Pacific Lamprey
2018 Regional Implementation Plan
for the
Upper Columbia
Regional Management Unit

Submitted to the Conservation Team August 26, 2018

Authors	
Ann Grote – US Fish and Wildlife Service	Paul Wagner – Colville Confederate Tribes
Ralph Lampman – Yakama Nation	Steve Hemstrom – Chelan County PUD
Bob Rose – Yakama Nation	Mike Clement – Grant County PUD
RD Nelle – US Fish and Wildlife Service	John Crandall – Methow Salmon Recovery Foundation
Barb Kelly-Ringel US Fish and Wildlife Service	

Projects proposed and discussed within this Regional Implementation Plan are in accordance with direction provided within the *Conservation Agreement for Pacific Lamprey in the States of Alaska, Washington, Idaho, Oregon and California, 2012.* Cooperative efforts through the Agreement intend to: a) develop regional implementation plans derived from existing information and plans; b) implement conservation actions; c) promote scientific research; and d) monitor and evaluate the effectiveness of those actions.

Projects identified in this Regional Implementation Plan do not imply or intend a funding obligation or any related activity from any of the government agencies, tribes or non-governmental entities discussed within this document.

I. Status and Distribution of Pacific Lamprey in the RMU

General Description of the RMU

The Upper Columbia Regional Management Unit (RMU) is defined as the tributaries to Columbia River from the Snake River to Chief Joseph Dam in which there are 15 4th Field HUCs (Figure 1). This Regional Implementation Plan (RIP) focuses on five subbasins of the Columbia River: Yakima, Wenatchee, Entiat, Methow, Okanogan rivers. The priority 4th Field HUCs from these major tributaries include: Lower Yakima (#17030003), Naches (#17030002), Upper Yakima (#17030001), Wenatchee (#17020011), Upper Columbia-Entiat (#17020010), Methow (#17020008), Okanogan (#17020006), Similkameen (#17020007). Crab Creek (#'s 17020013,17020015), the Chelan River (#17020009) and various smaller tributaries (Colockum-area streams and Foster Creek) are also included, but little information is available on lamprey presence in these subbasins (Table 1). Although historic Pacific Lamprey distribution likely extended into Sanpoil (#17020004), Colville (#17020003), and Kettle (#17020002) HUCs, these areas were excluded from consideration at this time due to existing anadromous passage barriers at Chief Joseph and Grand Coulee dams.

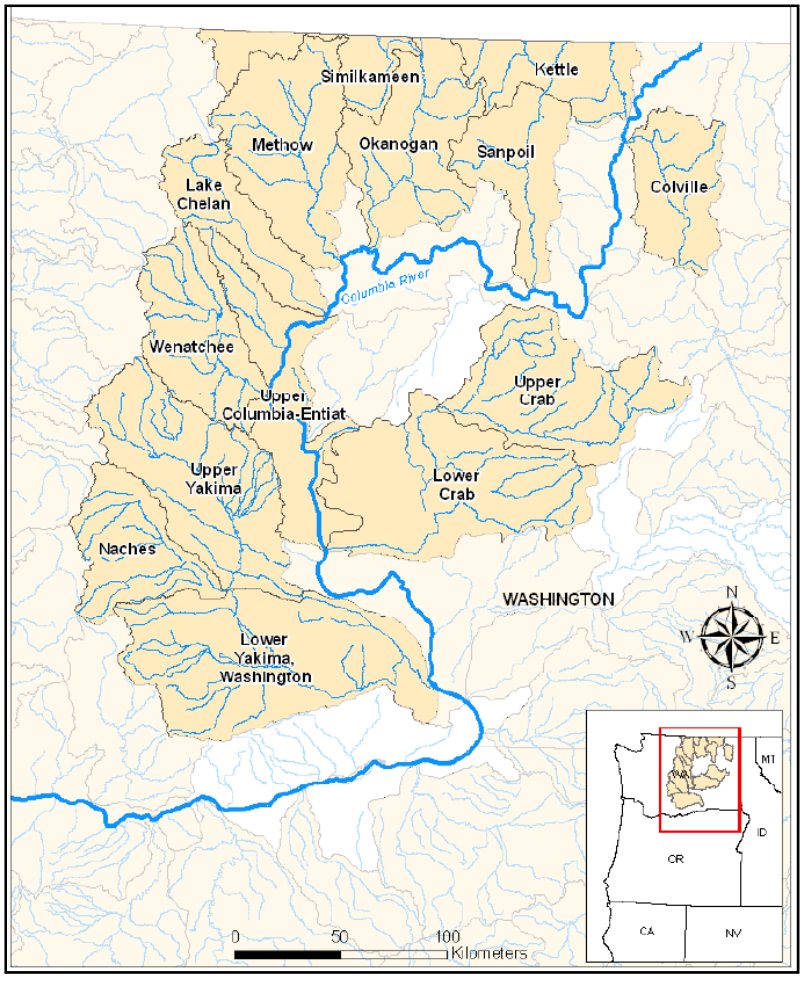


Figure 1: Map of the watersheds within the Upper Columbia Regional Management Unit.

Table 1: Drainage Size and Level III Ecoregions of the 4th Field Hydrologic Unit Code (HUC) Watersheds located within the Upper Columbia sub-unit.

Watershed	HUC Number	Drainage Size (km^2)	Level III Ecoregion(s)
Crab Creek	17020013,17020015	11,318	Columbia Plateau
Wenatchee	17020011	3,648	Columbia Plateau, North Cascades
Entiat	17020010	3,937	Columbia Plateau, North Cascades
Chelan	17020009	2,473	Columbia Plateau
Methow	17020008	4,714	Columbia Plateau, North Cascades
Okanogan	17020006	4,248	Columbia Plateau
Similkameen	17020007	1,735	Columbia Plateau, North Cascades
Upper Yakima	17030001	5,517	Columbia Plateau, Eastern Cascade Slopes and Foothills
Naches	17030002	2,927	Columbia Plateau, Eastern Cascade Slopes and Foothills
Lower Yakima	17030003	7,640	Columbia Plateau, Eastern Cascade Slopes and Foothills
Smaller Tributaries	--	2,512	Columbia Plateau

Status of Species

2017 Conservation Assessment and New Updates

Current Pacific Lamprey conservation status, distribution, and population information in the Upper Columbia RMU were updated in the 2017 Pacific Lamprey Assessment (Table 2). The 2017 Conservation Status Ranks changed in five HUCs: two improved and three declined (Table 2). Pacific Lamprey are still believed to be either Critically Imperiled (S1) or Possibly Extinct (SH), in all Upper Columbia RMU HUCs. Changes in status rankings largely resulted from real world declines in some subbasins, adult translocations in others, and implementation of an improved and more accurate approach to calculating historical and current range extent using steelhead intrinsic potential as a surrogate for absent lamprey distribution data.

Table 2: Population demographic and Conservation Status Ranks of the 4th Field Hydrologic Unit Code (HUC) watersheds located within the Upper-Columbia Region as of April, 2017. Steelhead intrinsic potential was used as a surrogate estimate of historical lamprey range extent in areas where historical occupancy information was not available. S1 = Critically Imperiled. SH = Possibly Extinct. Conservation Status rankings highlighted in yellow indicate a change in 2017 relative to the 2011 Assessment.

Watershed	HUC Number	Conservation Status Rank	Historical Occupancy (km^2)	Current Occupancy (km^2)	Population Size (adults)	Short-Term Trend (% decline)
Crab Creek	17020013, 17020015	SH	1000-5000	Zero	Zero	Unknown
Wenatchee	17020011	S1	1000-5000	20-100	250-1000	Stable
Entiat	17020010	S1	1000-5000	100-500	250-1000	Stable
Chelan	17020009	SH↓	Unknown	Zero	Zero	Unknown
Methow	17020008	S1	1000-5000	100-500	50-250	30-50%
Okanogan	17020006	SH↓	1000-5000	20-100*	1-50*	>70%
Similkameen	17020007	SH↓	<100	Zero*	Zero*	>70%
Upper Yakima	17030001	S1↑	1000-5000	20-100	1-50	Increasing (+ >10%)
Naches	17030002	S1↑	1000-5000	20-100	1-50	Stable
Lower Yakima	17030003	S1	1000-5000	100-500	250-1000	Increasing (+ >10%)
Smaller Tributaries	--	--	Unknown	Zero	Zero	Unknown

* The information and rankings listed above were current as of April 2017 and do not reflect August 2017 adult translocations to the Similkameen River and Okanogan/Columbia River confluence.

Across the Upper Columbia RMU, understanding of current Pacific Lamprey distribution has improved due to increased sampling efforts and use of additional survey methods (e.g. electrofishing, occupancy, eDNA sampling, smolt trapping, nest surveys, and adult passage counts). A compilation of all known larval and adult Pacific Lamprey occurrences in the Upper Columbia RMU are displayed in (Figure 2). Annual electrofishing surveys conducted by the Yakama Nation in the Lower Yakima (Beals and Lampman 2016a), Upper Yakima (Beals and Lampman 2016b), Naches (Beals and Lampman 2016c), Wenatchee (Beals and Lampman 2016d), Entiat (Beals and Lampman

2016e) and Methow (Beals and Lampman 2016f) HUCs were used to define the current distribution in those systems (Beals and Lampman 2018a), as was USFWS electrofishing data from the Wenatchee, Entiat, Chelan, Methow and Okanogan Rivers and Smaller Tributaries (USFWS, unpublished data).

Population abundance was updated in the Yakima, Wenatchee, Entiat, Methow, and Okanogan subbasins based on adult dam passage counts (Fish Passage Center, 2018). Spawner escapement of adult Pacific Lamprey to a tributary was estimated by subtracting the number of lamprey passing a downstream dam by the number passing the adjacent upstream dam and termed dam conversion number. Abundance estimates were also informed by adult translocation numbers. Beginning in 2011, the Yakama Nation translocated adult Pacific Lamprey collected at the downstream Columbia River hydroelectric dams to the Yakima, Wenatchee, and Methow subbasins (Table 3). In August 2017, the Colville Confederated Tribes also began translocations, releasing adults near the Okanogan/Columbia River confluence and into the Similkameen River downstream of Enloe Dam. (Note the CCT translocations occurred after the time period covered by the 2017 Assessment). Despite translocations, population status appears to be severely diminished and current adult escapement believed to be very low (zero to 1000) for all HUCs within the RMU.

Table 3: Summary of adult Pacific Lamprey Translocations to HUCs within the Upper Columbia RMU as of July, 2018.

Watershed	Translocation Years	YNF Translocated Adults	USFWS Translocated Adults	CCT Translocated Adults	Translocation Totals
Wenatchee	2016 - 2018	793	0	0	793
Methow	2015 - 2018	704	0	0	704
Upper Yakima	2013 - 2018	162	45	0	207
Naches	2013 - 2014	0	44	0	44
Lower Yakima	2011 - 2018	2214	164	0	2378
Columbia/Okanogan Confluence	2017 - 2018	0	0	49	49
Similkameen	2017 – 2018	0	0	124	124

Short-term population trend (defined as the degree of change in population size over 3 lamprey generations or 27 years), was ranked as using dam passage counts, dam conversion number and expert opinion (Table 2). Mainstem and tributary dam counts provide one of the only long term records of adult Pacific Lamprey numbers in the Columbia River basin. Despite data gaps and monitoring inconsistencies, counts of adult Pacific Lamprey at Bonneville Dam indicate a significant downward trend in abundance over time. Counts of adult Pacific Lamprey prior to 1970 averaged over 100,000 fish (1939-1969), while the recent 10 year average is 32,579 fish (USACE 2017). The 2017 adult returns countered the long term trend, as large numbers of adult lampreys were counted at Bonneville Dam (82,564) and across the region. The mechanisms behind the increased 2017 returns are not clear at this time, but may include: passage improvements, favorable ocean conditions, and increased larval production from translocations.

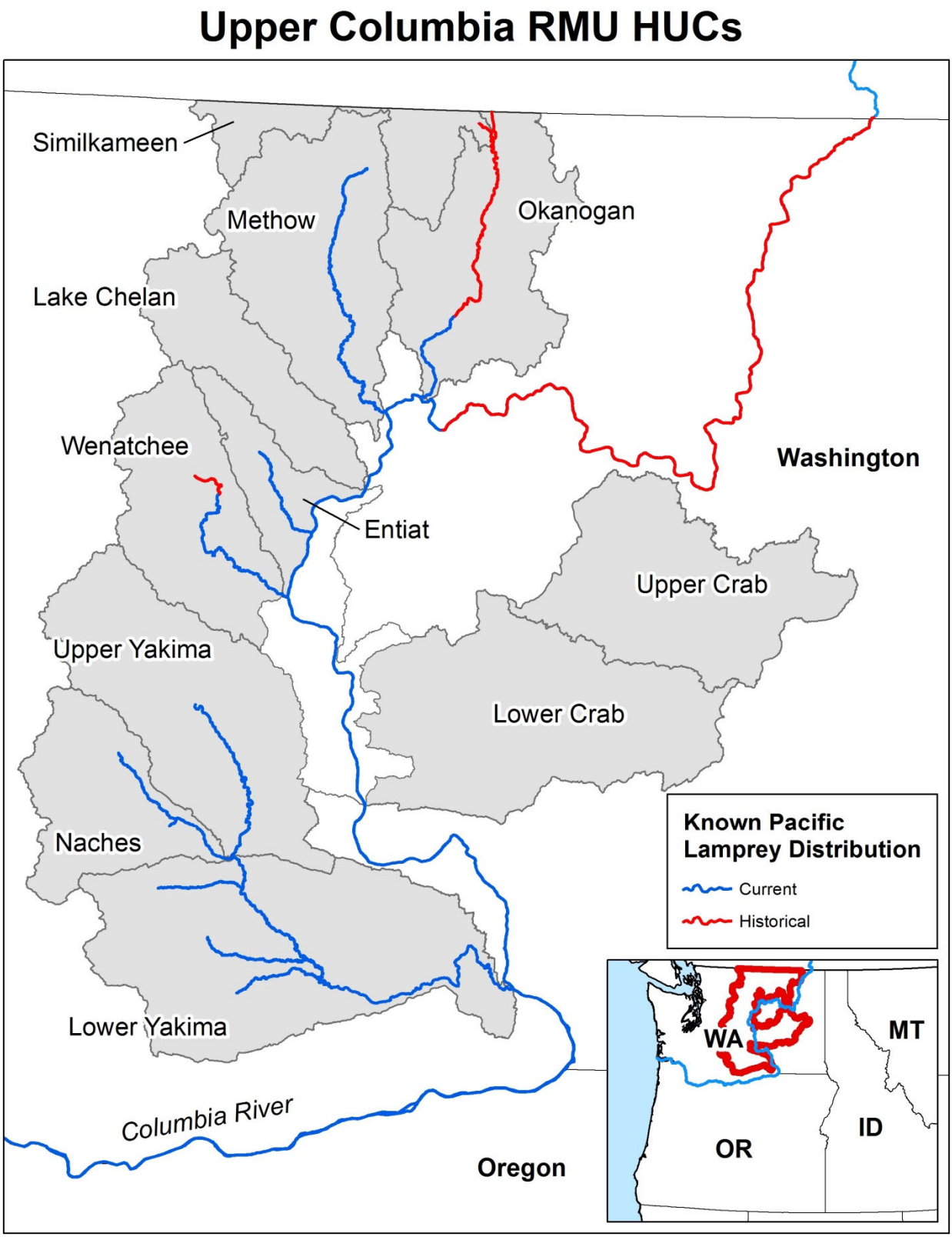


Figure 2: Current Pacific Lamprey distribution and location of 16 4th Field HUCs in the Upper Columbia RMU (USFWS Data Clearinghouse 2017).

Distribution and Connectivity

There are five hydroelectric dams on the Columbia River within the Upper Columbia RMU downstream of Chief Joseph Dam: Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells dams. Although the mainstem dams are outside of the purview of this RIP, it is important to note that the combined impacts from Columbia River dams have greatly reduced the number of adults that can contribute to the tributary adult escapement. Within the subbasins, there are also many irrigation dams and diversions used for a variety of purposes including hydropower, irrigation, water storage and fisheries management. The impacts to connectivity of these smaller tributary dams vary by structure and subbasin.

The Yakima River has multiple diversion dams on the mainstem and many more on its tributary streams. Based on radio telemetry studies, mainstem Yakima River diversion dams impeded Pacific Lamprey upstream migration with passage rates ranging between 0% and 82% (Johnsen et al. 2013, Grote et al. 2014, Grote et al. 2016). Cumulative passage through successive dams was very low, as less than 5% of adult lamprey successfully passed three or more of the lowermost diversion dams. No lamprey are known to have voluntarily passed Roza Dam (rkm 210.5). Prior to translocations, Pacific Lamprey were assumed to be functionally extirpated from the Upper Yakima HUC upstream of Roza Dam.

In 2017, two experimental Lamprey Passage Systems (LPS) were deployed on the right side of Prosser Dam. The LPS units are aluminum "vertical wetted walls" supplied with water via sump pump that terminate in a trap box. During 2017, Pacific Lamprey used one of the two structures to pass Prosser Dam, highlighting the importance of proper siting for the LPS entrance. Building on the successes and lessons from 2017, the unused LPS was relocated to the Left Island at Prosser dam in 2018, where a third LPS unit was also deployed. The current focus of this project is to: 1) site and install additional LPS units to the Center Island at Prosser Dam, 2) modify the existing LPS trap boxes to allow for volitional passage into the Prosser Dam forebay, and 3) refine and automate the video-monitoring system used to produce passage counts.

In the Wenatchee River, Pacific Lamprey were historically documented upstream of Tumwater Dam (49.6) in Lake Wenatchee and the upper mainstem, and likely occupied four large upper basin tributaries (Chiwawa, White, and Little Wenatchee Rivers, and Nason Creek). Extensive electrofishing surveys conducted from 2011-2016 identified Tumwater Dam, as the upper limit of lamprey distribution in the Wenatchee River (Beals and Lampman 2016d, Kelly-Ringel 2016, USFWS unpublished data). Adult lamprey passage at Tumwater Dam has not been formally evaluated. In 2017, for the first time in several decades, Pacific Lamprey were observed at the Tumwater Dam fish counting window (n =10). Incidental PIT detection data from translocated adults suggest lamprey passage is very rare; however the current PIT antenna array is not configured to estimate passage. Following the 2016 adult translocations, larval surveys detected ammocoetes for the first time in Wenatchee River between Tumwater Dam and Lake Wenatchee and in Nason Creek (Beals and Lampman 2017a). Genetic parentage analysis of these larvae is ongoing, and they are assumed to be the progeny of translocated fish. Dryden Dam (rkm 28.3) on the Wenatchee River is passable by lampreys but has likewise not been evaluated.

Distribution in the Entiat River is not limited by dams. Entiat River rotary screw trap counts of larval and juvenile lamprey have varied from close to 1,200 to just over 5,500 over the past 10 years (USFWS unpublished data). Larval lamprey are distributed widely from river mouth to upstream at

river km 46.4 (Beals and Lampman 2015e).

Migratory connectivity in the Methow HUC is generally better, although several structures have not been evaluated. Prior to adult translocation in the Methow subbasin, lamprey distribution was severely reduced and larval recruitment was absent or severely limited. Since translocation began in 2016, larval lamprey have been detected at most mainstem survey sites from mouth to Chewuch River confluence, and up the Chewuch River to rkm 23.9 (Beals and Lampman 2016a). In spring 2018, larval lamprey were captured for the first time in the Twisp River screw trap (John Crandall, personal communication).

In the Okanogan River, no lamprey were found during distribution work in 2015 (electrofishing) and 2017 (electrofishing and eDNA sampling) (USFWS unpublished data). Juvenile Pacific Lamprey were last observed at the CCT Okanogan screw trap in in 2010 (Paul Wagner, personal communication). In the Similkameen River, the Enloe Dam (rkm 8) has blocked all fish passage in since 1919/1920. In August 2017, CCT released adult Pacific Lamprey near the confluence of the Columbia and Okanogan rivers, and into the Similkameen River.

USFWS distribution surveys in the Chelan River, Colockum and LT Murray Wildlife Area creeks, and Foster Creek have not detected lamprey. Pacific Lamprey are believed to be absent in Crab Creek as recent electrofishing surveys detected no larvae (Timko et al. 2017).

Threats

Summary of Major Threats

Ranking of Upper Columbia RMU threats was based on the 2017 Assessment and further developed through information and consensus of the participating Upper Columbia RMU members at a conference call on August 9, 2018 (Table 4). Project prioritization in this RMU is based upon and consistent with the highest-ranked threats indicated in the Table.

Among the threats identified in the Upper Columbia RMU, some showed a pervasive impact in the entire region (Small Population Size, Stream and Floodplain Degradation). Other threats were more location specific, but nevertheless cause severe impacts to the local populations, such as Tributary Passage, Dewatering & Flow Management and Predation. Although Mainstem Passage is a key threat for this region, it was not included in the priority actions because the RIP is focused on the tributaries. As of 2018, there is a separate RIP for the Mainstem Columbia RMU, under which the ongoing mainstem passage impacts and improvements are addressed.

Small Population Size is the highest-ranked threat in the Upper Columbia RMU in 2018. Small Population Size is the cumulative effect from reduced mainstem dam passage and the other threats listed above. Small Population Size can result in a lack of pheromone attraction to migrating adults, inability of migrating adults to pass barriers en-masse, inability of spawning adults to find mates, the loss of functional ecological services provided by healthy larval populations, and potential for catastrophic loss of the local population from environmental perturbations. Current adult translocation programs throughout the RMU aim to combat this threat. However, conservation actions targeting the causal mechanisms behind diminished populations (poor adult passage, juvenile entrainment, etc.) will likely be needed to improve Upper Columbia Pacific Lamprey runs.

Table 4: Threats to Pacific Lamprey within the Upper Columbia RMU, as identified and ranked the at RIP conference call on August 9, 2018. H=3.5-4.0, M=2.5-3.4, L=1.5-2.4, I=≤1.4, U=No value

2017	Tributary Passage		Dewatering and Flow Management		Stream and Floodplain Degradation		Water Quality		Predation		Small Population Size	
Watershed	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
U. Columbia Drainages												
Crab Creek	-	-	(2)	(2)	(3)	(3)	(4)	(4)	(2)	(3)	-	-
Smaller Tributaries	(1)	(1)	(3)	(2)	(1)	(2)	(1)	(2)	(1)	(1)	-	-
Wenatchee	3	3	3	2	3	3	2	2	1	1	3	3.5
Entiat	1	1	2	2	3	3	2	2	1	1	2	2
Chelan	-	-	-	-	1	1	1	1	1	1	-	-
Methow	1	1	2.5	1	3	3	1	1	2	2	3.5	4
Okanogan	1	1	3	3	3	3	3	3	2.5	3	4	4
Similkameen	4	4	3	3	2	2	2	2	2.5	3	4	4
Yakima Drainages												
Upper Yakima	4	4	4	3	2	2	2	2	2	2	4	4
Naches	3	3	2	2	2	2	2	2	2	2	4	3
Lower Yakima	4	3	3	4	2	2	4	4	4	4	3	3
Upper Columbia RMU												
Mean Score	2.63	2.5	2.81	2.50	2.33	2.33	2.11	2.11	2.00	2.11	3.44	3.44
Mean Scope & Severity	2.56		2.66		2.33		2.11		2.06		3.44	
Drainage Rank	**M**		**M**		**L**		**L**		**L**		**H**	

Tributary Passage is a key threat in the Yakima, and Wenatchee subbasins as evidenced by radio telemetry (Yakima) and juvenile distribution surveys (Yakima, Wenatchee). Adult passage in the lower subbasins severely limits distribution into the upper watersheds. Prior to translocation, larval lamprey distribution of Pacific Lamprey stopped immediately downstream of Tumwater Dam (Wenatchee River) and Roza Diversion Dam (Yakima River). Counts from both of these dams also support the hypothesis that few to no adult lamprey currently move past these structures; counts at Tumwater Dam viewing window in 2017, indicate that some Pacific Lamprey adults (n = 10) did pass the fish ladder. How many attempts were made and the number of unsuccessful passage events is unknown, as lamprey passage efficiency at this facility has yet to be evaluated. The Okanogan River has several dams that have not been evaluated for Pacific Lamprey passage such as Zosel Dam and the Lake Osoyoos Control. The Enloe Dam on the Similkameen River has no fish passage structures and is impassable.

Dewatering & Flow Management was also identified as a key threat in the Yakima Basin but meaningful restoration actions will require large scale institutional changes involving water rights and salmonid management and is likely a long-term action. Many of these actions are being addressed within the Yakima Basin Integrated Water Resources Management Plan. Larval and juvenile entrainment in included in the Dewatering and Flow Management threat category. Larval entrainment has been examined extensively and intensively by the Yakama Nation within the Yakima Basin and Wenatchee Subbasin. Because of their small size, larval lamprey less than 80 mm in length were easily entrained past the existing fish screens which are designed exclusively for juvenile salmonids. Diversion waterways were also found to provide ample larval lamprey habitat. However, dewatering in the winter months severely impacts juvenile lamprey and their ability to survive or return back to the river.

Stream and Floodplain Degradation is a low to moderate threat in most RMU subbasins, as all of these systems have undergone extensive channel modifications. Along tributary mainstems, wetlands and side channels have been channelized, diked, diverted or drained to prevent flooding, create farmland or pastures, and provide land for commercial and residential development. In upland areas, historical and ongoing mining and timber practices, agriculture, road construction, and urbanization have deforested or altered the function and diversity of riparian vegetation. Owing to their complex, multi-stage life history, Pacific Lamprey require varied freshwater habitats (spawning gravels, well oxygenate permeable fines, etc.) that are often absent or lacking in highly-modified rivers.

Water Quality is considered a threat in some watersheds within the RMU, particularly the Lower Yakima and the Okanogan rivers. Summer water temperatures are a concern in both these systems, where warm water "thermal barriers" may persist at the river mouths and prevent migratory adults from entering. Concentrations of a wide variety of contaminants in lamprey tissue as well as larval lamprey habitat (fine sediment) was found to be severely high in the Yakima Basin based on a collaborative research by the USGS, CRITFC, YN, and PNNL. Pesticide and herbicide loads from agricultural runoff and irrigation returns are a concern throughout the RMU.

Predation from both invasive species (Smallmouth Bass, Largemouth Bass, Carp, Bullhead, etc.) and native species (Northern Pikeminnow, White Sturgeon, salmonids, River Otters, Pelicans, etc.) is likely higher than was initially identified. Predation is assumed to be especially problematic in areas where invasive species are more prevalent (as a result of stocking history, or altered hydrologic conditions) such as the Lower Yakima, Okanogan and Similkameen subbasins.

Restoration Actions

Tributary restoration projects have been implemented by numerous stakeholders and cover a wide range of activities including: installation of lamprey-specific passage systems at Prosser Dam, survival and outmigration monitoring of acoustic tagged macropthalmia, distribution and abundance surveys throughout the RMU, juvenile rescue and salvage operations, adult translocations, and artificial propagation. For a list of lamprey-focused restoration projects and the agencies involved, see Table 5. Within the mainstem Columbia River, restoration actions continue to be implemented by Grant, Chelan, and Douglas County PUDs at their respective hydroelectric dams. The majority of these efforts are focused on increasing adult fishway passage and improving detectability at counting stations. Owing to their location on the mainstem and not the tributaries, these actions fall outside of the RIP.

Table 5. Conservation actions specifically for or substantially benefitting lampreys that were initiated or completed in the Upper Columbia RMU from 2012-2018.

HUC	Threat	Action Description (Agency)	Type	Status
Okanogan	Population	Distribution surveys to evaluate larval lamprey presence in the main stem Okanogan River (USFWS, CCT)	Survey	Ongoing
Methow	Population	Distribution surveys to evaluate the upper extent of larval lamprey presence in the main stem Methow, Chewuch, and Twisp rivers (USFWS, YN, MSRF)	Survey	Ongoing
Chelan	Population	Distribution surveys to evaluate larval lamprey presence in the lower Chelan River (USFWS)	Survey	Complete

Table 5 Continued. Conservation actions specifically for or substantially benefitting lampreys that were initiated or completed in the Upper Columbia RMU from 2012-2018.

HUC	Threat	Action Description (Agency)	Type	Status
Entiat	Population	Nest surveys to evaluate spawn timing and distribution (USFWS)	Survey	Ongoing
Entiat	Population	Distribution surveys to evaluate the upper extent of larval lamprey presence in the main stem Entiat River and Mad River (USFWS, YN)	Survey	Ongoing
Wenatchee	Population	Distribution surveys to evaluate larval lamprey presence in the main stem Wenatchee River and tributaries (Peshastin Creek, Icicle Creek)(USFWS, YN)	Survey	Ongoing
Smaller Tributaries	Population	Distribution surveys to evaluate larval lamprey presence in the Colockum Plateau Streams and Foster Creek (USFWS)	Survey	Complete
Lower Yakima	Population	Distribution surveys to evaluate larval lamprey presence in the main stem Yakima River and tributaries (YN)	Survey	Ongoing
Upper Yakima	Population	Distribution surveys to evaluate larval lamprey presence in the main stem Upper Yakima River and tributaries (Wenas Creek, Teanaway River) (YN)	Survey	Ongoing
Naches	Population	Distribution surveys to evaluate larval lamprey presence in the main stem Naches River (YN)	Survey	Ongoing
Methow	Population	Translocate & release adult lamprey to (YN)	Supplementation	Ongoing

Table 5 Continued. Conservation actions specifically for or substantially benefitting lampreys that were initiated or completed in the Upper Columbia RMU from 2012-2018

HUC	Threat	Action Description (Agency)	Type	Status
Wenatchee	Population	Translocate & release adult lamprey (YN)	Supplementation	Ongoing
Lower Yakima	Population	Translocate & release adult lamprey (YN)	Supplementation	Ongoing
Upper Yakima	Population	Translocate & release adult lamprey (YN)	Supplementation	Ongoing
Naches	Population	Translocate & release adult lamprey (USFWS)	Supplementation	Ongoing
Okanogan	Population	Truck and release adult lamprey (CCT, GCPUD)	Supplementation	Ongoing
Similkameen	Population	Truck & release adult lamprey (CCT, GCPUD)	Supplementation	Ongoing
RMU	Population	Artificial propagation and larval rearing (YN, CTUIR, USFWS)	Supplementation	Ongoing (in lab)
RMU	Population	Genetic analyses of lamprey - tissue/eDNA (YN, USFWS, CRITFC, USFS)	Assessment	Ongoing
Wenatchee	Passage	Fish trap/forebay bypass operations at Tumwater Dam (CCPUD, WDFW)	Instream	Ongoing
Wenatchee	Passage	Fishway, count window, hopper modifications at Tumwater Dam (CCPUD)	Instream	Underway
Lower Yakima	Passage	Construction, operation, and evaluation of LPS units at Prosser Dam (USBOR, USFWS, YN)	Assessment	Ongoing
Lower Yakima	Dewatering /Flow Management	Acoustic telemetry and PIT tag assessment of juvenile lamprey downstream passage (YN, BOR, USGS)	Assessment	Ongoing

Table 5 Continued. Conservation actions specifically for or substantially benefitting lampreys that were initiated or completed in the Upper Columbia RMU from 2012-2018

HUC	Threat	Action Description (Agency)	Type	Status
Lower Yakima	Passage	Radio telemetry assessment of adult lamprey passage at Wanawish, Prosser, Sunnyside, and Wapato Dams (USFWS)	Assessment	Complete
Upper Yakima	Passage	Radio telemetry assessment of adult lamprey passage Roza Dam (USFWS)	Assessment	Complete
Naches	Passage	Radio telemetry assessment of adult lamprey passage Cowiche Dam (USFWS)	Assessment	Complete
Lower Yakima	Passage	Coordinate funding and design of LPS passage structures at Sunnyside and Wapato dams (YN, NRCS)	Coordination	Underway
Wenatchee	Passage	Investigate passage constraints for lampreys Tumwater Dam (CCPUD)	Assessment	Complete
Wenatchee	Dewatering/Flow Management	Monitore, salvage, and reduce mortality for larval/juvenile lamprey entrained at the Dryden irrigation diversion (CCPUD, USFWS, YN, WDFW)	Instream	Ongoing
Lower Yakima	Dewatering/Flow Management	Monitor, salvage, and reduce mortality for larval/juvenile lamprey entrained at multiple irrigation diversions/canals (YN, BOR, WDFW, Irrigation Districts)	Instream	Ongoing

Table 5 Continued. Conservation actions specifically for or substantially benefitting lampreys that were initiated or completed in the Upper Columbia RMU from 2012-2018

HUC	Threat	Action Description (Agency)	Type	Status
Upper Yakima	Dewatering/Flow Management	Monitor, salvage, and reduce entrainment for larval/juvenile lamprey entrained at multiple irrigation diversions/canals (YN, BOR, WDFW, Irrigation Districts)	Instream	Ongoing
Upper Yakima	Dewatering/Flow Management	Monitoring the impacts of "Flip-Flop" flow management in Yakima Basin	Assessment	Complete
Naches	Dewatering/Flow Management	Monitor, salvage, and reduce mortality for larval/juvenile lamprey entrained at multiple irrigation diversions/canals (YN, BOR, WDFW, Irrigation District)	Instream	Ongoing
RMU	Water Quality	Toxicology/ Contaminant levels of larval, juvenile, and adult lamprey (CRITFC, USGS, PNNL, YN)	Assessment	Complete
Lower Yakima	Lack of Awareness	Role of spawned out lamprey carcasses in Lower Yakima River tributaries (University of Idaho, Heritage University, YN, CTUIR, CRITFC)	Assessment	Complete
RMU	Lack of Awareness	Elder interviews on Pacific Lamprey - Traditional Ecological Knowledge (YN, Heritage University)	Assessment	Ongoing

Table 5 Continued. Conservation actions specifically for or substantially benefitting lampreys that were initiated or completed in the Upper Columbia RMU from 2012-2018

HUC	Threat	Action Description (Agency)	Type	Status
RMU	Lack of Awareness	Conduct outreach and provide educational opportunities (USFWS, YN)	Education	Ongoing
RMU	Lack of Awareness	Conduct lamprey identification training (YN, USFWS)	Education	Complete
RMU	Lack of Awareness	Developing lamprey tagging methods - VIE, PIT, Acoustic (USFWS, YN, USGS, PNNL)	Lack of Awareness	Complete
Lower Yakima	Predation	Lab study to investigate larval lamprey susceptibility to predators (YN)	Research	Complete

II. Selection of Priority Actions

A. 2017 Funded Projects

In 2017, Bonneville Power Agency funded a priority lamprey conservation project from the Upper Columbia RMU. Under this project, the dam owner (USBOR) is installing additional LPS units at Prosser Dam on the Yakima River. Contracting for the project is expected to be complete in August 2018, with construction over the winter and installation in March 2019.

B. Prioritization Process

Participating members of the Upper Columbia RMU met in met in August 2018 to discuss completed and ongoing conservation actions and identify specific projects and research needed to address threats and uncertainties within the region. Prioritization of projects is based on consensus by all participating members of the Upper Columbia RMU. Criteria used in prioritization include: (1) action will provide significant and persistent benefit to the subbasin population, (2) action is supported by all affected parties, and (3) action can and will be implemented contingent upon securing funding.

The following projects were submitted by RMU members for the Upper Columbia Regional Implementation Plan in 2018:

C. 2018 Priority Proposed Project Information

Project Title: Larval/Juvenile Supplementation Monitoring

Project Applicant/Organization: Yakama Nation Fisheries, Pacific Lamprey Project
Contact: Ralph Lampman
Email: lamr@yakamafish-nsn.gov
Phone: 509-388-3871

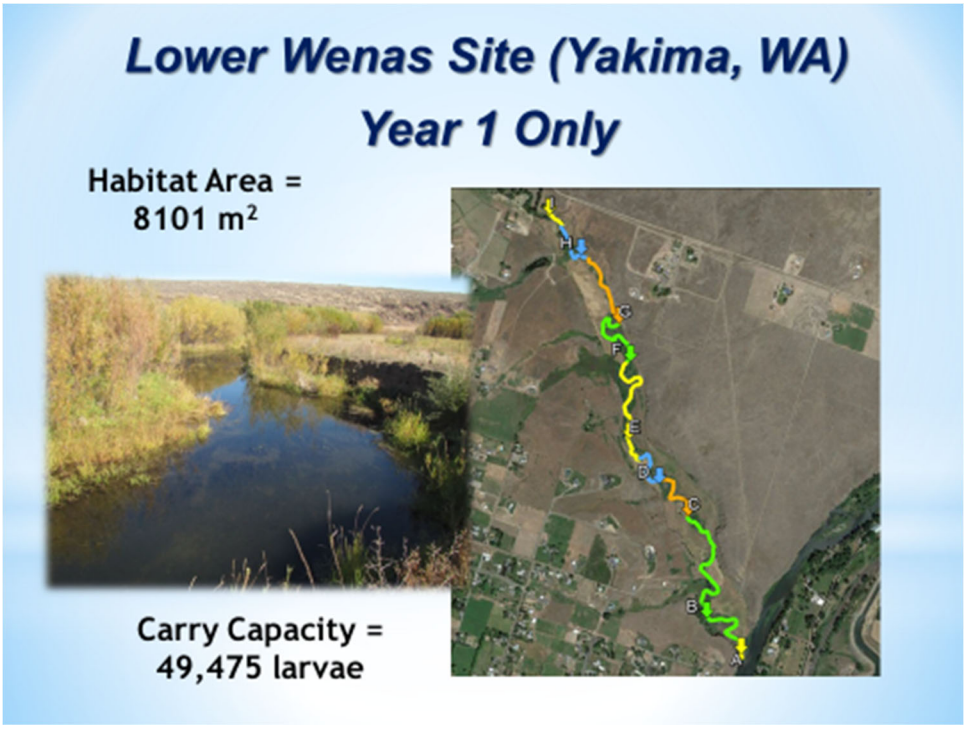
Landowner Organization/Contact Person (if different)**:** Bureau of Reclamation (Lower Wenas Cr.), Yakama Nation (Holmes Acclimation Pond and Cle Elum Hatchery Side Channel, Yakima R.), and Yakima County (Eschbach Park Side Channel, Naches R.)
Project Location: Wenas Creek, Holmes Acclimation Pond, Cle Elum Hatchery Side Channel, and Eschbach Park Side Channel
NPCC Subbasin (4th HUC Field) name: Upper Yakima (#17030001), Naches (#17030002)
Watershed (5th HUC Field): Wenas River (#1703000106), Taneum Creek-Yakima River (1703000105), Kachess River-Yakima River (1703000103), Tieton River-Naches River (1703000203)
Lamprey RMU population: Upper Columbia
HUC4 Risk Level: High

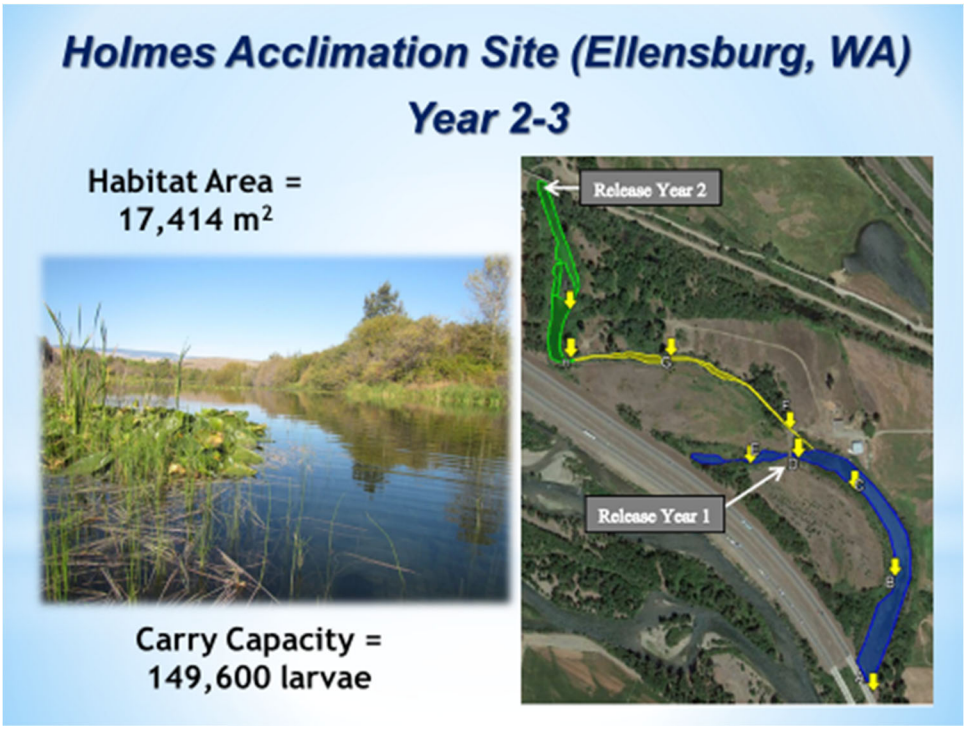
Requested funds: $33,000
Total Project cost (if different)**:** $208,213 = $33,000 (requested funds) + $175,213 (artificial propagation, larval rearing, and release)

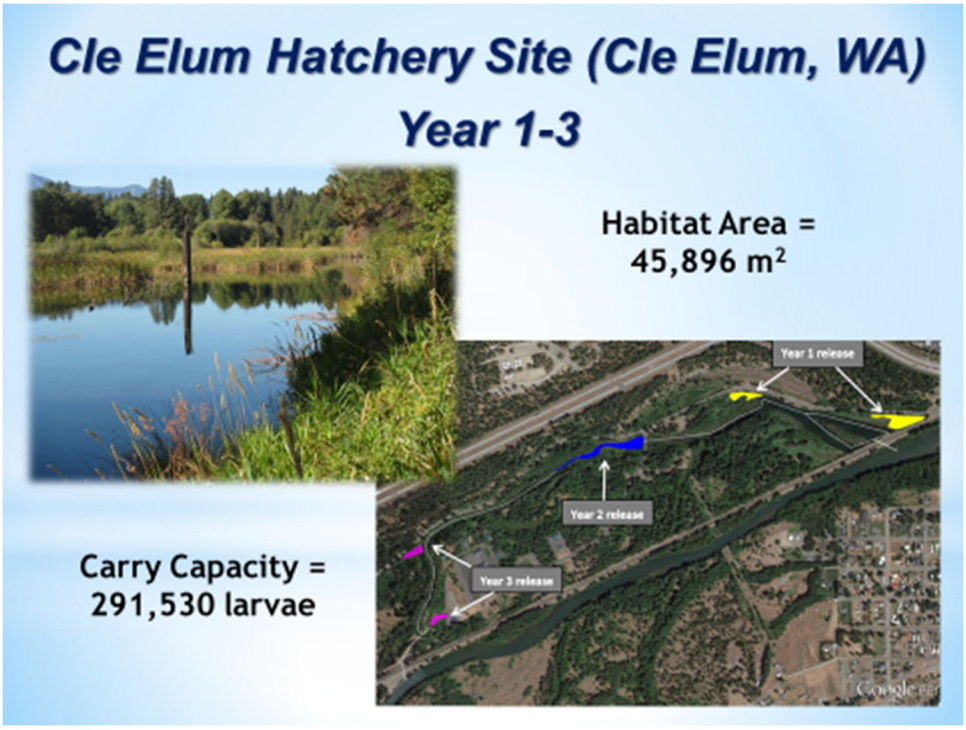
Short Project Description (200-word maximum):

The goal of this project is to monitor the survival, growth, and movement of artificially propagated larval lamprey released in four sites in Upper Yakima and Naches subbasins. BPA, the Independent Science Review Panel, and the Northwest Power and Conservation Council reviewed and recently approved the "Master Plan" (Pacific Lamprey Artificial Propagation, Translocation, Restoration, and Research) submitted by CRITFC, Yakama Nation, Confederated Tribes of the Umatilla Indian Reserve and the proponents are currently moving forward with the necessary environmental compliance and plans for the release. Upon implementation in 2019 (spring through fall), effectiveness monitoring would evaluate the success of larval outplanting using 1) parentage genetics, 2) enclosures for continuous monitoring, 3) VIE and PIT tagging a subset of the release group, 4) plankton net monitoring to assess emigration, and 5) electrofishing surveys in Index Sites and new exploratory sites, potentially including deep water sampling.

Descriptive Photographs-illustrations-Maps:






Cle Elum Hatchery Site (Cle Elum, WA)
Year 1-3
Habitat Area =
45,896 m2
Year 1 release
Year 2 release
Year 3 release
Carry Capacity =
291,530 larvae


Eschbach Park Site (Naches, WA)
Year 1-3
Habitat Area =
23,425 m2
3rd Year Outplanting
2nd Year Outplanting
1st Year Outplanting
Carry Capacity =
197,636 larvae

1.0 Detailed Project Description

The Master Plan describes ongoing and proposed adult translocation and artificial propagation activities, as well as identifies existing and proposed facilities needed to meet artificial propagation objectives. The goal of this plan is to evaluate the feasibility of using artificial propagation and translocation techniques to better understand and ultimately restore Pacific Lamprey throughout its range, with emphasis on the Columbia River basin population segment. Regional entities have indicated that supplementation related activities may be an important component in active lamprey restoration as well as in the evaluation of existing and emerging limiting factors.

Following a summary (Chapter 1) and introductory chapter (Chapter 2), Chapter 3**Error! Reference source not found.** provides a general overview of regional and range-wide lamprey declines as well as completed and ongoing lamprey restoration projects, specifically those that involve artificial propagation, translocation, restoration, and research activities. Chapter 3 focuses attention on the vision and goals of existing plans and assessments within the Columbia River basin, specifically the Tribal Pacific Lamprey Restoration Plan. Chapter 3 also summarizes the reasons why a Master Plan for Pacific Lamprey Artificial Propagation, Translocation, Restoration, and Research should be developed to address needs and objectives contained within existing plans and assessments.

Chapter 4 provides more detail describing the regional and tribal context for the proposed Master Plan. This chapter also includes background information about specific subbasins expected to be influenced by the Master Plan, describes the relationship to other lamprey restoration efforts, specifically Accord funded projects and processes, and describes supporting documents. Furthermore, this chapter presents the research efforts within a local and regional management context, and outlines the coordination with other entities and ongoing projects on a regional and subbasin scale.

Chapter 5**Error! Reference source not found.** describes in detail the proposed actions of the Master Plan through the CTUIR (199402600), YN (200847000), and CRITFC (200852400) BPA-funded Accord projects under the general guidance of the Tribal Pacific Lamprey Restoration Plan. Within Chapter 5, the proponents describe four distinct, overlapping phases of progress for the selected, preferred alternative over the next 10 years. Phase 1 is characterized as the initial efforts towards successfully propagating and rearing lamprey through the first 6-12 months of their life history. Phase 2 is characterized by the initiation and monitoring of a variety of lamprey reintroduction strategies. Phase 3 is characterized by the evaluation and analysis of the results obtained in Phases 1 and 2 as well as the potential development of a restoration strategy utilizing artificial propagation and translocation. Phase 4 is characterized by the implementation of the restoration strategy developed in Phase 3. Pacific Lamprey monitoring, research and evaluation efforts are also described in the context of seven biological objectives.

Chapter 6**Error! Reference source not found.** describes how the preferred alternative of this Master Plan is consistent with principles of the Council's Program and Chapter 7details the environmental compliance needs for the Pacific Lamprey program.

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. Despite relatively recent restoration efforts, Pacific Lamprey do not appear to be recovering and are at high risk throughout much of their range. 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. In addition, 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 and managers in the Columbia Basin.

Upper Columbia River tributaries, such as Yakima, Wenatchee, and Methow hold an abundance of low gradient, lamprey spawning and rearing habitat; however, current population segments are severely depressed in many of these tributaries (to the point that assessing limiting factors are impossible using wild fish).

Our primary goal is to reintroduce and supplement Pacific Lamprey larvae in currently extinct and functionally extinct subbasins within the Upper Columbia (primary focus is in the Upper Yakima and Naches subbasins). Adult translocation is on-going since 2012; Larval/juvenile lamprey supplementation is scheduled to take place within the Yakima Basin initially starting in 2019.

All the release sites that Yakama Nation Fisheries have proposed have an abundance of larval lamprey habitat (Type I) and we estimated these sites could sustain 49,000 to 290,000 larval lamprey (80 mm, 1 g larvae) (Fig. 1, 2, 3, and 4). Pacific Lamprey is currently absent in three of the four sites (Eschbach Park side channel on Naches R. has a small population) and similarly Western Brook Lamprey abundance is low or non-existent in most of the sites.

2.0 Regional Priorities: Linkage of actions to Identified Threats

- What threat(s) does this project address?
    - *"Small Population Size"*

- How does this project address this key threat(s)?
    - *Larval/Juvenile outplanting (through artificial propagation) is an alternative supplementation strategy to the adult translocation. Neither will fix the root problem for the "Small Population Size," but is a tool that may be useful now (or in the future) for furthering our understanding of Pacific Lamprey's early life history, limiting factors, and threats for these early life stage, and may be a useful tool for supplementation in some cases/scenarios. When adult counts are very limited (to the point that adult translocation options are limiting), the best management practices gained from the conservation hatchery and release experiments could become extremely valuable.*

- Does this project address a threat(s) specific only to this RMU or does the project address the threat(s) for multiple RMUs?
    - *"Small Population Size" is a condition increasingly observed across the species range (especially in the southern extent in California and Interior Columbia Basin). The knowledge gained here will be useful for supplementation projects across the species range.*

3.0 Project Goals/Objectives and Species/Habitat Benefits:

- What life stage or stages will benefit from action? How?
    - *Larval lamprey will initially increase directly as a result of the supplementation in the release sites. This may translate to increased larvae/juvenile further downstream as these lamprey migrate downstream. There may potentially be increased adult attraction to the subbasin or watershed as a result of increased larval pheromone, attracting adults to spawn in or near the release sites.*
- What other species may benefit from action?
    - *Potential direct and indirect benefits to other species (such as salmonids) through increased food sources (however, not the focus of our monitoring)*
- How will the project provide meaningful measureable results to improve lamprey populations and/or their habitat conditions?
    - *The primary goal, at least in the short-term, is to maximize our learning from the releases, rather than large scale supplementation. Questions include 1) how many of the larvae will emigrate from the release site and its relationship to habitat availability, 2) what will be the survival and growth rates in the newly occupied habitat, 3) how many of these larvae will survive and be detected at monitoring stations downstream (index sites, Chandler Juvenile Fish Facility, Lower Columbia hydro dams), and 4) what is the best lifestage (egg, prolarvae, larvae) to outplant early life stage lamprey for best survival and growth.*

4.0 Project Design / Feasibility

- Have the designs for the project been completed already or will they be completed before planned project implementation?
    - *The overall plans including artificial propagation and releases are outlined in detail in the Master Plan.*
- Are the appropriate permits (ESA and environmental compliance) in place already or will they be in place before planned project implementation?
    - *Yes, on schedule to be complete by 2018 / early 2019.*
- Can the project be implemented within the defined time frame?
    - *Yes, unless there is unforeseen administrative hurdles, the release can be completed by 2019.*

5.0 Partner Engagement and Support:

- What partners are supporting the project?
    - *Yakama Nation, BOR, BPA, WDFW, USFWS*
- What partners are active in implementing the project?
    - *Yakama Nation*

- What partners are providing matching funds or in-kind services that directly contribute to the project?
    - *BOR, BPA, Yakama Nation*

6.0 Monitoring and Evaluation – Contribution to Knowledge Gaps:

If this is a monitoring or evaluation project or an on the ground project with a monitoring or evaluation component:

- Is there a monitoring framework in the proposal?
    - *Yes, we are requesting funding to help complete as much monitoring as possible for the initial release events. See the description above as well as the "Master Plan" and "Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin" for more information.*
- Does the monitoring framework provide clear objectives and measureable metrics that can be observed over time?
    - The primary objectives/metrics are:
        - *What is the best early life stage to release lamprey (eggs, prolarvae, larvae)?*

- Does the framework provide a clear description of the expected outcome?
    - *Release of early life stage lamprey in four select release sites (three sites in Upper Yakima and one site in Naches)*
    - *Reintroduction and increase in larval lamprey abundance*
    - *Increased knowledge of the best early life stage for release (under various conditions)*
    - *Increased knowledge of the survival and growth of early life stage larvae*
    - Increased knowledge of the emigration rates and downstream migration behavior

If this is an on the ground project without a monitoring or evaluation component:

- How is completion of the project going to be documented?
    - *N/A*
- Is the project's effectiveness linked to another M&E project?
    - *N/A*

7.0 Budget and Timelines

Funding for the adult translocation work has been provided primarily by BPA funding. Artificial propagation is funded primarily by BOR and BPA, with some funding from Chelan County PUD (2016-2018). Funding is considerably limited for effectiveness monitoring for both adult translocation and larval/juvenile outplanting; approximately $33,000 is needed.

8.0 References (If Applicable)

See III. Literature Cited section at the end.

Project Title: Reduction of Larval/Juvenile Entrainment

Project Applicant/Organization: Yakama Nation Fisheries, Pacific Lamprey Project
Contact: Ralph Lampman
Email: lamr@yakamafish-nsn.gov
Phone: 509-388-3871

Landowner Organization/Contact Person (if different)**:** primarily Bureau of Reclamation (Yakima R.) and Chelan County PUD (Wenatchee R.) – smaller diversions owned by local irrigation districts
Project Location: Sunnyside Diversion, Ahtanum Diversions, and Dryden Diversion
NPCC Subbasin (4th HUC Field) name: Lower Yakima (#17030003), Wenatchee (#17020011)
Watershed (5th HUC Field): Deep Canyon-Yakima River (#1703000305), Ahtanum Creek (1703000301), Wenatchee River (1702001107)
Lamprey RMU population: Upper Columbia
HUC4 Risk Level: High

Requested funds: $62,630 = $41,630 (FVES) + $25,000 (Lamprey Sifter)
Total Project cost (if different)**:**
FVES: $761,730 = $41,630 (requested funds) + $720,100 (cost share)
Lamprey Sifter: $55,000 = $23,000 (requested funds) + $32,000 (cost share)

Short Project Description (200-word maximum):

The goal of this project is to implement the two best known solutions available currently within the Lower Yakima and Wenatchee subbasins for mitigating the effects of larval/juvenile lamprey entrainment. Entrainment of larval/juvenile lamprey is well documented and each year tens of thousands of lamprey are lost each year as a result. We propose to utilize Flow Velocity Enhancement System (FVES) to reduce entrainment and simultaneously increase passage through bypass facility at Sunnyside Diversion (or potentially other diversions that are conducive to the study, such as on Naches R. or Ahtanum Cr.). Another project is the creation and development of a lamprey sifter. Of the three conceptual designs, we propose to build two designs and test them in the field in 2019 (during irrigation dewatering or in river - such as dredging project areas).

Descriptive Photographs-illustrations-Maps:

Flow Velocity Enhancement System

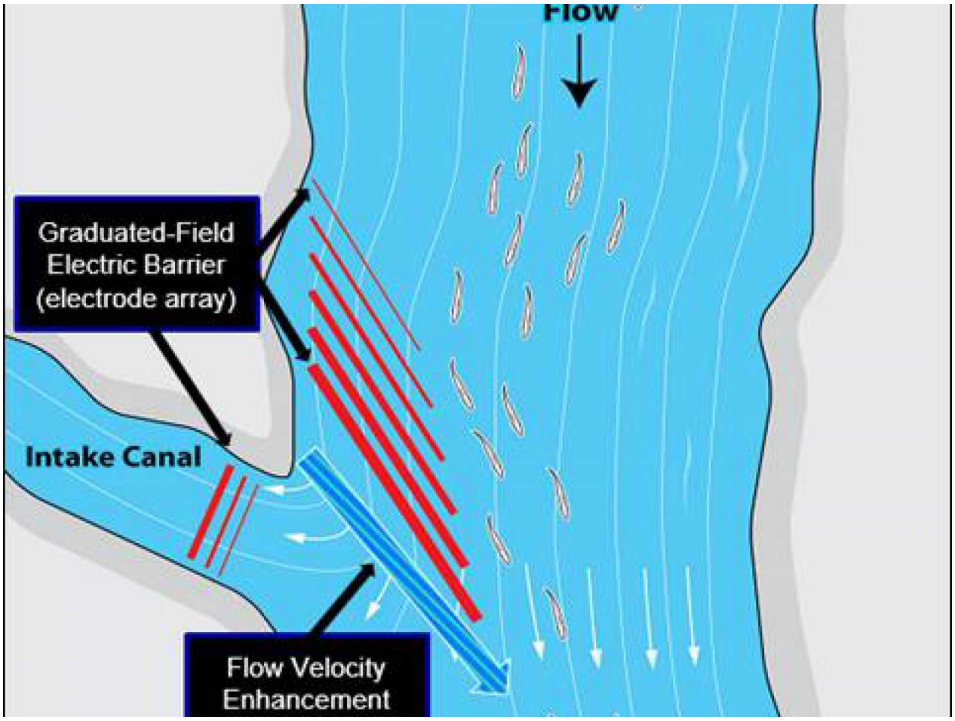


Figure 1. Conceptual GFEB+FVES hybrid technology deployed to exclude migrating fish from water intake structure and guide them safely downstream.

Figure 2. Surface view of a turbulent velocity plume in the upper Mississippi River from a FVES unit placed under the orange float at bottom of photo (low river flow from right to left).

Figure 3. Lamprey Sifter (pilot project in Wapatox Diversion, Naches River

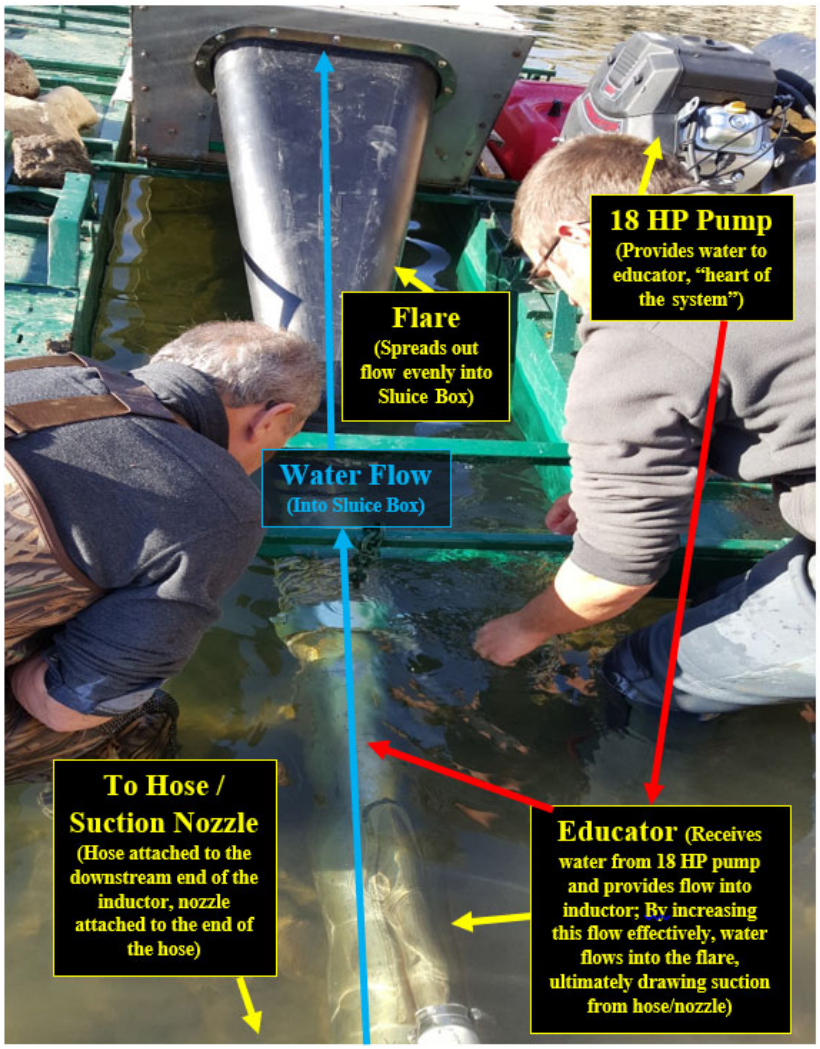


Figure 4. Overview of the venturi pump that was attached to the modified sluice box at Wapatox Diversion. The key components of the pump (18 HP pump, educator, and flare) are described in yellow lettering (locations highlighted with yellow arrows). The order of pump components used in the pump's operation, and direction of the water flow is highlighted by the red and blue arrows. The nozzle and hose (used for dredging the fine sediment) are not shown, but their location relative to the other components is shown.

Figure 4. Overview of lamprey sifter developed by Jordan Gold (Mari-Gold Environmental Consulting, Inc.) and used in California.

1.0 Detailed Project Description

Juvenile lamprey entrainment into various irrigation facilities within the Yakima Basin (primarily at Sunnyside and Wapato diversions, but also in smaller tributary diversions) and at Dryden irrigation diversion (Wenatchee Subbasin) is well documented and in many cases substantial - an estimate of 10,000~40,000 larvae annually entrained in some of these diversions (Beals and Lampman 2017b; Beals and Lampman 2017c; Beals and Lampman 2018b; Lampman 2018). Larval and juvenile lamprey are also very susceptible to dewatering impacts due to their natural inclination to burrow in fine sediment (Liedtke et al. 2015). Prevention of entrainment by screening is difficult due to the very small size of larvae/juvenile lamprey that enter diversion intakes. Replacement of existing screens (designed for juvenile salmonids) would be expensive and likely impractical because screen mesh size would need to be reduced significantly (<1 mm, less than half the size of current requirement) for significant reduction / prevention of larval lamprey entrainment (Rose and Mesa 2012). Screen technology is not currently available for fish below 60-80 mm size. A portion of the lamprey can be salvaged from these facilities using electrofishing or dredging; however, it is labor intensive, time consuming, and capture efficiencies can be low (especially when the abundance is high).

Flow Velocity Enhancement System (FVES; http://www.fishpassage.com) is a design developed by Natural Solutions – A Dam Site Better, LLC (Gordon Burns, President), and has been tested in the Columbia and Cowlitz rivers (as well as in other states and countries) and has partnered with PNNL and Smith-Root for implementation. Field visits have been completed by Gordon Burns and stakeholders and a conceptual design have been developed for Sunnyside Diversion for a system in front of the fish screens. Initial designs will be completed by 2018 and final designs will be completed by early 2019, pending funding availability.

A large sifter for fish salvage has been developed by Jordan Gold (Mari-Gold Environmental Consulting, Inc.) and have been used in the San Joaquin River delta and port of Stockton for several years (primarily for cutter head dredging) and improvements have been made over the years to enhance lamprey salvage. A smaller pilot lamprey sifter was tested in fall 2017 in Wapatox Diversion (Naches R.) through the help of Natural Solutions – A Dam Site Better, LLC, BOR, Yakama Nation, and WDFW. New conceptual designs have been developed based on these past field tests. Initial designs will be completed by 2018 and final designs will be completed by early 2019, pending funding availability.

Improvement work in smaller diversions, such as Bachelor-Hatton Diversion (Ahtanum Cr.), Diversion 14 (Ahtanum Cr.), and/or Wapatox Diversion (Naches R.), has advantages in that they are smaller diversions, making fine scale manipulation in the headgate and/or fish screen areas much easier and simpler. If there are any major hurdles in implementing the project at the large scale diversion (e.g. Sunnyside Diversion), one option would be to implement the project in a smaller scale diversion as a pilot project. However, priority will be given to the implementation in Sunnyside Diversion.

Mechanism of entrainment has been evaluated jointly by USGS/WDFW (in laboratory) and the YN (in the field) in recent years. The next logical step is to apply low-cost short-term solutions to mitigate these impacts.

The primary stakeholders in the Yakima Basin are the BOR, USFWS, WDFW the Yakama Nation and associated irrigation Districts. Each of these entities have remained in close coordination during the past 5-years of preliminary evaluations. Both BOR and the YN have been active in providing updated information to the irrigation Districts within the Yakima Basin. The same entities and CCPUD are the key stakeholders for Dryden irrigation facility. Considerable conversation associated with juvenile entrainment at Dryden is occurring with the partners, involving coordinated salvage efforts for dredging and dewatering.

2.0 Regional Priorities: Linkage of actions to Identified Threats

- What threat(s) does this project address?
    - *"Dewatering and Flow Management" & "Juvenile Entrainment"*
- How does this project address this key threat(s)?
    - Each of the identified diversions (as well as several other diversions within the region) entrain tens of thousands of lamprey each year, the majority of which are subject to desiccation and predation (especially if salvage actions are not taken in a timely manner). This project will greatly expand the tools available for reducing entrainment and mitigating the impacts from dewatering and dredging.
- Does this project address a threat(s) specific only to this RMU or does the project address the threat(s) for multiple RMUs?
    - *Larval/Juvenile entrainment and juvenile passage is a threat that exists throughout the range of the species, and has applications across the range of the species.*

3.0 Project Goals/Objectives and Species/Habitat Benefits:

- What life stage or stages will benefit from action? How?
    - *Larval and juvenile lamprey – by reduction in mortality through reduced entrainment and enhanced salvage during dredging and dewatering activities*
- What other species may benefit from action?
    - *Potential benefit to salmonid spp. (as a result of increased sweeping velocity)*
- How will the project provide meaningful measureable results to improve lamprey populations and/or their habitat conditions?
    - *Mortality associated with entrainment, dewatering, and dredging will be reduced using new methods (Flow Velocity Enhancement System and a few types of lamprey sifters). Pilot projects will be implemented to evaluate these unique tools and measures, including how they could be improved and refined to make them even more efficient and valuable.*

4.0 Project Design / Feasibility

- Have the designs for the project been completed already or will they be completed before planned project implementation?
    - *FVES is a design developed by Natural Solutions – A Dam Site Better, LLC (Gordon Burns, President), and has been tested in the Columbia and Cowlitz rivers (as well as in other states and countries) and has partnered with PNNL and Smith-Root for implementation. Field visits have been completed by Gordon Burns and stakeholders and a conceptual design have been developed for Sunnyside Diversion for a system in front of the fish screens. Initial designs will be completed by 2018 and final designs will be completed by early 2019, pending funding availability.*
    - *A large sifter for fish salvage has been developed by Jordan Gold (Mari-Gold Environmental Consulting, Inc.) and have been used in the San Joaquin River delta and port of Stockton for several years (primarily for cutter head dredging) and improvements have been made over the years to enhance lamprey salvage. A smaller pilot lamprey sifter was tested in fall 2017 in Wapatox Diversion (Naches R.) through the help of Natural Solutions – A Dam Site Better, LLC, BOR, Yakama Nation, and WDFW. New conceptual designs have been developed based on these past field tests. Initial designs will be completed by 2018 and final designs will be completed by early 2019, pending funding availability.*
- Are the appropriate permits (ESA and environmental compliance) in place already or will they be in place before planned project implementation?
    - *FVES - environmental compliance discussion was initiated in 2016-2017, working with NOAA Fisheries, USFWS, and BOR. This technology has been tested previously in the Cowlitz River with salmon smolts (Chinook) and proposals have been developed for new work in the Lower Columbia River hydro dams in partnership with PNNL (for enhancing bypass passage for salmonids). Environmental compliance for a pilot study in Sunnyside Diversion can likely be implemented in 2019, given funding and support.*
    - *Lamprey Sifter – if used downstream of the fish screens, there is no effect to other fishes. If used upstream of fish screens or in the natural rivers/streams, some levels of environmental consultation will be needed. However, species using the river bottom with fine sediment are limited and these sifters will provide a means to salvage those species as well. A pilot testing of the sifter can be easily approved in the project timeframe, given funding and support.*
- Can the project be implemented within the defined time frame?
    - *FVES - given close coordination with all partners (see below) and private consultants, a pilot project can be implemented within 2019 (spring – fall irrigation season).*
    - *Lamprey Sifter – two designs of pilot lamprey sifters will be constructed in 2019, and tested in fall 2019 (Dryden Diversion or others), given funding and support.*

5.0 Partner Engagement and Support:

- What partners are supporting the project?
    - *BOR, WDFW, Yakama Nation, USFWS, CCPUD, and BPA*
    - *There is high consensus within the RMU group that this project is high priority due to 1) the potential for high lamprey biological productivity within the Yakima Basin and Wenatchee Subbasin especially near the facilities of focus, 2) and the recent history of successful collaboration among the USFWS, BOR, WDFW, CCPUD, and Yakama Nation, and 3) the range wide impact of entrainment and this project's applications to other subbasins within and outside of the Upper Columbia RMU.*
- What partners are active in implementing the project?
    - *BOR, WDFW, USFWS, Yakama Nation*
- What partners are providing matching funds or in-kind services that directly contribute to the project?
    - *BOR, BPA, WDFW, USFWS, Yakama Nation*

6.0 Monitoring and Evaluation – Contribution to Knowledge Gaps:

If this is a monitoring or evaluation project or an on the ground project with a monitoring or evaluation component:

- Is there a monitoring framework in the proposal?
    - *FVES – there will be monitoring associated with the pilot project, using acoustic and PIT tagged juvenile/larval lamprey. Lamprey will also be monitored after dewatering.*
    - *Lamprey Sifter – number of lamprey salvaged will be enumerated and capture per unit effort will be monitored closely in comparison with other means of salvage.*
- Does the monitoring framework provide clear objectives and measureable metrics that can be observed over time?
    - FVES – objectives 1) ratio of lamprey entrained vs. passed through bypass, and 2) number of lamprey detected downstream of fish screens during dewatering.
    - *Lamprey Sifter – objective 1) increase the number of lamprey (all species and larval/juvenile size classes) salvaged at dewatered diversions and dredging projects, and 2) compare its efficacy with other means of salvage.*
- Does the framework provide a clear description of the expected outcome?
    - FVES – expected outcome is reduced entrainment through the fish screens and enhanced passage through the bypass at Sunnyside Diversion.
    - Lamprey Sifter – expected outcome is improved and enhanced salvage of larval/juvenile lamprey at dredging and dewatered diversion activities.

If this is an on the ground project without a monitoring or evaluation component:

- How is completion of the project going to be documented?
    - **N/A**
- Is the project's effectiveness linked to another M&E project?
    - **N/A**

7.0 Budget and Timelines

FVES

It is reasonable to estimate 2.5 weeks of project management associated with the planning, implementation, and monitoring of the FVES project (for BOR/USGS and Yakama Nation). Another 2.5 weeks is needed for on the ground support from technicians to support the implementation and monitoring (for BOR/USGS and Yakama Nation). The estimated cost for the subcontracting is $22,000. Additional funding is needed for operational support at the facility. There is a large amount of cost sharing involving the implementation of acoustic telemetry project (year 2 in 2019) and PIT tagging of larval/juvenile lamprey as well as various diversion salvage projects.

		# Hours or Units	Cost per Unit ($)	Funds Requested ($)	Cost Share ($)	Total ($)
a	**Personnel**	-	-	-	-	-
	i. Project Leader (BOR/USGS)	110	$75	$8,250	-	$8,250
	ii. Project Leader (YN)	-	-	-	$8,250	$8,250
	iii. Technician (BOR/USGS)	110	$35	$3,850	-	$3,850
	iv. Technician (YN)	-	-	-	$3,850	$3,850
b	**Travel**	-	-	-	-	-
c	**Equipment**	-	-	-	-	-
	i. Facility Support (BOR)	-	-	$3,000	-	$3,000
	ii. Acoustic Telemetry / PIT Array	-	-	-	$708,000	$708,000
d	**Supplies**	-	-	-	-	-
	i. Facility Support (BOR)	-	-	$1,000	-	$1,000
	ii. Tags (Acoustic, PIT)	-	-	-	$59,200	$59,200
e	**Subtotal**	-	-	$15,100	$720,100	$735,200
f	**Indirect Charges**	30%	-	$4,530	-	$4,530
g	**Subcontract**	-	-	$22,000	-	$22,000
h	**TOTALS**	-	-	$41,630	$720,100	$761,730

Lamprey Sifter will be constructed using a subcontractor ($23,000). Cost share will be provided through multiple agencies (Yakama Nation Fisheries, USFWS, and WDFW) working collaboratively on salvage activities at these irrigation diversions.

8.0 References (If Applicable)

See III. Literature Cited section at the end.

Project Title: Juvenile Passage in Lower Yakima / Columbia Rivers

Project Applicant/Organization: Yakama Nation Fisheries, Pacific Lamprey Project
Contact: Ralph Lampman
Email: lamr@yakamafish-nsn.gov
Phone: 509-388-3871

Landowner Organization/Contact Person (if different)**:** various landowners – Yakima R. diversion dams owned by Bureau of Reclamation, Columbia R. dams owned by ACOE
Project Location: Wapato, Sunnyside, Chandler, Horn Rapids dams and diversions, McNary, John Day, The Dalles, Bonneville dams
NPCC Subbasin (4th HUC Field) name: Lower Yakima (#17030003),
Watershed (5th HUC Field): Deep Canyon-Yakima River (#1703000305), Ahtanum Creek (1703000301), Wenatchee River (1702001107)
Lamprey RMU population: Upper Columbia
HUC4 Risk Level: High

Requested funds: $37,292
Total Project cost (if different)**:** $487,292

Short Project Description (200-word maximum):

The goal of this project is to continue the implementation of an acoustic telemetry project for juvenile (macrophthalmia) Pacific Lamprey in the Yakima (lower reach) and Columbia rivers. This project was implemented in 2018 spring as a result of partnership funds (for the salmon portion) and McNary Mitigation Funds (for the lamprey portion), and have demonstrated that the new juvenile lamprey acoustic tags (JLAT) developed recently by PNNL performs extremely well and triggered a high rate of detections between mid-reach of Yakima River and Lower Columbia River (>70% detected at John Day Dam from our release). We have arrays located in the mainstem Yakima as well as all major diversion canals (even downstream of the fish screens) to assess juvenile lamprey passage intensively in the Yakima as well as Columbia rivers. These arrays will be available to use for only two more years (2019-2020), so it is a rare and unique opportunity to learn as much as we can about the juvenile downstream migration in these systems, which will lead to restoration and changes in operation focusing on the most problematic areas for juvenile migration.

Descriptive Photographs-illustrations-Maps (if applicable)**:**

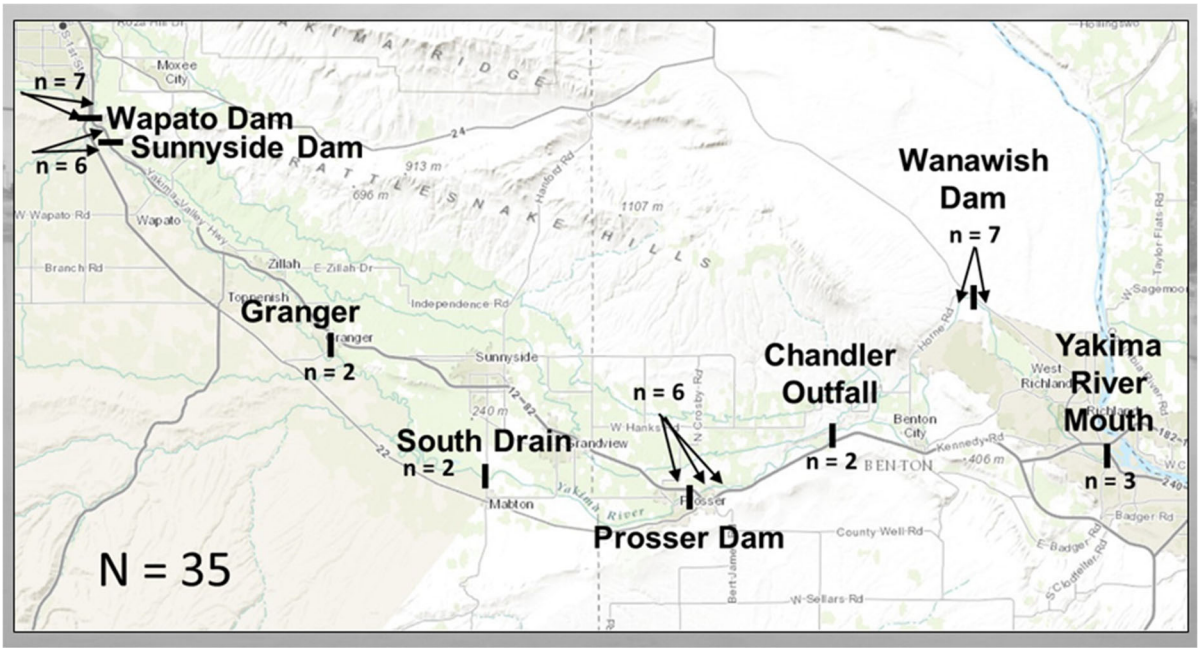


Figure 1. Locations where acoustic telemetry monitoring stations will be deployed for the YNF-USGS-BOR juvenile salmon study. The figure shows the number (n) of receivers at each monitoring location, and the overall (N) number of receivers.

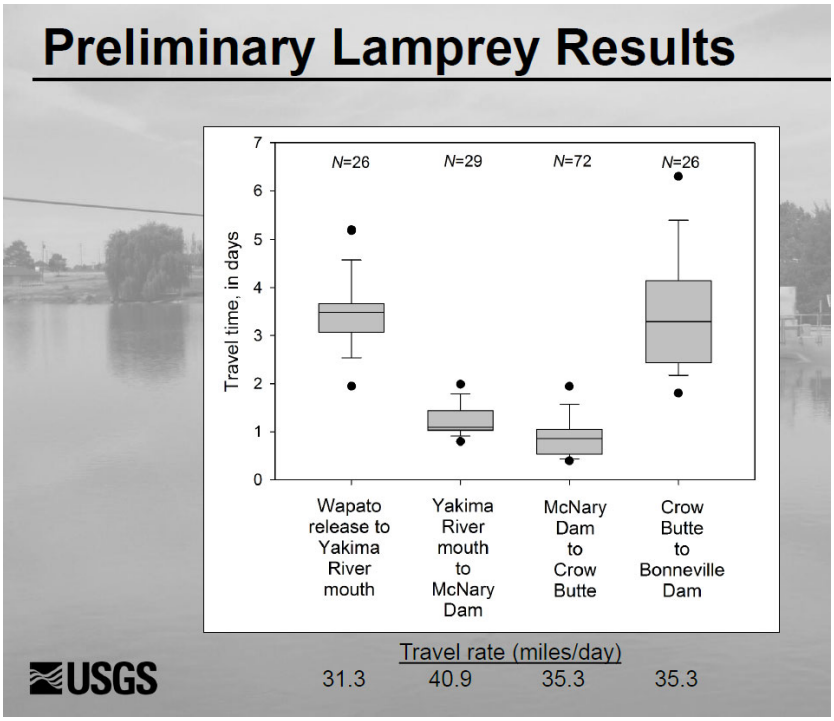


Figure 2. The preliminary acoustic telemetry juvenile lamprey data from the 2018 project. Seventy-two of the 97 tags were successfully detected between McNary Dam and Crow Butte reach in the Columbia River.

1.0 Detailed Project Description

This proposal addresses the lack of information about juvenile (i.e. macrophthalmia) Pacific Lamprey migration movements and survival by conducting an acoustic telemetry study. Recently, some limited information on juvenile lamprey movements has been attained through the use of 8.4 mm Passive Integrated Transponder (PIT) tags. However, PIT tag array detection efficiencies are very low in the Columbia River as well as tributaries, and more detailed information related to movements, survival, and predation has not been attainable using this technology. In addition, some controversy has arisen in the Columbia Basin over the use of full-duplex PIT tags to monitor lamprey, due to their tendency to attach to fishway walls which can then interfere with the detection of other tagged fish. A new acoustic transmitter, designed specifically for use in lampreys and eels, has been developed by the Pacific Northwest National Laboratory (PNNL) using the Juvenile Salmon Acoustic Telemetry System (JSATS). Based on preliminary results from a pilot-test in 2017 in the Mid-Columbia River (upstream of John Day Dam), the tag performance was outstanding (98-100% detection at each of the three receiver stations). Although this tag model is not yet commercially available, this proposal outlines a collaborative research opportunity that would use the tag to monitor juvenile lamprey in the Yakima River in 2018 in conjunction with an existing study that will be monitoring juvenile salmon. The juvenile salmon study is a joint effort by the U.S. Geological Survey (USGS),Reclamation, Yakama Nation Fisheries (YNF), and local irrigation districts, with funding 2018 provided primarily by YNF and Reclamation.

This salmon survival study will have a large array of JSATS receivers installed in the lower Yakima River to monitor fish migration past Reclamation diversion dams, and the arrays will be compatible with the newly developed lamprey tag. This proposal details a plan to partner with the juvenile salmon study in order to leverage the investment made into the installation and maintenance of the JSATS monitoring arrays, to allow a pilot-level evaluation of juvenile lamprey movements without the high costs typically associated with telemetry projects. This collaborative approach will serve the duel functions of field testing of the innovative lamprey transmitter in the tributary and mainstem environment and providing valuable insights into lamprey migration behavior and passage bottlenecks that will be applicable region wide (Columbia River Basin, tributary subbasins, and beyond).

Juvenile lamprey entrainment into various irrigation facilities within the Yakima Basin (primarily at Sunnyside and Wapato diversions, but also in smaller tributary diversions) is well documented and in many cases substantial - an estimate of 10,000~40,000 larvae annually entrained in some of these diversions (Beals and Lampman 2017b; Beals and Lampman 2017c; Beals and Lampman 2018b; Lampman 2018). Prevention of entrainment by screening is difficult due to the very small size of larvae/juvenile lamprey that enter diversion intakes. Replacement of existing screens (designed for juvenile salmonids) would be expensive and likely impractical because screen mesh size would need to be reduced significantly (<1 mm, less than half the size of current requirement) for significant reduction / prevention of larval lamprey entrainment (Rose and Mesa 2012).

The proposed project was identified following development and funding of the juvenile salmon acoustic telemetry study in the Yakima River. The YNF and USGS worked with Reclamation to secure project funding and to develop and refine the study plans. As the salmonid study effort progressed, it became apparent that significant investments were being made in the telemetry monitoring arrays for the study, and other projects could leverage those investments by purchasing transmitters to tag and release fish. The concurrent development and testing of the JSATS compatible lamprey tag by PNNL made an acoustic telemetry evaluation of juvenile lamprey feasible for the first time. The timing is well aligned to use a relatively small investment in transmitters and access to a large number of monitoring arrays (without further investment) to execute the first study of juvenile lamprey movements in the Yakima River and Mid Columbia River. The proposed project would not be feasible without the collaboration with PNNL to allow the use of the newly developed transmitter and without collaboration with the juvenile salmon study to allow the use of the monitoring arrays.

This study was initiated in 2018 using McNary Dam mitigation funds to purchase acoustic tags for juvenile lamprey, and is currently underway. The first year of study tagged 97 lamprey and successfully monitored fish from Wapato Dam all the way to Bonneville Dam. Juvenile lamprey traveled at a rate of 30-40 miles per day. Additional data such as canal survival or entrainment is not currently available. We know almost nothing about juvenile lamprey behavior relative to other important fish species and this is the technology that will allow us to advance our understanding of these unique creatures. This is a new technology which promises to provide great insight in to juvenile lamprey movements, behavior and survival in canals and river reaches. Because the Yakama Nation and Reclamation have already invested in the architecture to develop a juvenile salmonid survival study in the lower Yakima River, it makes sense to advance our understanding of both tag technology for lamprey as well as fish behavior and survival. If we find specific fish screens or fish bypasses in Reclamation diversion dams that are affecting juvenile lamprey we may be able to take corrective measures to fix them.

Our hope is that this tag can become commercially available to researchers once PNNL perfects the design, similar to the JSATS tags that were first developed there and then made widely available through firms such as Advanced Telemetry Systems, Vemco, and others. If this acoustic transmitter developed by PNNL becomes commercially available then other researchers including international researchers will have access to this new technology and will advance our understanding of lamprey, potentially world-wide. The goal of developing the acoustic tag is not the tag itself, but to understand the impacts Reclamation facilities have on juvenile lamprey. If lamprey are negatively affected, we may be able to find ways to reduce impacts to fish, wildlife and the environment from Reclamation facilities and operations.

The primary stakeholders in the Yakima Basin are the BOR, USFWS, WDFW the Yakama Nation and associated irrigation Districts. Each of these entities have remained in close coordination during the past 5-years of preliminary evaluations. Both BOR and the YN have been active in providing updated information to the irrigation Districts within the Yakima Basin.

USGS is the data steward for the study, they follow all Department of Interior guidelines for the collection, storage, and use of scientific data for fisheries and water management projects. A USGS written report summarizing all data collection and analysis, focused on the study objectives will be prepared. In addition, the USGS typically also publishes their studies in the appropriate peer reviewed scientific journal(s). Study results will be made available to interested stakeholders and the general public, and results will be presented at the annual Yakima Basin Science and Management Conference.

2.0 Regional Priorities: Linkage of actions to Identified Threats

- What threat(s) does this project address?
    - *"Dewatering and Flow Management" and "Juvenile Passage"*
- How does this project address this key threat(s)?
    - *Each of the identified diversions entrain tens of thousands of lamprey each year, the majority of which are subject to desiccation and predation (especially if salvage actions are not taken in a timely manner). This project, for the first time, will allow us to evaluate the entrainment issue in the entire Lower Yakima River reach and passage within the Columbia River as well and will provide specific answers for how and where entrainment / passage bottlenecks could be mitigated/improved within the region.*
- Does this project address a threat(s) specific only to this RMU or does the project address the threat(s) for multiple RMUs?
    - *Larval/Juvenile entrainment and juvenile passage is a threat that exists throughout the range of the species, and has applications across the range of the species. Columbia River passage has implications for many RMUs. The research results can be shared widely wherever juvenile lamprey migration is of interest to researchers. Understanding lamprey behavior as they approach diversion dams, through canal entrainment, and out to the river through bypass systems may be widely used in the West Coast where lamprey interact with irrigation diversions.*

3.0 Project Goals/Objectives and Species/Habitat Benefits:

- What life stage or stages will benefit from action? How?
    - *Larval and juvenile lamprey – by providing specific answers for where entrainment and passage are problematic in the lower Yakima reach and Columbia River*
- What other species may benefit from action?
    - *Potential benefit to salmonid spp. (as a result of increased sweeping velocity)*
- How will the project provide meaningful measureable results to improve lamprey populations and/or their habitat conditions?
    - *Mortality associated with entrainment, dewatering, and dredging will be reduced using new methods (Flow Velocity Enhancement System and a few types of lamprey sifters). Pilot projects will be implemented to evaluate these unique tools and measures, including how they could be improved and refined to make them even more efficient and valuable.*

4.0 Project Design / Feasibility

- Have the designs for the project been completed already or will they be completed before planned project implementation?
    - Yes, JSAT tags for Pacific Lamprey (called LSAT or eel/lamprey tags) have been developed recently by PNNL and is available (they were first tested in 2017 by PNNL in the Columbia River reach above John Day Dam). The study design was developed in 2017-2018 and this will be a continuation of the 1st year study.
- Are the appropriate permits (ESA and environmental compliance) in place already or will they be in place before planned project implementation?
    - This project has no effect to ESA species. Permits were successfully acquired in 2018 for transferring juvenile lamprey from McNary and John Day dams (as well as within the Yakima River) and will be easy to renew the permits.
- Can the project be implemented within the defined time frame?
    - Yes, the first year of the project was implemented successfully by USGS, BOR, and YN and the continuation of the 2nd year just depends on the funding for purchasing the tags and inter-agency coordination.

5.0 Partner Engagement and Support:

- What partners are supporting the project?
    - *BOR, USGS, Yakama Nation, BPA and local Irrigation Districts*
    - *There is high consensus within the RMU group that this project is high priority due to 1) the potential for high lamprey biological productivity within the Yakima Basin especially near the facilities of focus, 2) and the recent history of successful collaboration among BOR, USGS, and Yakama Nation, and 3) the range wide impact of entrainment and this project's applications to other subbasins within and outside of the Upper Columbia RMU.*
- What partners are active in implementing the project?
    - *BOR, USGS, Yakama Nation*
- What partners are providing matching funds or in-kind services that directly contribute to the project?
    - *BOR, BPA, Yakama Nation, and local Irrigation Districts*

6.0 Monitoring and Evaluation – Contribution to Knowledge Gaps:

If this is a monitoring or evaluation project or an on the ground project with a monitoring or evaluation component:

- Is there a monitoring framework in the proposal?
    - *Yes, the monitoring framework was developed in 2017-2018 and was first implemented in 2018 spring. The primary objectives of this project are to (1) test a non-commercially available acoustic telemetry tag designed for Pacific lamprey, and (2) to monitor the movements of juvenile lamprey in the Yakima River and in the Columbia River in order to better understand these unique fish and to inform future management actions. Entrainment of migrating lamprey in to canals and potentially through fish screens is considered a significant threat for Pacific Lamprey in the Yakima Subbasin This is the only type of study that will be able to finally provide answers about the rate of entrainment into the diversion,*

and rate of return through the bypass. Predation is also another critical threat for Pacific Lamprey. Recent studies on Northern Pike Minnow predation in the lower Columbia River have continuously shown that predation on juvenile Pacific Lamprey, despite the depressed numbers of lamprey, happens as frequently or more frequently than juvenile salmonid predation.

- Does the monitoring framework provide clear objectives and measureable metrics that can be observed over time?
    - *Objectives 1) ratio of lamprey entering diversion canals through the headgates, 2) ratio of lamprey entrained through fish screens vs. passing through bypass, 3) number of lamprey holding in diversion canals, 4) loss potentially attributed to predation, and 5) downstream migration rates displayed by juvenile lamprey and their association with flow and temperature*
- Does the framework provide a clear description of the expected outcome?
    - *Expected outcomes are increased knowledge of 1) juvenile lamprey migration behavior, 2) key flow and temperature requirements for safe migration, 3) source of mortality within the study area (Lower Yakima and Columbia rivers), and 4) specific solutions for mitigating entrainment and/or predation.*

If this is an on the ground project without a monitoring or evaluation component:

- How is completion of the project going to be documented?
    - **N/A**
- Is the project's effectiveness linked to another M&E project?
    - **N/A**

7.0 Budget and Timelines

Agency	Funds Requested ($)	Cost Share ($)	Total ($)
USGS	11,967		11,967
BOR	5,200	300,000	305,200
YN		150,000	150,000
PNNL	20,125		20,125
Total	**37,292**	**450,000**	**487,292**

List below are the specific project tasks:

Acoustic Tag Acquisition: Develop interagency agreement with Pacific Northwest National Laboratory to acquire lampery acoustic telemetry tags by January, 2019.

Collect, tag, release, and monitor tagged lamprey: Juvenile lamprey will be collected beginning in the spring after the telemetry monitoring arrays begin operating and running each year, anticipated late March, 2019. Acoustic transmitters will be surgically implanted into juvenile lamprey. USGS will be responsible for telemetry data collection and analysis.

Lamprey Holding Study: In addition to monitoring of tagged animals in the river systems, we will conduct a small-scale tank study to evaluate tag effects on juvenile lamprey. The tank study will use juvenile lamprey collected at the same sites, on the same dates as the acoustically-tagged lamprey, using the same taggers and tagging procedures. The findings of the tank study will be used to evaluate the basic assumption of all telemetry studies that tagged animals behave similarly to untagged animals.

Data analysis and reporting: USGS recently developed methods to model migration survival in relation to individual time-varying covariates using a Bayesian framework (Perry et al., in press). We will adapt these methods to analyze data collected in the Lower Yakima River during 2018–2020. A series of time-varying covariate data will be collected throughout the study period including fish size, release date, day of year, discharge, water temperature, turbidity, and predator index.

8.0 References (If Applicable)

See III. Literature Cited section at the end.

D. **Long-Term Priority Projects:**

In addition to the Priority Projects detailed above, RIP participants developed a list of long-term projects that would ideally be funded and implemented by 2025 (Table 6). Like the Priority Projects, these long-term projects address the major threats identified through the RIP process. However, these projects are currently not "shovel-ready" and need to be further developed in the near term.

Table 6: Long-term (2020-2025) priority Pacific Lamprey conservation projects for the Upper Columbia RMU.

HUC	Threat	Action Description	Agencies	Approach
Lower Yakima	Adult Passage	Passage improvements at Wanawish, Prosser, Sunnyside, Wapato dams, Toppenish Unit 2	YN, BOR, USFWS	LPS, ladder modification
Upper Yakima	Adult Passage	Adult passage improvements Roza, Town Canal dams	YN, BOR, USFWS	LPS, ladder modification
Wenatchee	Adult Passage	Passage evaluation & improvement Tumwater, Dryden Dams	CCPUD, USFWS, WDFW	LPS, ladder modification, telemetry
Okanogan	Adult Passage	Passage evaluation Zosel Dam	CCT	Telemetry

Table 6 Continued: Long-term (2020-2025) priority Pacific Lamprey conservation projects for the Upper Columbia RMU.

HUC	Threat	Action Description	Agencies	Approach
Similkameen	Adult Passage	Passage evaluation & Enloe Dam	CCT	Telemetry, LPS
Lower Yakima	Juvenile Passage	Acoustic Telemetry of juvenile lamprey passage	YN, BOR, USGS	Telemetry
Upper Yakima	Dewatering/Flow Management	Juvenile entrainment improvements at irrigation diversions & "Flip-Flop"	YN, BOR, Irrigation Districts	Operational, FVES, large sifter
Naches	Dewatering/Flow Management	Juvenile entrainment improvements at irrigation diversions	YN, BOR, Irrigation Districts	Operational, FVES, large sifter
Lower Yakima	Dewatering/Flow Management	Juvenile entrainment improvements at irrigation diversions	YN, BOR, Irrigation Districts	Operational, FVES, large sifter
Wenatchee	Dewatering/Flow Management	Juvenile entrainment improvement at Dryden Irrigation Canal	CCPUD, WDFW, USFWS, YN	Operational and sluice gates
Lower Yakima	Water Quality	Yakima Delta Restoration	YN, ACOE, DNR, MCRFEG	Bateman Island Causeway Modification
All	Water Quality	Toxicological Evaluations	YN, BOR, USGS, etc.	Research

III. Literature Cited

Beals, T., and R. Lampman. 2016a. Lower Yakima Subbasin larval lamprey monitoring report, 2016. Annual Report, BPA Project No. 2008-470-00, 70 pp.

Beals, T., and R. Lampman. 2016b. Upper Yakima larval lamprey monitoring report, 2016. Annual Report, BPA Project No. 2008-470-00, 66 pp.

Beals, T. and Lampman, R. 2016c. Naches larval lamprey monitoring report, 2016. Annual Report, BPA Project No. 2008-470-00, 29 pp.

Beals, T., and R. Lampman. 2016d. Wenatchee Subbasin larval lamprey monitoring report, 2016. Annual Report, BPA Project No. 2008-470-00, 43 pp.

Beals, T., and R. Lampman. 2016e. Entiat Subbasin larval lamprey monitoring report, 2016. Annual Report, BPA Project No. 2008-470-00, 27 pp.

Beals, T., and R. Lampman. 2016f. Methow Subbasin larval lamprey monitoring report, 2016. Annual Report, BPA Project No. 2008-470-00, 37 pp.

Beals, T., and R. Lampman. 2017a. Wenatchee Subbasin larval lamprey monitoring report, 2017. Annual Report, BPA Project No. 2008-470-00, 35 pp.

Beals, T., and R. Lampman. 2017c. Intensive monitoring of larval/juvenile lamprey entrainment within Dryden Diversion, Wenatchee River, 2016. Annual Report, BPA Project No. 2008-470-00, 7 pp.

Beals, T., and R. Lampman. 2017b. Intensive monitoring of larval/juvenile lamprey entrainment within the Yakima Subbasin, 2016. Annual Report, BPA Project No. 2008-470-00, 18 pp.

Beals, T., and R. Lampman. 2018a. Distribution and occupancy of Pacific Lamprey in six major Columbia River subbasins within the Yakima Nation Ceded Lands: Summary from 2009-2017 surveys. Annual Report, BPA Project No. 2008-470-00, 27 pp.

Beals, T., and R. Lampman. 2018b. Summary assessment of larval/juvenile lamprey entrainment in irrigation diversions within the Yakima Subbasin, 2017. Annual Report, BPA Project No. 2008-470-00, 7 pp.

CRITFC (Columbia River Inter-Tribal Fish Commission). 2014. Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin. Columbia River Inter-Tribal Fish Commission, Portland, OR.

CRITFC (Columbia River Inter-Tribal Fish Commission). 2018. Master Plan: Pacific Lamprey Artificial Propagation, Translocation, Restoration, and Research. Columbia River Inter-Tribal Fish Commission, Portland, OR.

Fish Passage Center. Lamprey Observed as Columbia and Snake River Adult Ladders. Web. 6 Aug. 2018.

Grote, A.B., M. C. Nelson, C. Yonce, A. Johnsen, D. J. Sulak, and R. D. Nelle. 2014. Passage of radio-tagged adult Pacific lamprey at Yakima River diversion dams. 2013 Annual Report. U.S. Fish and Wildlife Service, Leavenworth, WA.

Grote, A.B., M. C. Nelson, C. Yonce, K. Poczekaj, RD Nelle. 2016. Passage of radio-tagged adult Pacific lamprey at Yakima River diversion dams. 2014 Annual Report. U.S. Fish and Wildlife Service, Leavenworth, Washington.

Johnsen, A., M. C. Nelson, C. Yonce, D. J. Sulak, and R. D. Nelle. 2013. Passage of radio-tagged adult Pacific lamprey at Yakima River diversion dams. 2012 Annual Report. U.S. Fish and Wildlife Service, Leavenworth, WA.

Kelly-Ringel, B. 2016. Opportunistic surveys of Pacific Lamprey in the Wenatchee River. USFWS Memorandum, February 2, 2016. Leavenworth, WA. 6 pp.

Lampman, R. 2018. Intensive monitoring of larval/juvenile lamprey entrainment within Dryden Diversion, Wenatchee River, 2017. Annual Report, BPA Project No. 2008-470-00, 21 pp.

Timko, M., Le, B., and Nass, B. 2017. Assessment of Juvenile Lamprey Presence/Absence, Habitat Use, and Relative Abundance in the Priest Rapids Project Area. 19 pp.