumulation of some contaminants, such as pesticides and flame retardants, occurs at the larval stage, while others such as PCBs may be taken up primarily during the anadromous, adult portion of the life cycle. Nilsen et al. (2015) also identified the individual compounds detected most frequently and at the highest concentrations in both sediments (flame retardants, hydrocarbons, pesticides, mercury (Hg), and contaminants of emerging concern) and tissues (pesticides, flame retardants, and Hg) at sites across a large geographic area including multiple subbasins and diverse land use. The documented detrimental effects of contaminants on lamprey in other parts of the world, effects of contamination on anadromous salmonid health in the Pacific Northwest, along with the concentrations of concern measured in Nilsen et al. (2015), suggest that water quality and contamination could be playing an important role in the observed decline of Pacific Lampreys in the CRB.

5.3 Question 4.3 – What are the Major Impediments to Implementation of Recovery Plans? Will mainstem passage problems be resolved to enable sufficient numbers of adults to migrate into tributaries to initiate recovery in synchrony with translocation and habitat improvements such as ramps on low head dams and irrigation screens?

Summary – During initial lamprey restoration efforts, primary impediments to implementation of recovery plans included lack of awareness, understanding, and prioritization for Pacific Lamprey declines and restoration actions. Since 2004, awareness of

Pacific Lamprey and their important cultural and ecological roles has improved significantly. However, a lack of lamprey-specific resources still impedes consistent progress in implementing restoration efforts.

As described in Section 3, a variety of existing documents and ongoing efforts are aimed at restoring and conserving Pacific Lamprey within the CRB. The primary objectives of these efforts range from identifying threats and critical uncertainties (CRBLTWG; see Section 3.4), to ranking regionally evaluated threats throughout the range of Pacific Lamprey (USFWS; see Section 3.9), to providing guidance for regional lamprey restoration (TPLRP; see Section 3.10), and to identifying needs and implementing actions for specific threats (USACE; see Sections 3.8 and 3.14). During initial lamprey restoration efforts (1995-2004) primary impediments included lack of awareness, understanding, and prioritization for Pacific Lamprey declines and restoration actions. Since 2004, awareness of Pacific Lamprey declines and their important cultural and ecological roles within the CRB has improved significantly, exemplified by the diverse group of participants at the 2008 and 2012 Lamprey Summits. Currently, a variety of tribes, federal agencies, states, NGO's, universities, and public utility districts, throughout the range of Pacific Lamprey, have an increasing, committed interest in restoring and conserving lamprey (USFWS 2012).

Despite this positive paradigm shift, an overall lack of lamprey-specific resources still impedes consistent progress in implementing restoration efforts. The Agreement, coupled with its regional implementation planning effort, has identified and prioritized restoration actions within regional management units and the Agreement policy group is working to determine how to address these identified needs. A significant amount of planning and collaboration throughout the range of Pacific Lamprey since 2012 has identified as many as 50 high priority lamprey restoration projects with various costs and levels of feasibility. Unfortunately, most of these projects are outside of the scope of the existing regional lamprey and restoration projects (see Table 4-1 through Table 4-4). As a result, alternative funding sources will be required to effectively address these needs.

Restoration and recovery of Pacific Lamprey lack legal mandates such as the Endangered Species Act, which requires efforts to recover listed species such as some anadromous salmonids. However, the Program (see Section 3.15), developed by the NPCC and funded by BPA, includes guidance on implementing actions that result in increased abundance and survival for Pacific Lamprey. Currently, Pacific Lamprey projects are allotted a small proportion of the total funding directed towards anadromous fish.

Improving both mainstem and tributary passage will be critical to recovery. Although the USACE has implemented its Passage Improvements Plan (see sections 3.8 and 3.14), implementing passage improvements throughout the mainstem Columbia and Snake rivers is a daunting task that will require a long-term commitment. Most passage improvement efforts to date have focused on adults; much remains to be learned about identifying and addressing passage issues for larvae and juveniles. Cost of replacing screens to reduce impingement and mortality would be extremely high. In tributaries, reducing entrainment of larvae and juveniles at diversions will be an expensive undertaking that would likely require site-specific solutions. Significantly improving the mainstem and tributary passage environment for lamprey at all life history stages will require a long-term commitment (> 30 years).

Mainstem passage improvements will need to occur in unison with actions within the tributary environment (e.g. translocation and habitat improvements) in order for restoration plans (e.g. CRITFC 2011) to be implemented successfully.

Lack of status under the Endangered Species Act also reduces the potential for agencies such as the USACE to require safeguards for lamprey when reviewing actions and issuing permits. However, the USACE and other signatories to the Agreement (see Section 3.13) might consider using the Agreement as a mechanism for instituting stronger requirements for lamprey protection. Finally, the lack of understanding of lamprey requirements, and the lack of effective monitoring tools remain impediments to recovery.

In short, work on Pacific Lamprey is decades behind that of anadromous salmonids, and decades were required to gain a comprehensive understanding of salmonid requirements and to develop effective monitoring tools.

5.4 Question 4.4 – Is the Draft Lamprey Master Plan for Tribal Pacific Lamprey Restoration that Will Guide Recovery Efforts Completed? (Project #2008-524-00)

Summary – The TPLRP was completed in December of 2011. The CRITFC and its members developed the TPLRP for the restoration of Pacific Lamprey in the CRB to numbers adequate for the Columbia River basin's ecological health and tribal cultural use.

The TPLRP was completed in December of 2011 (CRITFC 2011; see Section 3.10). The CRITFC and its members developed the TPLRP for the restoration of Pacific Lamprey in the CRB to numbers adequate for the Columbia River Basin's ecological health and tribal cultural use. The goals of the TPLRP are to immediately halt the decline of Pacific Lamprey and ultimately restore these fish throughout their historic range in numbers that provide for ecological integrity and sustainable tribal harvest.

The objectives of the TPRLP are listed below and the full plan is available on the CRITFC website (www.critfc.org/wp-content/uploads/2012/12/lamprey_plan.pdf).

- Mainstem Passage and Habitat
    - Objective 1: Improve lamprey mainstem passage, survival and habitat
- Tributary Passage and Habitat
    - Objective 2: Improve tributary passage and identify, protect, and restore tributary habitat
- Supplementation/Augmentation
    - Objective 3: Supplement/Augment interior lamprey populations by reintroduction and translocation of adults and juveniles into areas where they are severely depressed or extirpated
- Contaminants and Water Quality
    - Objective 4: Evaluate and reduce contaminant accumulation and improve water quality for lamprey in all life stages
- Public Outreach and Education

    - Objective 5: Establish and implement a coordinated regional lamprey outreach and education program within the region
- Research, Monitoring and Evaluation
    - Objective 6: Conduct research, monitoring and evaluation of lamprey at all life history stages

As stated in the TPLRP, several potential issues may be acting upon lamprey declines with varying levels of understanding. The TPLRP suggests, that given the existing body of knowledge, improving passage at both mainstem and tributary projects and at all lamprey life history stages should be a high priority for the CRB. Successful passage by adult lamprey is less than 50% at most projects within the CRB. The existing body of knowledge (Keefer et al. 2012a) strongly suggests that passage issues are limiting the distribution of Pacific Lamprey within their historical range, especially into productive habitats within the middle Columbia and Snake River basins.

5.5 Question 4.5 – Are Study Designs and Sampling Methods Coordinated Among Projects? Some proponents noted that key technical issues, such as sampling efficiency for juvenile lamprey during instream trapping, as well as our inability to tag juvenile life stage lamprey to obtain travel time and survival information, have yet to be resolved. Others did not, suggesting increased communication among groups is needed. The ISRP is therefore concerned that data may not be comparable between projects, or that critical information is lacking, e.g., juvenile travel time and survival.

Summary – Coordinating research and restoration actions for lamprey have improved tremendously. Regional partners are developing comprehensive research, monitoring, evaluation, and reporting strategies, improving and standardizing lamprey identification protocols, and working to collect and share distribution information in collaborative manner within the region.

As mentioned in the Synopsis (CRBLTWG and CBFWA 2012), coordinating research and restoration actions for lamprey have improved tremendously. Regional partners are developing comprehensive research, monitoring, evaluation, and reporting strategies, improving and standardizing lamprey identification protocols, and working to collect and share distribution information in collaborative manner within the region. Described below are select regional efforts aimed at strengthening communication and collaboration in relation to study designs, sampling methods, and research, monitoring, and evaluation strategies.

5.5.1 Framework for Pacific Lamprey Supplementation Research

The CRITFC, its member tribes, and other partners developed a Framework for Pacific Lamprey Supplementation Research (Framework) in the Columbia River Basin (CRITFC 2014) which is intended to initiate the development of a regionally coordinated and long-term research monitoring, evaluation, and reporting plan directed towards supplementation and recovery actions for Pacific Lamprey within the CRB. Additionally, the Framework intends to "standardize" key elements of supplementation RME and reporting so that findings associated with status and trends and other important objectives can be

reported in a common and consistent format. Finally, the Framework provides specific guidance for the future development of Subbasin Supplementation Research Plans.

5.5.2 Master Plan for Pacific Lamprey Supplementation, Restoration, and Research

The Master Plan for Pacific Lamprey Supplementation, Restoration, and Research (Master Plan), being developed by CRITFC and two of its member tribes (YN and CTUIR), 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, the Agreement, the Framework, subbasin plans, and the Columbia Basin Fish Accords within a feasible, cost effective, and biological conservative manner.

The Master Plan intends to use adult translocation, as well as the structured, strategic, and phased release of artificially reared Pacific Lamprey, as a way to reintroduce, augment, and/or supplement Pacific Lamprey within select CRB subbasins to achieve the stated, long-term goals identified in various lamprey planning documents and restoration efforts. The long-term restoration goals guiding the development of this Master Plan are derived directly from the Vision and Goal of the TPLRP (CRITFC 2011). The Master Plan intends to support the TPLRP Vision and Goal by implementing supplementation actions aimed at restoring Pacific Lamprey in areas where they have been extirpated or substantially reduced.

5.5.3 Lamprey Occupancy Modeling

To reach a common understanding on lamprey occupancy sampling approaches (e.g. core variables, standardized methods), the USFWS hosted workshops in July and October of 2014 to convene partners that are conducting lamprey distribution surveys throughout the CRB. The purpose of the workshops was to integrate a statistically defensible approach of lamprey occupancy sampling, developed by the USFWS, into existing larval lamprey sampling programs. Participants in the workshop reached a common understanding of the occupancy sampling approach. Sampling for Pacific Lamprey can be focused on three spatial scales to assess conservation progress regionally, by watersheds, and for specific conservation actions. The three recommended scales were (1) RMUs, (2) 4th Field HUC, and (3) finer scale analysis units within each 4th Field HUC. The first two levels focus on evaluating changes in distribution at those spatial scales. The third level informs finer scale issues such as effectiveness of restoration actions or informing our knowledge on detection probabilities for lamprey for the sampling methods (focusing on electrofishing approach for larval lamprey). Most of the workshop discussion revolved around how the proposed USFWS sampling approach could be applied at smaller scales (third level) and how it could be integrated seamlessly in existing programs without undue burdens.

Since the 2014 workshop, a small workgroup has been working to reach regional consensus on topics such as electrofishing techniques, defining proper scale for occupancy analysis, identifying “core” fish metrics (e.g. length, weight, life stage, tagged/untagged, condition, etc.), refining fish identification protocols, defining the term “occupancy”, and developing “core” reporting metrics for occupancy sampling.

5.5.4 CRBLTWG Pacific Lamprey Passage Standards Subgroup

The lamprey passage subgroup has been working to develop passage metric standards for adult lamprey through a phased approach. These three phases are (1) identify potential research metrics that quantify indirect or direct effects on survival and fitness of juvenile and adult Pacific Lamprey related to up- or downstream passage, (2) determine which of the above-listed metrics are measurable with scientific rigor and quantify effects of biological relevance, and (3) develop and recommend basin-wide passage standards or objectives for metrics deemed as measurable and biologically relevant in Phase Two. The subgroup has completed the first two phases of this effort and is in the process of completing the third phase; however, varying objectives, tagging methods, and funding availability between the USACE, Federal Energy Regulatory Commission (e.g. Mid-Columbia PUDs), and other projects have made it difficult to complete phase 3.

The subgroup is currently working to update the Passage Metrics and the supporting summary *Run Characteristics, Current Distribution, and Efforts to Improve Passage of Adult Pacific Lamprey in the Columbia River Basin, 2011* document (Pacific Lamprey Technical Workgroup Passage Standards Subgroup 2011), proceed with modeling exercise(s) to conceptualize the scale of effort needed to measure scientifically defensible and estimate ecologically viable passage levels, use best passage metrics measured to date as the standards for all dams, and use the existing variability in measured metrics to identify generally “good” performance levels at the current standard.

5.5.5 CRBLTWG Tagging Subgroup

The lamprey tagging subgroup was developed to provide an updated database describing tagging studies conducted to date on juvenile, larval, and adult Pacific Lamprey. To date, the various types of tags that have been identified for monitoring lamprey are half/full duplex PIT-tags, all types of PIT-tags, downsized acoustic tags for juveniles (in development), long life acoustic tags (in development), flexible long-life energy harvesting tags (in development), radio-tags, coded wire tags, visible implant elastomer (VIE), and thermal markers. The subgroup also aims to provide technical guidance based on research studies to help answer questions regarding impacts to fish resulting from tagging, limitations of availability of obtaining fish for research, time of year (water temperature considerations), types of tags to use based on fish size, best practices for tagging (tagging protocols), and limitations for subsequent fish detection. In the long-term, the subgroup wants to develop a searchable database that describes tagging studies conducted throughout the Pacific Northwest, help identify and prioritize studies that would most benefit from tagging studies, and evaluate impacts to juvenile and adult lamprey migrations from tagging studies.

5.5.6 CRBLTWG Genetics Subgroup

The lamprey genetics subgroup is developing a database describing environmental DNA (eDNA) studies currently ongoing or conducted to date on Pacific Lamprey. A best management practices document will ultimately be developed describing case studies and the benefits and limitations of this technology for determining lamprey distribution.

5.6 Question 4.6 – What are the Escapement Goals for Lamprey, Recognizing that Development of these Metrics is Difficult Because of Lack of Historical Information?

Summary – Escapement goals for Pacific Lamprey within the Columbia River have not been established. Overall CRB goals are presented in the TPRLP. Though developing escapement goals for lamprey may be an important long-term management tool, given the known passage issues in the mainstem and tributary environments, there remains a need to focus on improving the passage environment for lamprey at all life stages.

Escapement goals for Pacific Lamprey within the Columbia River have not been established but overall CRB goals are presented in the TPLRP (CRITFC 2011) based on historic population levels at Bonneville Dam – levels that were thought to be achievable with restoration efforts today (by 2035, 1,000.000 adults counted at Bonneville Dam). As previously stated in the Synopsis (CRBLTWG and CBFWA 2012), the complex life history of lamprey makes developing escapement goals using traditional methods (e.g. stock-recruitment indexes) difficult. The salmon paradigm of developing "optimum" or "sustainable" escapement goals to maintain sustainability may not be practical for Pacific Lamprey. Sustainability would first have to be defined and unfortunately, due to the combination of declining adult returns, limited data availability, as well as inconsistent and biased historical counts, the region does not have a clear understanding of how to accurately define lamprey sustainability. Despite some conflicting results (e.g. Lin et al. 2008; Hess et al. 2012; Spice et al. 2012), genetic studies generally corroborate the pattern that rates of gene flow are high among Pacific Lamprey, particularly in the Pacific Northwest. From the viewpoint of conservation management, Hess et al. (2012) emphasize that, although lamprey are capable of high levels of gene flow across most of their range, it is important to maintain "local" diversity (a suitable geographic area has not yet been described), primarily those adaptive genetic variants that have optimal fitness in localized conditions. At this point in our understanding, the Columbia River is being conservatively managed as one population.

Although prudent to manage the CRB as one population, tribes are restoring, monitoring, and/or managing lamprey in their respective ceded area streams (e.g. CTWSRO in the Deschutes River, CTUIR in the Umatilla River, etc.). Within the TPLRP (CRITFC 2011), the Tribes provided numeric restoration goals for the CRB (above Bonneville dam) based on historical returns. In the short-term, restoration goals could be derived from historical returns at existing monitored passage points (e.g. mainstem and tributary dams). However, from a tribal perspective, long-term goals may be better defined in terms of the availability of lamprey at all tribal usual and accustomed fishing sites within the CRB. This is adequately described in the TPLRP Vision with Pacific Lamprey being "widely distributed within the CRB in numbers that fully provide for ecological, tribal cultural and harvest values." In this way, lamprey returns are being managed both at the regional and range-wide scale, which makes sense biologically, as well as within the cultural constraints that are guiding the long-term restoration of Pacific Lamprey within the CRB.

Though developing escapement goals for lamprey may be an important long-term management tool, given the known passage issues in the mainstem and tributary environments, there remains a need to

focus on improving the passage environment for lamprey at all life stages. This would include increasing adult passage efficiencies at mainstem Columbia and Willamette River dams, which range from 22-70% (22-34% at Willamette Falls, Mesa et al. 2010; ~50% at Bonneville Dam, Moser et al. 2002a, 2002b; >70% at Priest Rapids, Wanapum, and Rocky Reach dams, Le et al. 2015) and obtaining a better understanding of juvenile passage and entrainment issues. Within the TPLRP, the tribes proposed an interim adult passage efficiency standard of 80% based on the best available passage information (e.g. 80% passage efficiency at The Dalles; Keefer et al 2012a). At this point, improving the passage environment for Pacific Lamprey is a higher priority than developing escapement goals given the previously described difficulties in developing these for Pacific Lamprey.

Alternative methods for determining escapement goals for Pacific Lamprey within the CRB may be appropriate (i.e. estimates based on spawning and rearing capacities within subbasins). It is expected that as existing CRB lamprey projects (see Table 4-1 through Table 4-3) gather data about larval abundance, presence and absence, rearing habitat, intrinsic habitat potential, and adult spawning habitat, this growing body of knowledge will allow the development of more analytical strategies for developing escapement goals.

5.7 Question 4.7 – What is the Status of Lamprey in Various Subbasins and Can a Comparison of Their Status Inform an Analysis of Limiting Factors?

Summary – Based on the USFWS Assessment, the Puget Sound/Strait of Juan de Fuca/Coastal Washington region was characterized as "rapidly declining". The Columbia River geographic groupings were characterized as "high risk", particularly in the Snake, Mid-Columbia, and Upper Columbia regions. The Coastal Oregon geographic grouping was classified "relatively lower risk" than those of the CRB. Most of the California geographic grouping was characterized as "extinct, possibly extinct, critically imperiled, or imperiled."

As systematic approaches have been widely applied for assessing lamprey (or other aquatic species with limited biological data) status and informing conservation, the USFWS applied this type of system to guide conservation planning for Pacific Lamprey within its Assessment (Luzier et al. 2011). The USFWS applied the NatureServe Conservation approach to collect a suite of factors to assess conservation by evaluating the risk of extirpation at discrete geographic groupings.

A modification of the NatureServe ranking system (Faber-Langendoen et al. 2009; Master et al. 2009) for discrete geographic units (primarily watersheds at the 4^{th} Field HUC, approximately 3rd Field HUC in California) was used to rank the risk to Pacific Lamprey relative to their vulnerability of extirpation (Figure 5-1). Data used to rank 4th Field HUCs consisted of updated information on population abundance, distribution, population trend, and threats. These relative ranks of risk were then summarized by regional area.

The Assessment used a modified suite of seven factors to assess the relative risk ranking of Pacific Lamprey by watershed throughout its range. The following seven factors were selected because of the ability to collect the required information for them over the majority of geographic populations:

- Rarity Category
    1. Range Extent (historic distribution)
    2. Area of Occupancy (current distribution)
    3. Population Size
    4. Ratio of Area of Occupancy to Range Extent
- Trends Category
    5. Short-term trend
- Threats Category
    6. Scope
    7. Severity
        - Passage
        - Dewatering and Flow Management
        - Stream and Floodplain Degradation
        - Water Quality
        - Harvest/Overutilization
        - Predation
        - Translocation
        - Disease
        - Small Effective Population Size
        - Lack of Awareness
        - Climate Change
        - Mainstem Passage (if applicable)

Though the application of the calculated rank scores from the Assessment were not used to determine conservation status, the ranks were used to evaluate relative risk among geographic population groupings from population attributes and threats. These relative rankings could then be used to systematically guide prioritizing potential conservation measures within a geographic grouping and among geographic groupings in a region.

Based on the USFWS NatureServe ranking approach, the Puget Sound/Strait of Juan de Fuca/Coastal Washington region was characterized as "rapidly declining", though risk calculations were only performed in a limited number of watersheds. The Columbia River geographic groupings were characterized as "high risk", particularly in the Snake, Mid-Columbia, and Upper Columbia regions. The Coastal Oregon geographic grouping was classified "relatively lower risk" than those of the CRB. Most of the California geographic grouping was characterized as "extinct, possibly extinct, critically imperiled, or imperiled." A risk assessment and query of ongoing and needed actions and research was conducted for Pacific Lamprey in the Alaska region. Comparatively, the use of adult translocation in some CRB tributaries (e.g. Umatilla River) has reestablished a "lamprey presence" and therefore provided an opportunity to collect abundance information in a location actively being restored.

The Assessment provides a risk assessment within all major basins throughout the range of Pacific Lamprey (Table 5-1 through Table 5-4). The Agreement, through its regional implementation planning

process, is systematically identifying limiting factors within these basins (see Table 5-6 through Table **5-10** for summaries from the Assessment).

5.8 Question 4.8 – Comparative Data on the Non-Anadromous Brook Lamprey Might Help Determine if Limiting Factors in the Ocean are Important for the Pacific Lamprey.

Summary – Resident lamprey occupancy data is currently being used to monitor and evaluate high-value spawning and larval rearing habitat, particularly in locations upstream of difficult or incomplete passage.

The Synopsis (CRBLTWG and CBFWA 2012) indicated that in stark contrast to the relatively panmictic genetic structure of Pacific Lamprey, resident Western Brook Lamprey exhibit fine scale genetic differentiation. Comparative data on the status and threats impacting resident lamprey could be helpful in determining the impacts of the ocean on Pacific Lamprey; however other threats such as passage issues affect anadromous lamprey more than resident lamprey. Resident lamprey occupancy data is currently being used to monitor and evaluate high-value spawning and larval rearing habitat, particularly in locations upstream of difficult or incomplete passage. In the Yakima Subbasin and other subbasins with resident lamprey species, the ratio of Pacific Lamprey to Lampetra species within long-term index sites have been used to compare and assess the success of translocation (Lampman et al. 2017a).

6 REGIONAL AND RANGEWIDE EFFORTS

Today, Pacific Lamprey return to the CRB at a fraction of their historical numbers. Despite the implementation of a variety of restoration efforts within the CRB, adult returns remain relatively low and as a result, the spatial distribution of Pacific Lamprey is confined to the lower portions of the CRB (Section 5.1). Pacific Lamprey do not appear to be recovering in the CRB and are at high risk throughout much of the region, particularly in the Snake River, the Mid-Columbia and the Upper Columbia Region (Section 5.1).

Pacific Lamprey face a multitude of threats (Section 5.2) at various life history stages (e.g. passage, dewatering and stream flow management, stream and floodplain degradation, small effective population, ocean conditions, climate change, water quality, harvest/overutilization, predation, disease, and lack of awareness). These threats vary in combinations and severities across the range of Pacific Lamprey (Section 5.7). This suite of threats has been collaboratively identified, evaluated, and updated through a variety of efforts since 1994 (Sections 3.1, 3.3, 3.7, 5.4). However, passage, dewatering and stream flow management, stream and floodplain degradation, small effective population, and lack of awareness are consistently identified as the primary threats to Pacific Lamprey (Section 5.2). Other threats such as ocean conditions, climate change, water quality, and predation, are also likely important however, due to limited information, their perceived role in lamprey declines in less quantifiable (Section 5.2).

6.1 Current State of Lamprey Science

Pacific Lamprey are of great importance throughout the CRB for cultural, spiritual, and ecological reasons (Section 1.2). Since the early 1990's, primarily due to tribal concerns of declining returns, lamprey restoration and research efforts within the CRB have gradually increased (Close et al. 1999). Various efforts have worked to identify and update threats, limiting factors, and critical uncertainties associated with lamprey restoration (Section 3). In 1999, the CTUIR developed a restoration plan for the Umatilla River (Close 1999) that focused on estimating lamprey abundance before and after adult outplanting, increasing larval abundance, determining reproductive success of adult outplants, estimating adult lamprey abundance in the Columbia River, and assessing artificial propagation (Section 3.2). In 2005, the CRBLTWG generated a prioritized list of critical uncertainties, based on expected biological benefit (Sections 3.1, 3.3). In 2009, Mesa and Copeland (2009) provided an updated list of critical uncertainties and research needs that included population status, systematics, passage at dams, culverts, screens and other structures, species identification in the field, and general biology and ecology. Since 2012, through the Lamprey Conservation Agreement (Section 3.13) and the development of Regional Implementation Plans (Section 3.16), general research needs have been collaboratively identified as mainstem and tributary passage monitoring, larval and juvenile distribution surveys, adult translocation and supplementation monitoring, larval and juvenile entrainment, screening, and dewatering research, and habitat restoration techniques for lamprey. In 2013, a workshop aimed at identifying emerging links and unknowns in the biology, research and management of lampreys, effectively summarized and updated critical uncertainties for CRB and West Coast Pacific Lamprey. Key research needs were identified as collecting accurate and fine-scale knowledge of distribution and occupancy, estimating relative abundance and estimating survival at each life stage, assessing limiting factors and the effectiveness of creative and applied solutions, and characterizing genetic population structure(s) of the species (Clemens et al. 2017; Section 3.16).

6.1.1 Passage

Throughout the research and restoration efforts since 1994, important advances have been made in understanding the factors contributing to lamprey declines. Passage for Pacific Lamprey continues to be poor at most mainstem and tributary dams and diversions (Section 2.3). For most mainstem Columbia River dams, adult passage efficiency is still less than 65%. Certain fishway segments, characterized by high velocities, right angles, vertical steps, confusing flows, and predators, are likely impeding lamprey migration (Section 2.3). It is generally understood that the difficult adult mainstem passage environment is limiting access to underutilized, high-value lamprey habitat within upper reaches of the Columbia and Snake River basins. The cumulative effects of the poor mainstem passage environment are most noticeable in upper reaches (e.g. upstream of Wells and Lower Granite Dams) in which available adult populations are reduced by > 90%. In general, passage by adults through mainstem dams appears to select for larger individual fish (Section 2.3) which suggests that the natural river system (e.g. with no barriers to migration) may have been more conducive to higher levels of genetic diversity accessing upper river reaches. Adult Pacific Lamprey have been observed recolonizing multiple rivers after removal of impassible barriers (e.g. Little White Salmon River, WA and Hood River, OR) which suggests that if adults are in proximity to accessible habitat, they can expand their distribution. However, in areas

where both Pacific Lamprey and resident lamprey species are largely absent (e.g. above Wells Dam), attraction for upstream migrating adults may be limited and natural recolonization may not happen as quickly as the aforementioned examples. In such locations and instances, adult translocation may be an important strategy for maintaining or reintroducing attraction cues for migrating adults.

6.1.2 Genetic Understanding

Based on studies of neutral population genetic structure –compared to salmonids– Pacific Lamprey appear to exhibit low genetic differentiation among geographic groups and their population structure reflects a single broadly distributed population across much of its range in the Pacific Northwest (Section 2). In general, lamprey can be loosely grouped genetically by large geographic areas (e.g. Vancouver Island, BC/Puget Sound; US West Coast/lower Columbia River; interior Columbia River; Northern BC). Adult Pacific Lamprey traits, primarily body size, were shown to be significantly correlated with the adaptive genetic divergence in the Columbia River. Specifically, adaptive genetic variants (Single Nucleotide Polymorphism (SNP) markers) were found to be associated with large adult body size, and large adults tend to migrate furthest into the interior Columbia River. While Pacific Lamprey appear to segregate per body length and upstream distance, they have low probability of spawning in their natal stream. A lack of natal-stream-fidelity appears to have allowed a sufficient level of gene flow throughout their range to homogenize the neutral variation of the population.

6.1.3 Marine Life History Phase

The marine phase of Pacific Lamprey is not well understood; however, due to their parasitic life history and the considerable growth of adults that occurs during this life phase, it likely plays an important role in abundance. Surveys from the Columbia River estuary indicate that lamprey adults are returning to freshwater earlier (e.g. March) and that juveniles are entering the ocean earlier (e.g. January) than previously understood (Section 2.1, Weitkamp et al. 2014). Distribution of lamprey throughout the Pacific Ocean is likely considerable as evidenced by the return of an adult lamprey, tagged in the Bering Sea, to the Deschutes River, OR (J. Murauskas, Anchor QEA, personal communication). Recent research suggests a close correlation of adult lamprey returns in the CRB with abundance indices of potential prey species that may be related to ocean conditions (Section 2.1, Murauskas et al. 2013). The mechanisms signaling mature adults to return to freshwater spawning areas have been hypothesized to include environmental cues (e.g. freshwater discharge and water temperature), changes in physiological condition (e.g. length), as well as gonadal maturation (Clemens et al. 2012b).

6.1.4 Awareness

Awareness of Pacific Lamprey declines and their important cultural and ecological roles within the CRB has improved dramatically in some areas (Section 5.3). A variety of groups throughout the region have increased their knowledge, understanding, awareness, and commitment to restoring and conserving lamprey (Sections 3.13, 3.16). Though the lamprey restoration paradigm has shifted in a positive direction, work remains. Many people within the general population are unaware that Pacific Lamprey exist within the CRB. Lamprey are often negatively associated with the invasive and nuisance Sea Lamprey of the Laurentian Great Lakes and more work is needed to help the public make the distinction between the two. While restoration projects have highlighted lamprey decline, helped to reestablished

cultural and ecological connections, and elevated regional awareness, additional outreach and education programs are critical to dispelling myths associated with the species and advancing regional and range-wide restoration efforts.

6.1.5 Translocation

Translocation of adult Pacific Lamprey has emerged as a potential strategy to maintain population segments while limiting factors such as passage and habitat restoration are being addressed (Clemens et al. 2017). Translocation has been successfully implemented since 2000, though well-designed post-reintroduction monitoring programs are imperative to documenting success (Close et al. 2009; Ward et al. 2012). Regional translocation efforts to date have resulted in the development of successful transportation and long-term holding techniques for adults (Ward et al. 2012). By monitoring the movements of translocated adults, researchers have been able to increase the knowledge of migration timing, adult passage behavior at low-elevation diversion dams, spawning behavior, and larval distribution (Jackson and Moser 2012; Grote et al. 2014; McIlraith et al. 2015; Clemens et al. 2017; Lampman et al. 2017a). Although monitoring and evaluation of these efforts have yielded substantial information about effectiveness and have contributed to critical life history information on lamprey, further monitoring is needed to investigate whether translocation can help increase the overall number of adults returning to the CRB.

Translocation has also resulted in successful spawning, and subsequently to increased numbers of larvae and juveniles (Ward et al. 2012). When combined with other restoration actions, steams receiving translocated adults have experienced an increase in the number of adults returning naturally (Ward et al. 2012; Jackson and Moser 2013).

6.1.6 Artificial Propagation

To prevent further decline and local extirpations of Pacific Lamprey, the Columbia Basin tribes and a consortium of partnering agencies have been developing artificial propagation and early rearing techniques since 2012. Artificial propagation programs have demonstrated success in producing larvae (Lampman et al. 2016c). Work to date has focused on developing the best methods and techniques associated with gamete holding, gamete fertilization, egg incubation and prolarvae holding, transportation of gametes and larvae, disinfection (adult broodstock, eggs, and larvae), and larval culture. Lampman et al. (2016c) provides the most up to date description of the best management practices, techniques, and protocols developed over the years for the artificial propagation and early rearing of Pacific Lamprey. In addition, Lampman et al. (2016c) describes specific protocols for all life stages including space requirements for larval and juvenile lamprey as well as the survival bottleneck life stage (identified as 1-3 months), during which prolarvae transition to burrowing first feeding larvae. Strategic monitoring of focused larval outplanting may yield insights into larval growth and survival rates, changes in morphology associated with metamorphosis, and migration behavior of larval and juvenile lamprey.

6.1.7 Water Quality and Contaminants

Pacific Lamprey are in contact with stream sediments throughout their ontogeny and sediment contaminants have the potential to influence individual physiological processes and population dynamics at multiple life history stages. The implications of contemporary and legacy contaminants have been demonstrated in several studies in the CRB (Section 2.8). Larvae grew very poorly and exhibited impaired burrowing performance in contaminated sediments (Unrein et al. 2016). Jolley et al. (2012) observed lower occupancy rates of larval lampreys in contaminated sites within the Willamette River. Nilsen et al. (2015) screened regional Pacific Lamprey tissues and observed concentrations of contaminants (pesticides, flame retardants, mercury, and DDT) that were high enough to be detrimental to individual organisms. Linley et al. (2016) analyzed Hg concentrations within the fine sediment and larval lamprey tissues. The concentrations in larvae from Lower Columbia River tributary mouths suggest that many of these fish may have experienced and/or continue to experience lethal and sub-lethal adverse effects from Hg that constrain population recruitment. Numerous contaminants, including PCBs, have been observed within adult lamprey collected at Willamette Falls and John Day Dam (Nilsen et al. 2015). Contaminants may also impair the pheromone perception of adult Pacific Lamprey (Smith 2012). Schultz et al. (2014b) suggested that water quality issues may impede passage of adult lamprey into tributaries. Tribal harvesters have also voiced concern over the potential health implications of contaminant accumulations in harvested adult lamprey (Sheoships 2014). Together these studies suggest that contaminants likely negatively impact Pacific Lamprey and might be involved in the decline (Nilsen et al. 2015).

6.2 Remaining Restoration, Research, and Monitoring Needs

6.2.1 Tribal Restoration Priorities

The CRITFC and its members developed the Tribal Pacific Lamprey Restoration Plan for the restoration of Pacific Lamprey in the CRB to numbers adequate for the basin's ecological health and tribal cultural use (CRITFC 2011; Sections 3.8, 5.4). The TPLRP addresses lamprey issues at the CRB scale, generally focused on the mainstem Columbia and Willamette Rivers and the issues affecting lamprey at these locations. Since initiation of lamprey restoration efforts, the CRITFC and its member tribes' lamprey projects have aimed to restore natural production of Pacific Lamprey to a level that will provide robust species abundance, significant ecological contributions and meaningful harvest throughout the CRB. Though the tribal lamprey projects have similar overall goals and objectives, threats to lamprey vary in combinations and severities among subbasins and ceded areas. As a result, tribal lamprey projects have been designed to best address their unique set of issues (Close 1999; Jackson et al. 2014; Baker et al. 2016).

The YN lamprey project has worked to reestablish lamprey in Ceded Area tributaries through adult translocation, developed best management practices and protocols for the artificial propagation of Pacific Lamprey, obtained a better understanding of passage issues and solutions in various subbasins, completed extensive status, trend, and exploratory surveys for larval and juvenile lamprey, and established a strong Pacific Lamprey outreach and education program through various activities (Table 4-1).

The CTUIR lamprey project has translocated ~6700 adult lamprey into high-value spawning habitat in the Umatilla and Grande Ronde river subbasins, monitored the increased distribution of larval lamprey and outmigration of juvenile lamprey in the Umatilla River, developed and implemented juvenile lamprey tagging technologies, completed extensive status, trend, and exploratory surveys for larval and juvenile lamprey in the CTUIR's Ceded Areas tributaries, identified and monitored adult passage barriers and obstacles utilizing radio-telemetry in the Umatilla River, designed and implemented lamprey passage structures to aid adult Pacific Lamprey passage in the Umatilla River, monitored increasing adult returns in the Umatilla River, assembled regional Pacific Lamprey disease related information, helped develop the best management practices and protocols for the artificial propagation of Pacific Lamprey, and established a strong Pacific Lamprey outreach and education program through various activities (Table 4-2).

The CTWSRO lamprey program has provided abundance and escapement estimates, estimated adult abundance and spawning habitat, evaluated status and trends and distributions of lamprey in CTWSRO Ceded Area streams, and refined larval sampling and habitat identification methods and techniques (Table 4-3). The CRITFC lamprey project has improved the understanding of migration characteristics, passage issues, and distribution/occupancy patterns of lamprey in the Willamette River, contributed to significant improvements in understanding lamprey genetics and population substructure of local, regional, and range-wide population segments, developed an improved baseline for water quality and contaminant accumulation in CRB lamprey, improved local and regional perceptions of Pacific Lamprey, and provided leadership in the development and implementation of alternative forms of restoration (Table 4-4).

The Nez Perce Tribe (NPT) lamprey project has translocated ~2500 adult lamprey into high-value spawning habitat in the Snake, Salmon, and Clearwater river subbasins, used next generation genetic monitoring techniques to evaluate adult translocation efforts, monitored the distribution of larval lamprey and outmigration in the Clearwater River, completed exploratory surveys for larval and juvenile lamprey in the NPT's Ceded Areas tributaries, provided guidance in identifying and prioritizing improvements to passage for lamprey at all life history stages, and established a strong Pacific Lamprey outreach and education program.

Based on regional and project specific results (Sections 4 and 5), the CRITFC member tribes aim to prioritize the following research and restoration objectives:

- Improve mainstem adult lamprey passage.
- Improve passage within the tributary environment.
- Develop and improve alternative passage routes and strategies.
- Develop, improve, and implement supplementation and restoration research activities.
- Continue to understand limiting factors and lamprey life history at all levels.
- Strengthen lamprey outreach and education.
- Continue to identify, evaluate, and monitor status, trends, and distribution of lamprey within the Columbia River Basin.

6.2.2 Range-Wide Themes for Restoration

Since 2012, through the Lamprey Conservation Agreement (Section 3.13), RIPs have identified programmatic themes for lamprey restoration across RMUs including, but not limited to (1) passage improvement (for both adults and juveniles), (2) habitat restoration for all life stages, (3) adult and juvenile supplementation research and actions, (4) contaminants research and reduction, and (5) climate change impacts. Key threats for the Upper Columbia were identified as mainstem passage, climate change, small population size, and dewatering and flow management. The highest priority threat in the Mid-Columbia watersheds is mainstem passage followed by climate change. The highest priority threat in the Lower Columbia watersheds is tributary passage, followed by dewatering and flow management, stream and floodplain degradation, and water quality. Passage and stream and floodplain degradation are the highest priority threats in the Willamette followed by dewatering and flow management and water quality.

Specific, high priority projects, falling under these programmatic themes, have been identified and prioritized in eleven RMUs to date. Most high priority projects identified are related to:

- Improving tributary and mainstem passage while restoring habitat.
- Improving distribution and abundance information.
- Implementing and evaluating supplementation efforts.
- Assessing contaminants in lamprey.

High priority proposed project categories vary among regions and watersheds within regions. High priorities in the Upper Columbia include tributary adult passage, reduction of juvenile entrainment in tributaries, and toxicological evaluations. High priority proposed project categories in the Mid-Columbia include characterization of juvenile outmigration, developing new sampling techniques for juveniles, development of screening criteria, and reduction of dewatering mortality. In the Lower Columbia, high priority project categories include tributary passage, stream and floodplain restoration, and toxicological evaluations. High priority proposed project categories in the Willamette region include side channel/backwater enhancement, floodplain enhancement to improve spawning and rearing habitat, and abundance and distribution surveys.

6.2.3 Freshwater Research Needs

Clemens et al. (2017) effectively summarized and updated critical uncertainties for CRB and West Coast Pacific Lamprey in which freshwater research needs were identified as (1) collecting accurate and fine-scale knowledge of distribution and occupancy, (2) estimating relative abundance and estimating survival at each life stage, (3) assessing limiting factors and the effectiveness of creative and applied solutions, and (4) characterizing genetic population structure(s) of the species (Section 3.16). Limiting factors were identified as barriers to passage (e.g. dams, culverts, and screens), habitat, dredging and excavation, dewatering, perturbations to water quantity and quality, lack of awareness, and established protocols. Clemens et al. (2017) proposed six conservation and restoration actions that can greatly benefit Pacific Lamprey as (1) removing passage barriers or providing adequate passage for Pacific Lamprey, (2) modifying diversion screens and facilities to deter impingement and entrainment of larval

and juvenile lamprey, (3) restoring and managing river habitats to promote the dynamic equilibria of natural, free-flowing river ecosystems, (4) minimizing losses due to dredging and dewatering, (5) educating citizens about the importance of lamprey, and (6) implementing best management practices to include lamprey in planning and implementation for instream work.

6.3 Path to Prioritization

Since 2008, the Accords' lamprey projects and others have worked to address a variety of issues for Pacific Lamprey in the CRB (CRBLTWG 2005; Luzier et al. 2011; CRITFC 2011) including improving mainstem and tributary passage, providing regional abundance and distribution information, conducting supplementation research (e.g. adult translocation and artificial propagation), describing lamprey population substructure, identifying high-value habitat types (e.g. migration, spawning, and rearing), providing tributary escapement estimates, and guiding contaminant and water quality research (Table 4-1 through Table 4-3; Figure 4-1 and Figure 4-2). Although the results from these projects have contributed to addressing key questions, the geographic scope of these projects is limited in comparison to the entire range of distribution of Pacific Lamprey. As a result, many critical uncertainties and threats in a variety of geographic areas remain unaddressed (Figure 4-1 and Figure 4-2).

Through the Pacific Lamprey Conservation Initiative, tribal, federal, state and local partners, including the Accords projects' proponents, are working collaboratively to identify, prioritize, and address local, regional and range-wide threats to Pacific Lamprey (Section 3.13). Prioritization of needed restoration actions for Pacific Lamprey is occurring within the CRB and throughout the United States range of lamprey through the implementation of the Lamprey Conservation Agreement and the Regional Implementation Planning process (Sections 3.13 and 3.16). The Agreement is implemented in 17 RMUs from Alaska to Southern California. Under the Agreement, partners in each RMU work collaboratively to develop a specific RIP. Each of the RMUs develops a RIP that identifies: 1) threats that affect lamprey; 2) existing restoration and conservation efforts; 3) conservation actions and research needs to address those threats; 4) high priority projects; and 5) potential funding for high priority projects in their Regional Management Unit (USFWS 2015).

Lamprey projects implemented as part of the Accords are implemented by tribes or the CRITFC, and focus on restoration of lamprey in ceded areas or other areas of particular importance to tribes ((Table 4-1 through Table 4-3; Figure 4-1 and Figure 4-2). Although the geographic scope of most of these projects is therefore limited in comparison to the distribution of Pacific Lamprey, they constitute a substantial portion of efforts dedicated towards lamprey. The Accord projects contribute substantially to regional efforts for lamprey restoration.

The RIPs are updated annually and proposals for high priority projects identified by RMUs are submitted to the Lamprey Conservation Team (LCT) for review. The LCT reviews RIPs and associated high priority projects for feasibility, stakeholder support and adherence to identified threats. Upon review and approval, the LCT forwards its recommended proposals to the Policy Committee to seek funds for implementation. The information provided by the RMUs and reviewed by the LCT contributes to a feedback loop to the Policy Committee to guide the Agreement (Figure 6-1).

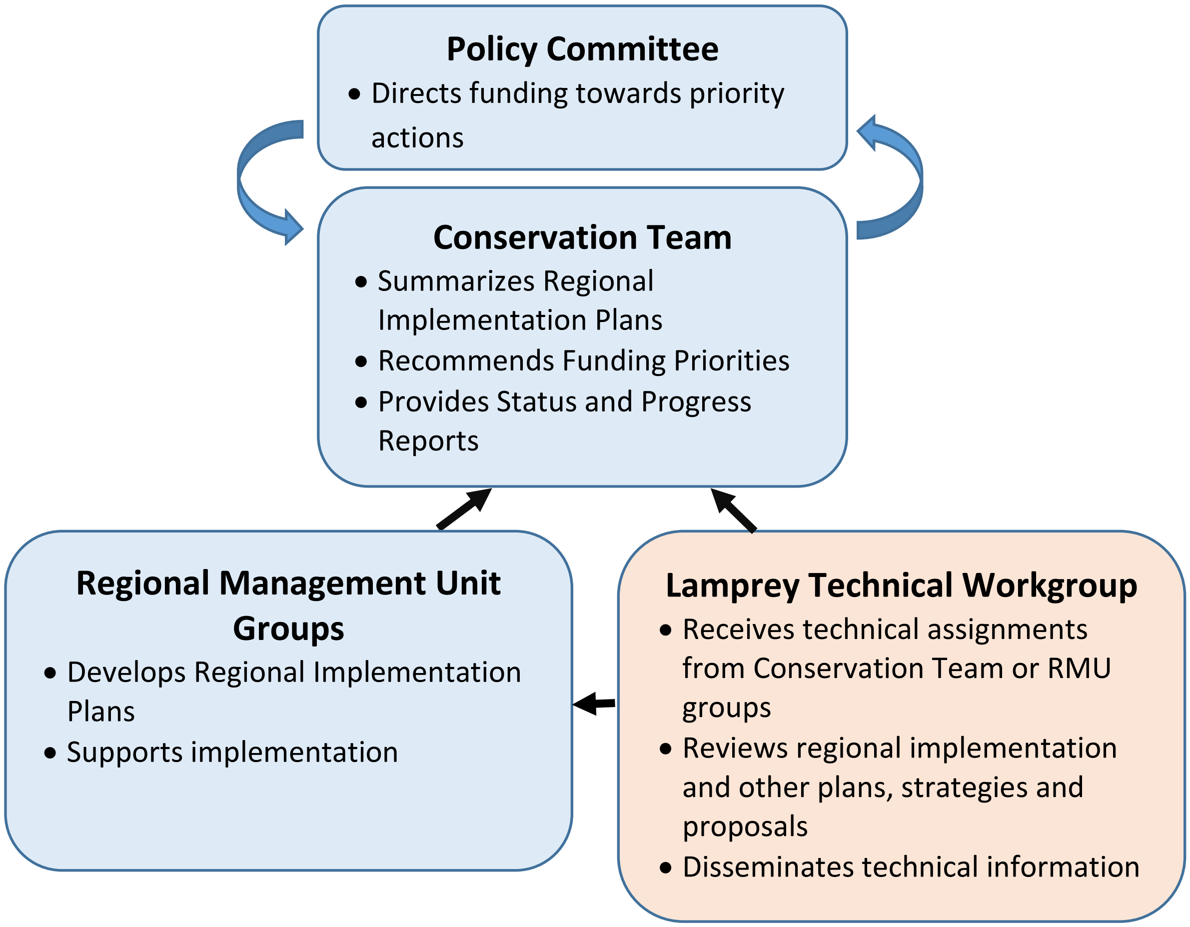

Figure 6-1. **Organizational and adaptive management framework for implementation of the Lamprey Conservation Agreement.**

The purpose of this process is to facilitate funding for high priority, regionally evaluated lamprey restoration and research actions that are currently unfunded. This process aims to work in parallel with other programs that are funding lamprey restoration and research (e.g., USACE Anadromous Fish Evaluation Program, Columbia Basin Fish Accords, NPCC Program). Projects that are already funded through other programs (e.g. Columbia Basin Fish Accords' projects) are not included in the RIP project prioritization process; however, information generated from existing efforts is critically important to this process. The intent of the RIP process is to collaboratively identify, prioritize, and address regional and range-wide gaps in lamprey restoration and research needs.

Many partners, including Accords project proponents, are already engaged in activities that address the priorities identified in RMU RIPs (Table 4-1 throughTable 4-3; Figure 4-1 and Figure 4-2). Among other things, improvements have been made to tributary passage through the construction of lamprey passage structures and barrier removal (Jackson and Moser 2013). Modifications of mainstem fish ladders have been made to accommodate lamprey passage through hydroelectric facilities (Keefer et al.

2012a). Lamprey habitat needs have been included in many salmon-focused restoration projects. Conservation hatchery practices continue to be developed and supplementation (e.g. adult translocation) has been implemented in areas at risk for extirpation (Ward et al. 2012). The development of a Pacific Lamprey data clearinghouse has made great advances with the inclusion of occupancy survey data throughout the entire range of Pacific Lamprey. In addition, the climate change vulnerability assessment is continuing to help inform prioritization of future conservation needs for lamprey (CRITFC 2011). Regardless, many gaps in lamprey restoration and research needs remain.

In short, the RIP process is exhaustive. All Accord Project proponents are highly involved in this collaborative process and the results of all Fish Accord projects (Table 4-1 throughTable 4-3; Figure 4-1 and Figure 4-2) are included in this process. The prioritization of high priority projects includes the identification of threats, existing projects (including Fish Accord projects), and remaining needs within Regional Management Units.

The Agreement RIP process provides a mechanism to prioritize actions and identify paths for completion. However, for the signatories and the supporters of the Agreement to achieve the objectives stated in the Agreement that mirror other efforts (USACE 2008; CRITFC 2011) – I.e. *The LCA parties envision a future where threats to Pacific Lamprey are reduced, historic geographic range and ecological role are re-established and traditional tribal harvest and cultural practices are restored* – regional and range-wide restoration will require continued collaboration among Fish Accord projects as well as all other stakeholders.

6.4 Conclusion

Pacific Lamprey are of great importance for cultural, spiritual, and ecological reasons. These fish face a multitude of threats at all life history stages which vary in combinations and severities across their geographic range. Although recent restoration and conservation efforts are helping in specific geographic locations, Pacific Lamprey do not appear to be recovering in many watersheds throughout the Columbia River Basin. Pacific Lamprey are at high risk throughout much of their geographic range which is particularly true in the Snake River, the Mid-Columbia and the Upper Columbia Regions. A variety of efforts have identified and updated threats, limiting factors, and critical uncertainties associated with Pacific Lamprey. Improving mainstem and tributary passage and habitat have been identified as the highest priority needs over the last 20 years of restoration and conservation efforts. A comprehensive and collaborative strategy to identify, prioritize, and address local, regional and range-wide restoration and research needs for Pacific Lamprey has been developed. However, for the supporters of Pacific Lamprey restoration to achieve their overall vision –

> *a future where threats to Pacific Lamprey are reduced, historic geographic range and ecological role are re-established and traditional tribal harvest and cultural practices are restored*

– consistent and long-term financial and collaborative support will be required. Leadership at all levels will be critical, which should include the CRITFC, its member tribes, as well as other tribal entities in close collaboration with all other stakeholders. The time to recover Pacific Lamprey is now.

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Appendix A. Pacific Lamprey Activities Summary Table (from Le et al. 2017)

Appendix Table A-1. Pacific Lamprey activities in the Columbia River Basin in 2016 (from Le et al. 2017).

	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 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).	CTWSR	Evaluate status and limiting factors of Pacific lamprey in the Deschutes River, Fifteen Mile Creek, and Hood River (Baker 2016a).
3.	Larval Lamprey Assessment	BOR projects in	Yakima	In 2015, PNNL and staff from the Yakama Nation conducted deep	PNNL	Larval Lamprey

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
		Yakima (Roza Dam)		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.		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 Fish Screening Facilities)	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 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.	PNNL and Yakama Nation	Larval Lamprey Assessment at Wapato and Sunnyside Fish Screening Facilities (DC Consulting LLC. And RP Mueller 2016).
5.	Conduct adult lamprey movement study using radio	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	USFWS	Personal communication with

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
	telemetry			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 Adult Fish Facility). Work on a final synthesis report is ongoing.		Ann Grote, USFWS (10/11/16) 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 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.	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 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	USFWS	Personal communication with Greg Silver, USFWS (10/6/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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.		
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 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.	USFWS	Personal communication with Greg Silver, USFWS (10/6/16)
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/m². About 100 small (< 20 mm) ammocoetes were observed at every sample site throughout	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
				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. 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 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	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
				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 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).	Yakama Nation	Personal communication with Ralph Lampman, Yakama Nation (12/4/16)
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	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
				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 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 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	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 Survey Length Requirements for Pacific Lamprey (Mayfield et al. 2014) The distribution and relative abundance of spawning and larval

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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.		Pacific lamprey in the Willamette River Basin (Schultz et al. 2014)
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).	NOAA Fisheries, CTUIR, Yakama Nation	Personal communication with Mary Moser, NOAA Fisheries (11/2/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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.		
18.	Lamprey artificial propagation	N/A	N/A	Since 2012, the Yakama Nation Fisheries in partnership with Confederated Tribes of the Umatilla 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.	Yakama Nation, CTUIR, NOAA Fisheries, USFWS	Personal communication 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)
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	CTUIR	Personal communication with Aaron Jackson, CTUIR (11/17/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				assessments (releases in the lower Umatilla River); and to support artificial propagation research occurring at the Walla Walla Community College, Water Environmental Center lab.		
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 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.	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)
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	Wells	Columbia	In 2015, Douglas PUD surveyed the Wells Reservoir for potential juvenile lamprey habitat and used backpack electrofishing to	Douglas PUD	Personal communication with

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
	presence/absence			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.		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 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.	University of Manitoba	Simple Genetic Assay Distinguishes Lamprey Genera *Entosphenus* and *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 associated more with low complexity, shallow riffle/run type habitats.	University of Idaho, Yakama Nation, CTUIR	Personal communication with Matt Dunkle, University of Idaho (9/28/2016)
28.	Pacific lamprey carcass decomposition and juvenile	No associated hydro project	Yakima, Umatilla	Lamprey carcass decomposition and benthic macroinvertebrate response was observed using video observation and sampling of	University of Idaho, CTUIR	Personal communication with

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
	salmon behavioral response			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.		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) 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.	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)
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	University of Idaho Cooperative Fish and Wildlife Research Unit	Adult Pacific lamprey migration behavior and survival in the Bonneville Reservoir

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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 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.		and Lower Columbia River Monitored Using the Juvenile Salmonid Acoustic Telemetry System (JSATS), 2011-2014 (Noyes et al 2015)
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 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,	USGS	Vulnerability of Larval Lamprey to Columbia River Hydropower System Operations – Effects of Dewatering on Larval Lamprey Movements and Survival (Liedtke et al. 2015)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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.		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 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	Personal communication with Ralph Lampman, Yakama Nation (12/4/2016)
35.	Juvenile lamprey data synthesis	Lower Granite, Little Goose,	Columbia and Snake	We compiled and summarized previous sources of data and research results related to the presence, numbers, and migration	USGS	Synthesis of Juvenile Lamprey Migration and

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
		Lower Monumental, Rock Island, McNary, John Day and Bonneville		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 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.		Passage Research and Monitoring at Columbia and Snake River Dams (Mesa et al. 2015)
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 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	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (10/25/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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. 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.	Douglas PUD	Personal communication with Chas Kyger, Douglas PUD (10/10/16)
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,	Yakama Nation	Personal communication with Ralph Lampman, Yakama Nation (12/4/2016)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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).		
	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. Although tours were again offered in 2015, participation has waned. Future tours will only include ladders with new modifications.	ACOE	Personal communication with Sean Tackley, 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, 2014 (Thompson et al. 2015).

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
						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)
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	PGE	Personal communication with Dan Cramer, PGE (09/29/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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.		
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. 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.	EWEB	Personal communication with Andy Talabere, EWEB (10/12/16)
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	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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 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)
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.	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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.		
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. The ACOE intends to field test this climbing structure in the Bonneville Dam Washington Shore Ladder in 2017.	NOAA Fisheries	Personal communication with Mary Moser, NOAA (11/2/16)
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	ACOE	Personal communication with Sean Tackley, ACOE (10/14/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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 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					
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	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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.		
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. 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.	CTUIR	Personal communication with Aaron Jackson, CTUIR (11/17/16)
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	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

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				areas were identified. A final report will be available by January 2017.		
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 – 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.	ACOE	Darren Gallion, Presentation at AFEP, Portland, OR (11/30/16)
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 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.	Chelan PUD	Personal communication with Steve Hemstrom, Chelan PUD (10/25/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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 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	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
				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. 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

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
						Steve 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), 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.	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).
	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	ACOE	ACOE Pacific lamprey passage improvements implementation plan,

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				be sure to include concerns for lamprey and adequate monitoring of lamprey predation in future efforts.		2008-2018 (ACOE 2009)
	Juvenile Passage at Hydroelectric Facilities					
	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 from the new locations as well. This is the current configuration and an ongoing action.	ACOE	Personal communication 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

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
						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)
	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 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).	PNNL	Daniel Deng, Presentation at AFEP, Portland, OR (11/29/16)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
	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 activities will indirectly benefit outmigrating juvenile lamprey throughout the project.	Grant PUD	Personal communication with Mike Clement, Grant PUD (10/12/16)
	Policy/Recovery Activities					
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	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
				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.		
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 **Error! Reference source not found.**).	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)
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	Grant PUD	Priest Rapids PLMP (Grant PUD 2009)

	Activity	Hydroelectric Project	Waterbody	Results / Description of Activity	Lead Entity(ies)	Source
				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.		
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 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.	USFWS	Personal communication with Christina Wang, USFWS (10/19/15)