# Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin

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# 1 Introduction

## 1.1 Framework Context

This document is a Framework for Pacific lamprey (*Entosphenus tridentatus*) supplementation research, monitoring, and evaluation (RME), and not for supplementation itself; therefore, not all questions regarding supplementation risks, benefits, protocols, etc., are fully addressed. This Framework also does not address important RME topics not related to supplementation, such as evaluation of habitat restoration or natural recolonization of areas not supplemented. Many such questions are important and should be addressed in a supplementation Framework, in specific supplementation plans, or in an overarching RME plan. Questions/topics that should be fully addressed in supplementation plans include (1) the effect that lack of homing to natal streams may have on supplementation efforts, (2) considerations involved when taking lamprey from one watershed to another, (3) hatchery vs. wild considerations often associated with salmonid supplementation, (4) criteria for stopping production/supplementation, and (5) ensuring co-manager support of supplementation actions.

Current information suggests that Pacific lamprey do not home to their natal spawning grounds as do anadromous salmonids; rather, they will mix with the largely panmictic population of the Pacific Northwest. Therefore, it is possible that only a small proportion of any increase of adults resulting from supplementation efforts would be realized in the interior Columbia River Basin (CRB). This potential lack of "efficiency" of artificial production regarding adult returns to specific subbasins or areas should be fully recognized and expected.

Moving lamprey between drainages raises the potential to alter future adult escapement in both donor and recipient areas. Though the latter may be a desired objective, shifting spawners from high to low productivity areas may serve to diminish overall productivity. Lamprey translocation programs should therefore not cause a substantial decrease in abundance in any currently occupied subbasin or area.

Risks associated with artificial production of salmonids include captive-bred adults producing offspring with reduced fitness (Araki et al. 2007; 2008), genetic adaptation occurring in a single generation in captivity (Christie et al. 2011), and the reduction of reproductive fitness of wild-spawning fish when they spawn with a captive-bred adults (Araki et al. 2009). Although Pacific lamprey differ from salmonids in many ways, these potential risks should be acknowledged using the best available knowledge prior to the implementation of a lamprey supplementation plan. If these risks apply to captive-bred lampreys, their adverse effects might be magnified by the fact that adult lampreys do not home to natal spawning grounds so their likelihood of straying and mixing with wild populations is greater than it is with salmonids.

In addition to developing criteria for implementing and monitoring supplementation efforts, specific supplementation plans should consider metrics and criteria for ceasing efforts. Triggers could include indicators that efforts have (1) been unsuccessful, (2) resulted in unacceptable risk to lamprey, or (3) have been successful in restoring lamprey to sustainable, harvestable levels.

Most subbasins within the CRB are co-managed by Tribes and state managers, with additional guidance for Pacific lamprey management provided by the U.S. Fish and Wildlife Service (USFWS). Threats to lamprey and proposed restoration and supplementation actions may vary among subbasins (see Appendices A through D). Although Tribes have generally been in the forefront of lamprey restoration actions, it is imperative to have agreement among co-managers regarding supplementation.

The Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, and the U.S. Fish and Wildlife Service reviewed previous drafts of this Framework and provided technical comments (Appendix B). The Framework is meant to be living document and provide a basis for discussion regarding the research, development, and improvement of existing and proposed lamprey supplementation strategies within the CRB and beyond.

## 1.2 Background

Pacific lamprey is an anadromous fish species that has occupied freshwater rivers of western North 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. Since pre-historic times, Native Americans have utilized lamprey for important subsistence, ceremonial, and medicinal purposes. Pacific lamprey are also important ecologically because they provide marine-derived nutrients to the freshwater riverine environment and the aquatic and terrestrial food web (Beamish 1980; Brown et al. 2009) and provide a high-calorie prey source for various marine and freshwater species.

Today, Pacific lamprey return to the CRB at a fraction of their historical numbers; daytime counts of adult Pacific lamprey at Bonneville Dam have declined from an estimated 400,000 in the 1960's and 1970's to lows of approximately 20,000 in 2009 and 2010 (Figure 1-1; CRITFC 2011a). At Willamette Falls, a traditional harvest location on the Willamette River, estimates of harvest declined from about 400,000 in the 1940's to about 4,000 in 2001 (Figure 1-1; Ward 2001).

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

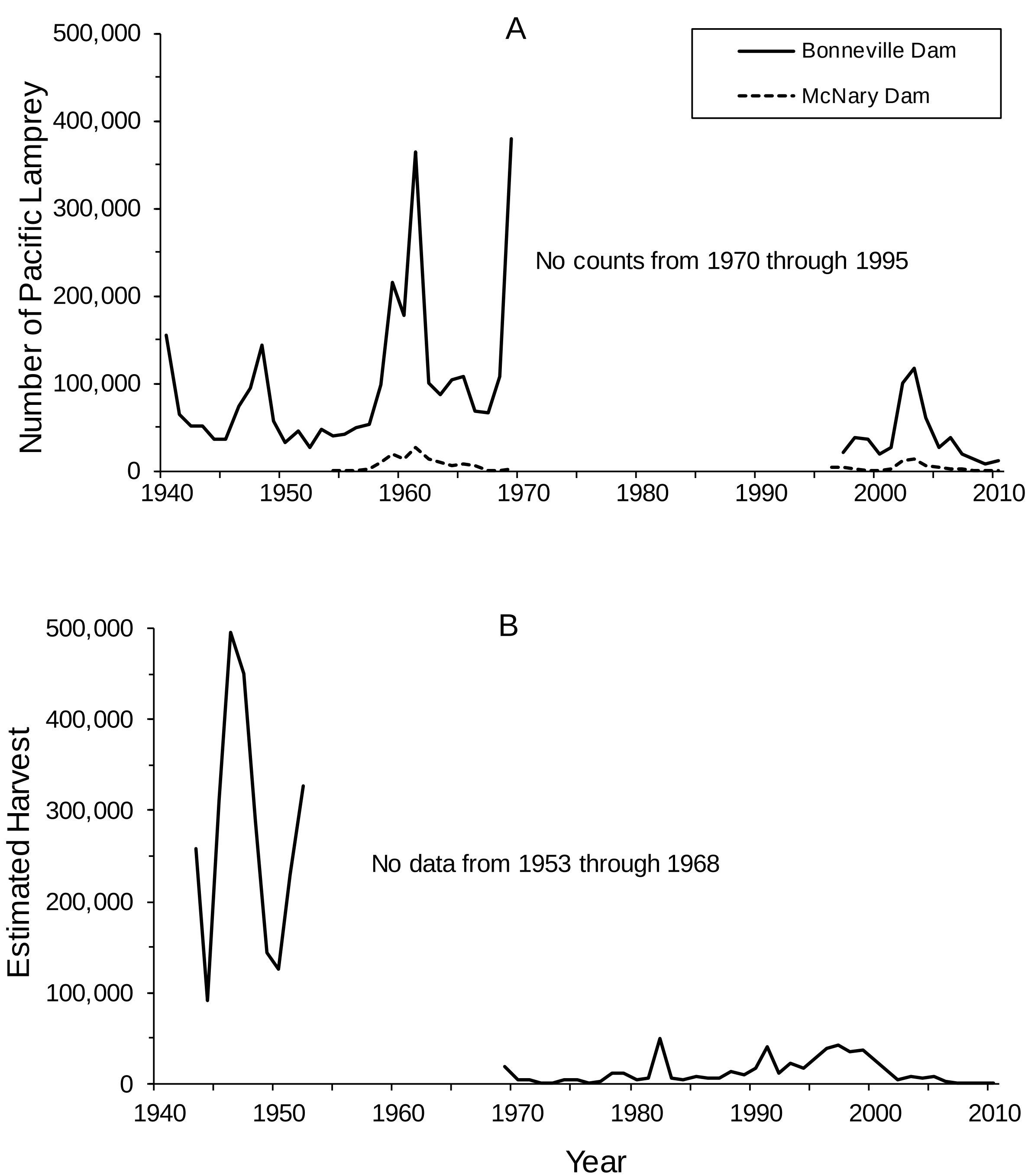


**Figure 1-1. Counts of adult Pacific lamprey reported for Bonneville and McNary dams (A); Estimated number of Pacific lamprey harvested at Willamette Falls (B).**

In addition to declines in the CRB, observational trends suggest that abundances of Pacific lamprey are declining from historical numbers in Pacific coast streams from Washington to southern California (Luzier et al. 2011). Pacific lamprey have been extirpated from many streams.

Considering the low numbers of Pacific lamprey, their value to the ecological health of the CRB, and their cultural significance, the time to address and recover lamprey stocks is now. Potential ecological impacts include decreased connectivity of marine with freshwater ecosystems, and decline in delivery of marine-derived nutrients into upper reaches of the Columbia River Basin. Low lamprey abundance may also decrease the potential prey base available to native fish, avian, and mammalian predators.

Cultural impacts include (1) loss of tribal heritage, (2) loss of fishing opportunities in traditional areas, and (3) necessity to travel great distances to the lower CRB for ever-decreasing lamprey harvest opportunities. As a consequence of reduced or eliminated harvest in the interior CRB, young tribal members are losing historically important legends associated with lamprey because they have not learned harvest and preparation methods.

Because of the long, complex, and poorly understood life history of Pacific lamprey, existing environmental conditions in the CRB, and scarcity of data, it remains unclear how quickly lamprey will recolonize extirpated streams, especially in the upper reaches of the CRB. Passage at mainstem dams for adult lamprey is low (~50%; Keefer et al. 2012), so natural recolonization of upper reaches may require extensive time, perhaps decades, considering that lamprey life history spans approximately 10 years.

Efforts to utilize restoration strategies such as artificial propagation, reintroduction, translocation, supplementation, and augmentation to aggressively maintain and reestablish Pacific lamprey in specific locations within the CRB have recently increased. Implementing these types of strategies create potential benefits and risks. Alternatively, taking no action also creates potential benefits and risks. Potential risks of these strategies are not all known, but some are briefly described in Section 1.1.

Pacific lamprey supplementation is defined here as an interim production facilitation strategy that supports region-wide efforts to reduce known threats to self-sustaining (natural) productivity. Facilitation actions include either the translocation of adults from one watershed to a watershed or the outplanting of artificially propagated larvae (ammocoetes) or juveniles (macrophthalmia) into a watershed to offset demographic concerns, to bolster populations above migration barriers, or to reestablish a presence of Pacific lamprey. Section 5 of this Supplementation Research Framework describes guidance on how supplementation can be incorporated into subbasin-specific plans for lamprey recovery. Initial trials and accompanying monitoring and evaluation activities will better inform fish managers on how to use supplementation as a restoration tool.

## 1.3 Supplementation Approaches

### 1.3.1 Adult Translocation

Translocation is defined as the collection of adult Pacific lamprey from one location and transport for release into another location where they are extirpated or in low abundance (Ward et al. 2012). Translocation has been successfully implemented by several treaty tribes in the Mid- to Upper Columbia River and Snake River basins, though well-designed post-reintroduction monitoring programs are imperative to documenting success (Close et al. 2009; Ward et al. 2012). In the short-term (~10 years), these efforts are designed to increase larval abundance and maintain a larval connection, through pheromone signals, to returning spawning adults, while also facilitating adult passage beyond difficult up-stream obstacles. Translocation is not designed to be a long-term restoration strategy but rather a short-term, stop-gap measure to maintain lamprey presence while known limiting factors and critical uncertainties are addressed. Although monitoring and evaluation of these efforts has yielded substantial information about effectiveness and has contributed to critical life history information for lamprey, it remains unclear whether efforts will result in increased adult returns in the future due to the relatively panmictic, non-homing life cycle of lamprey.

### 1.3.2 Larval Outplanting

A second supplementation approach is to outplant larval Pacific lamprey into targeted areas to offset demographic concerns, to bolster populations above migration barriers, or to reestablish a presence of Pacific lamprey. This requires successful collection, holding, spawning, incubation, and rearing of Pacific lamprey in a hatchery environment. It also requires the identification of suitable locations for the release of larval lamprey. Research on propagation of lamprey in hatchery settings began in the 1980s in Finland to address declines of an important commercial fishery. Over time, the success of lamprey propagation progressed to a level in Finland where fisheries managers were able to produce 17 million larvae per year for release into the Perhonjoki River between 1997 and 2009 (CRITFC 2011b). Unfortunately, very little post-release monitoring has been conducted in Finland or other countries.

### 1.3.3 Juvenile Outplanting

The third supplementation approach is to outplant older (~age 5+) larval and juvenile Pacific lamprey into targeted areas to offset demographic concerns, to bolster populations above migration barriers, or to reestablish a presence of Pacific lamprey. Protocols for rearing larvae for extended periods of time (5-7 years) to produce juveniles are lacking. In addition, the benefits of rearing fish to the juvenile stage may be difficult to assess because fish ready to immediately transform and migrate may not release the pheromones thought to attract returning adults.

## 1.4 Research and Monitoring Needs

Because of the low returns of lamprey and the assumption that successful natural recolonization to upstream tributaries may require many years, CRB Tribes and regional agencies have increasing interest in beginning research on the use of hatchery-reared larval and juvenile lamprey in short-term (0-10 years) and long-term supplementation (>10 years) efforts (CRITFC

2011a; USFWS 2012). In the short-term, hatchery-reared larvae and juveniles would be used as a research tool to help evaluate critical uncertainties and limiting factors of the species as well as their potential use in supplementing locally extirpated populations. In addition, careful monitoring and evaluation of these strategies will help in the development of a long-term research and restoration strategy for the CRB. Many important questions regarding the biology of Pacific lamprey remain unanswered to date, such as the age classes of all three life stages (larvae, juveniles, and adults), the natural annual growth and survival rates of larvae, and the general migration behavior of larvae before transforming to juveniles. Addressing all of these questions is essential to identifying factors limiting restoration of Pacific lamprey and to development of a life stage survival model for Pacific lamprey that will be a tool for evaluating conservation strategies. The use of artificial production and genetics analysis tools provide the opportunity to make incredible advancements in these unanswered biological questions. In addition, use of supplementation may help minimize the number of larval and juvenile fish taken from the wild for evaluations.

Besides laboratory use, some larval lamprey will be established in extirpated streams to evaluate important questions related to the viability of the local population (i.e. limiting factors, passage barriers). If larvae and juveniles are absent or functionally absent in these extirpated or near extirpated regions, there is virtually no way to identify and resolve major limiting factors. For instance, if irrigation diversions are a potential serious threat to migrating larval and juvenile lamprey, without the presence of larval lamprey either in the system or alternatively in lab settings, nothing can be effectively tested and evaluated to seek mitigation or resolution of the problem.

Hatchery-reared lamprey may also be used to supplement CRB lamprey by dramatically increasing larval/juvenile numbers, albeit in the short-term, with the goal of effectively compensating for the natural declines in adult returns. Doing this will not only allow the species to perform its natural ecological purposes in these extirpated streams and rivers, but it will also provide an opportunity to evaluate important overarching biological questions, such as stream selection criteria for returning spawning adults. For example, by releasing hatchery-reared lamprey in a tightly controlled field experiment, an evaluation of whether these fish can attract upstream migrating adult lamprey though the release of larval pheromones and ultimately contribute to increased recruitment, can occur.

Finally, if Pacific lamprey numbers continue to decline in the near future despite passage improvements, habitat restoration, and translocation, there will be a need for substantial research efforts to determine if a conservation hatchery is a feasible tool to protect the viability of the species and its remaining genetic diversity. The techniques and methods required for a successful conservation hatchery do not develop in a short time span, especially for an exceptionally cryptic and surreptitious species such as Pacific lamprey. It is important that learning and advancing conservation hatchery techniques and methods begin as soon as possible, so that they are available when needed. This will also help advance the knowledge on many of the important existing knowledge gaps in lamprey biology.

Before supplementation of Pacific lamprey with hatchery-reared fish can be used as a long-term restoration tool, it is important to develop and assess this type of strategy to the extent possible. Preliminary work includes (1) the development of basic propagation and rearing techniques for

lamprey, (2) an assessment of the cost/benefits of releasing hatchery reared fish into the environment, and (3) the development of consistent and standard protocols for monitoring and evaluating artificial propagation releases. In short, before supplementation with hatchery reared lamprey can be utilized, basic research needs to occur to (1) refine existing supplementation methods (translocation), (2) develop new methods (artificial propagation), (3) assess feasibility of artificial propagation, (4) identify existing facilities and prospective new facility locations within the CRB to support development and implementation of artificial propagation, (5) identify natural riverine features within the CRB that provide spawning sites for adults and rearing habitat for hatchery reared juvenile Pacific lamprey, and (6) develop and refine research, monitoring, and evaluation (RME) methods for long-term supplementation strategies. It is important to understand the inherent risks (generally associated with genetics; see Section 3) of supplementation, and be mindful of two important concepts: "do no harm" and "risk management" for both the donor and recipient areas.

For these reasons, a significant planning effort, led by the CRB tribes, has been undertaken by regional fishery managers to guide the use of Pacific lamprey supplementation as a short-term research and long-term restoration tool in the CRB. Three distinct, yet inter-related products will be developed over time (also see Section 4):

1. Regional Framework for Pacific Lamprey Research, Monitoring, Evaluation and Reporting in the Columbia River Basin (Regional RME Framework) which will encompass a broad scope of ongoing and needed research, monitoring and restoration activities;

2. Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin (Supplementation Research Framework) that will focus specifically on coordination and continuity in research and reporting of information associated with emerging and active lamprey restoration strategies such as propagation, reintroduction, translocation, and augmentation; and

3. Pacific Lamprey Restoration and Supplementation Research Subbasin Plans (Subbasin Supplementation Research Plans) which will summarize ongoing and proposed lamprey restoration activities in CRB subbasins within the context of the Regional RME Framework and the Supplementation Research Framework described above such that consistency and continuity of important methods, analysis and reporting formats can be achieved.

This document focuses on the Supplementation Research Framework and a template for Subbasin Supplementation Research Plans (Items 2 and 3 above), which will be integral components of the larger Regional RME Framework (Item 1). Collectively, these documents are anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan (CRITFC 2011a), (2) USFWS Conservation Agreement for Pacific Lamprey (Lamprey Conservation Agreement; USFWS 2012) and (3) Northwest Power and Conservation Council (NPCC) Fish and Wildlife Program (NPCC 2014). In total, each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be developed in years 2016-2017 and a Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research scheduled to be completed in 2015.

# 2 Purpose, Need and Scope for Supplementation Research Framework

## 2.1 Purpose

A framework is an organized foundation or structure that supports an intended area of research or the development of strategies that focus on the achievement of specific objectives. The framework typically consists of concepts, existing data and information, and various theories related to a particular research topic that, when assembled, form the basis of understanding. Relative to fisheries research and management, this foundation determines how information is interpreted, what problems are identified, and a range of appropriate solutions (Independent Scientific Group 1996) to achieve the ecological conditions necessary to meet specific goals and objectives. Lichatowich (1998) compares a conceptual foundation (i.e., framework) to the process of assembling a puzzle, where the foundation is the cover of the puzzle box, displaying what the fully assembled puzzle should look like.

As applied to Pacific lamprey supplementation research and ultimately the recovery of Pacific lamprey in the CRB, the USFWS and various state and tribal entities have developed visions for fully recovered Pacific lamprey. In the recent Lamprey Conservation Agreement, the ultimate future vision for lamprey is the “long-term persistence of Pacific lamprey… throughout their historic range in the United States”. This vision is consistent with that of the Tribal Pacific Lamprey Restoration Plan, which states that lamprey should be restored to sustainable, harvestable levels throughout their range by 2050. To this end, the development of this Supplementation Research Framework requires input from various stakeholders to ensure consistency in purpose, approach, analysis and reporting.

<u>The purpose of this Supplementation Research Framework is to initiate the development of a regionally coordinated and long-term RME and reporting plan (Section 1.4) directed towards the implementation of supplementation and recovery actions for Pacific lamprey within the CRB</u>. Additionally, this Supplementation Research Framework intends to "standardize" key elements of supplementation RME and reporting so that findings associated with status and trends and other important objectives can be reported in a common and consistent format. Finally, the Supplementation Research Framework provides specific guidance for the development of Subbasin Supplementation Research Plans.

The development of this regional Supplementation Research Framework is needed to coordinate supplementation RME on both a regional and local level. The Supplementation Research Framework will provide consistency and serve as a communication and management tool for stakeholders to remain focused on the overall goals of the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement.

This Supplementation Research Framework will be updated over time as new, pertinent information becomes available. Importantly, this Supplementation Research Framework is intended to serve as a foundation and template for consistency in the development of more specific Subbasin Supplementation Research Plans as well as a Master Plan for Pacific Lamprey

Supplementation, Aquaculture, Restoration, and Research. Findings associated with local planning and activities informed by this Supplementation Research Framework will provide sufficient information to update the Tribal Pacific Lamprey Restoration Plan. This can ensure the consistency among stakeholders in providing a more cohesive foundation for lamprey recovery in the CRB over the next five years, leading to the development of the Columbia River Basin Pacific Lamprey Management Plan. This management plan, envisioned to be developed in 2016–2017, will (1) update the Tribal Pacific Lamprey Restoration Plan (2) provide guidance for activities undertaken through the Lamprey Conservation Agreement and (3) direct future funding through the NPCC Fish and Wildlife Program. Contributors to this Supplementation Research Framework clearly recognize that because of our lack of knowledge and resources, this is a "work- in progress" and will be revisited and updated periodically to incorporate new findings and reflect management direction.

## 2.2 Need

### 2.2.1 Pacific lamprey are in low abundance or extirpated in many mid to upper watersheds, especially above McNary Dam

Abundance of Pacific lamprey has declined throughout the CRB, and counts decline rapidly from downstream to upstream areas (Table 2-1). Although counts at dams are incomplete, they serve as the only long-term index of Pacific lamprey abundance in the CRB. Annual cumulative daytime counts at Bonneville Dam prior to 1970 were regularly at least 50,000, with occasional peaks approaching 400,000 (Kostow 2002). Counts prior to 1970 at McNary Dam were generally in the few tens of thousands, but have decreased to less than 1,000.

In the Umatilla River, anecdotal information indicates that Pacific lamprey were historically abundant, with harvest occurring throughout the subbasin (Ward et al. 2012). Observations by tribal members and state and federal fisheries agency personnel (Jackson and Kissner 1997) indicate that lamprey were so abundant as to be a nuisance in the Umatilla River Subbasin. Abundance decreased precipitously in the late 1960s and early 1970s following broadscale chemical eradication (Close et al. 1995), and very few lamprey were observed in the subbasin during surveys conducted in the 1990s (Ward et al. 2012).

Few counts of Pacific lamprey at Snake River dams are available prior to the 1990's; however, counts ranged from approximately 5,000 to 7,000 at Ice Harbor dam from 1967 through 1969 (Fish Passage Center 2013). Recent counts have been under 1,000 fish at Ice Harbor Dam and under 100 fish at Lower Granite Dam (Table 2-1).

Although long-term information from dam counts in the Snake River is not available, information summarized by Cochnauer and Claire (2009) from the Clearwater Subbasin indicates a precipitous decline in Pacific lamprey abundance and distribution. The number of kilometers occupied by Pacific lamprey declined by an estimated 66% between 1960 and 2006. Counts at Lewiston Dam, near the mouth of the Clearwater River, decreased from over 5,000 in 1950 to zero by 1972, after which the dam was removed and lamprey once again had access to the upper drainage. Pacific lamprey larvae and juveniles were collected in Lolo Creek from 1994 through 2003; however, continued sampling failed to capture any lamprey from 2004 through 2006.

Anecdotal accounts indicate lamprey were historically plentiful in the Yakama Nation Ceded Lands, specifically in the Yakima River where adult lamprey were harvested locally at least till the 1960s and early 70s (Yakama Nation and GeoEngineers, Inc. 2012). Current adult lamprey occurrence data for the Yakima River Subbasin is based primarily upon observations at fishways at Prosser and Roza dams. At Prosser Dam, the number of adult lamprey counted at the fishway was low from 2000 to 2013, ranging from zero in 2000 to a high of 87 in 2003. In most years less than 20 adults pass Prosser Dam. No adults have been observed at Roza Dam since the counting program began (Yakama Nation and GeoEngineers, Inc. 2012). Recent abundance data indicates very low, numbers of larvae and juveniles throughout the subbasin as well. From 2000 to 2012, outmigrating larval and juvenile lamprey counts (unconfirmed species) from Chandler Canal Fish Collection Facility in lower Yakima River ranged between 18 and 1,450 (43% subsampling) with a mean annual count of 317.

In the upper Columbia River, numbers of Pacific lamprey passing Wells Dam (furthest upstream facility on the mainstem Columbia River with passage) each year have been declining, with some recent adult counts below ten per year (Table 2-1). Counts were over 1,400 fish as recently as 2004.

**Table 2-1. Counts of adult Pacific lamprey at Columbia and Snake River dams, 2002-12. Counts are during the day only at most dams. Priest Rapids and Wells dams have 24-hour counts. Counts at Lower Granite dam have been conducted 24 hours a day since 2009.**

| | Lower Columbia River | | Snake River | | Mid-Columbia River | |
|---|---|---|---|---|---|---|
| Year | Bonneville Dam | McNary Dam | Ice Harbor Dam | Lower Granite Dam | Priest Rapids Dam | Wells Dam |
| 2002 | 100,476 | 11,282 | 1,127 | 128 | 4,007 | 338 |
| 2003 | 117,029 | 13,325 | 1,702 | 282 | 4,339 | 261 |
| 2004 | 61,780 | 5,888 | 805 | 117 | 2,647 | 1,408 |
| 2005 | 26,664 | 4,158 | 461 | 40 | 2,598 | 291 |
| 2006 | 38,938 | 2,456 | 277 | 35 | 4,381 | 212 |
| 2007 | 19,313 | 3,454 | 290 | 34 | 6,593 | 21 |
| 2008 | 14,562 | 1,530 | 264 | 61 | 5,083 | 7 |
| 2009 | 8,622 | 676 | 57 | 12 | 2,714 | 9 |
| 2010 | 11,183 | 825 | 114 | 15 | 1,114 | 2 |
| 2011 | 18,305 | 868 | 269 | 48 | 3,868 | 1 |
| 2012 | 29,224 | 970 | 484 | 48 | 4, 025[a] | 3 |

[a] Lamprey must pass the fish ladder counting window at Priest Rapids Dam, whereas lamprey are diverted through a navigation lock at McNary Dam, making counting there more problematic.

### 2.2.2 Pacific lamprey in upstream subbasins may need to be supplemented so that recovery can occur in a timeframe consistent with existing restoration plans

Given the precipitous decline in Pacific lamprey abundance, particularly in the upper reaches of the CRB, it is unlikely that large-scale restoration and passage improvement activities, though necessary for long-term sustainability, will result in increased abundance or distribution at a rate sufficient to offset continuing declines and preclude further extirpations. The development of Pacific lamprey supplementation tools has therefore been identified as a recovery action that should occur concurrently with improvements in fish passage, water quality, and habitat (CRITFC 2011a; Luzier et al. 2011; USFWS 2012; Ward et al. 2012; Yakama Nation and GeoEngineers 2012).

Potential supplementation strategies include adult translocation and reintroductions using artificially propagated or naturally reared larval or juvenile lamprey. Translocation can be used to bypass corridors where migration is impeded or blocked, to increase number of spawning adults, to increase larval abundance and distribution, and to provide pheromones for potential attraction of additional adults. Hatchery rearing may be needed in some areas to increase larval abundance and provide pheromones. Both supplementation strategies are intended to be used while simultaneously improving known factors that limit productivity of lamprey in these specific watersheds. The goal is that self-sustaining natural productivity will provide meaningful ecological contributions and traditional tribal harvest. Research is needed to determine the feasibility of these approaches and to monitor and evaluate results.

One rationale for supplementation is the assumption that natural recolonization in the upper CRB will take too long. The assumption is based on attraction of adults to larval pheromones; if no larvae are rearing in a particular watershed, adults will not be attracted. Emerging evidence strongly suggests an association between larval and juvenile lamprey pheromones and adult returns (Sorensen et al. 2005; Lin et al. 2008; Close et al. 2009; Spice et al. 2012). Adult Pacific lamprey, like sea lamprey (Petromyzon marinus), may be attracted to spawning sites by pheromones released by larvae (Lin et al. 2008). However, other factors such as discharge, temperature, presence of Western brook lamprey rearing, and presence of other maturing Pacific lamprey adults may also help attract adults (Keefer et al. 2013).

One example of natural recolonization in the Hood River happened relatively rapidly. Hess et al. (2014) sampled the upper Hood River shortly (<3 years) after the removal of Powerdale Dam, which was considered a lamprey barrier, and found only age-0 Pacific lamprey. The lack of other age classes (and other species) suggests this was a recent, rapid recolonization of an area that did not have rearing larvae as an attractant. Of note is that Pacific lamprey need to migrate past only one mainstem dam to reach the Hood River. It is unknown if such rapid recolonization could occur upstream of multiple dams.

Although current passage rates at mainstem dams indicate that probability of successful passage past multiple dams is low (Keefer et al. 2013), work to improve passage at mainstem dams is ongoing. This exemplifies why dam passage improvement should be paired with supplementation and other restoration actions to improve conditions, without waiting for natural recolonization in all areas.

### 2.2.3 Supplementation research and use as a recovery and management tool will provide valuable insights into lamprey biology and ecology

In consideration of low numbers of adult lamprey, alternative management strategies must be employed as stop-gap measures to slow extirpation and re-establish genetic variability within local areas throughout the CRB. Potential areas of supplementation will be identified, prioritized, and defined by local area managers and tribal groups in order to ensure research is conducted efficiently. During this time, supplementation research should be implemented and important attributes, such as local genetic diversity must be monitored so that if/when supplementation is determined to move forward at a larger scale, the working knowledge will have increased to better plan and implement future management actions. As supplementation research is implemented in specific areas, monitoring and evaluation to determine action effectiveness of adult translocation, artificial propagation method development, and larval and juvenile reintroduction, will provide valuable insights into lamprey biology and ecology as well as provide the opportunity to research known and potential limiting factors and critical uncertainties.

Translocation efforts to date have resulted directly in successful transportation and holding techniques for adult Pacific lamprey. Successful holding and releases of adults have resulted in increased larval abundance (Ward et al. 2012), which has in turn increased knowledge of larval distribution and migration timing. In addition, by radio-tagging translocated adults, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Confederated Tribes and Bands of the Yakama Nation (YN) / USFWS have been able to collect information on adult passage at low-elevation diversion dams, providing insights on placement of lamprey passage structures such as the structure completed at Threemile Dam in the Umatilla River in 2009, and passage improvements currently being planned at Prosser Dam in the Yakima River. Ongoing translocation and future propagation research will have broad application in addressing other factors potentially limiting lamprey in the tributary environment including the effects of irrigation entrainment, flow management (ramping rates), emerging and legacy contaminants, and habitat availability.

Knowledge to be gained from evaluating lamprey artificial propagation includes information related to rearing techniques and with post-release monitoring. Development and evaluation of artificial propagation techniques will increase knowledge of laboratory protocols, growth and survival, food preferences, habitat needs, and changes in morphology associated with metamorphosis. Monitoring of larval or juvenile releases will provide information on growth and survival in the wild, distribution including downstream movement, and outmigration timing.

Monitoring of supplementation activities may also provide opportunities to increase understanding of known limiting factors and critical uncertainties. These may include larval and juvenile passage at specific facilities, contaminant accumulation and effects, and predation. If larval pheromones guide adults to spawning sites, supplementation might encourage natural production in suitable spawning and rearing areas. Research is currently being conducted to isolate these pheromones and investigate how they may be used to improve adult returns (Yakama Nation and GeoEngineers, Inc. 2012). By releasing hatchery-reared larval and juvenile lamprey in tightly controlled field experiments, an evaluation of whether these fish can attract

upstream migrating adult lamprey through the release of larval pheromones and ultimately contribute to increased recruitment can occur. Investigations such as these are important to initiate at this time so that, if need be, this management strategy can be confidently implemented when necessary.

### 2.2.4 A regional Supplementation Research Framework will provide for a more comprehensive and systematic research and monitoring strategy and will contribute to greater consistency in data analysis and reporting

A successful, economical and rapid recovery of Pacific lamprey will require regionally coordinated efforts from tribes, federal and state fishery agencies, and others involved in conducting or funding lamprey restoration efforts. An important component of this coordination is consistency in protocols, data collection and reporting metrics. The need for this coordination was clearly identified in both the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement. Both documents clearly established a context for coordinated action among stakeholders across the CRB towards conservation actions, funding and RME.

## 2.3 Scope

The scope of this Supplementation Research Framework is intentionally narrow due primarily to the conservative nature of this initial effort and budgeting constraints. Actions guided by this Supplementation Research Framework are expected initially to focus on addressing important management questions, limiting factors, and critical uncertainties identified in both the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement. With regard to supplementation research, the Supplementation Research Framework will provide guidance to address Objective 3 of Tribal Pacific Lamprey Restoration Plan, Supplementation/Augmentation, and Objective 7 of the Lamprey Conservation Agreement, Restore Pacific Lamprey of the RMUs. The Supplementation Research Framework and associated Subbasin Supplementation Research Plans are integral components of the larger Regional RME Framework.

The Supplementation Research Framework is further expected to guide consistent analysis methods and reporting formats for research and monitoring tools in the context of Objectives 5 and 6 of the Lamprey Conservation Agreement (Identify and characterize Pacific lamprey for the RMUs and Identify, secure and enhance watershed conditions contained in the RMUs) and Objective 6 of the Tribal Pacific Lamprey Restoration Plan (Research, Monitoring, and Evaluation).

Through adaptive management this Supplementation Research Framework will expand, with the intention of maintaining its relative simplicity. As more information becomes available through research efforts, the management actions guided by the Framework will be refined and additional individual subbasin strategies may be developed. Many critical uncertainties about Pacific lamprey remain and fishery managers expect that continued RME activities will likely modify the overall objectives and methods. For this reason, managers choose to maintain relative simplicity in the approach. Considering budgets, existing capacity, and the state of knowledge, it is not practical at this time to construct a Supplementation Research Framework overly burdened

with details built upon speculation and uncertainty. Simply based on a 10-year life history of Pacific lamprey, managers recognize many important objectives may require a decade and longer to achieve.

# 3 Pacific Lamprey Genetic Structure

Influence on genetic integrity is a primary concern for all supplementation efforts, but the field of regional genetic study of Pacific lamprey is still in its infancy. Although much more work is needed to better understand lamprey genetics, compared to salmonids, lamprey appear to exhibit low genetic differentiation among regional stocks, and its population structure reflects a single broadly distributed population across much of its range in the Pacific Northwest (e.g., Goodman et al. 2008, Spice et al. 2012). The need for genetic diversity in artificial salmonid propagation and rearing programs has been well documented. With salmon, collecting broodstock across the entire run is advised to maintain the genetic diversity of supplemented populations (Cuenco et al. 1993; Bilby et al. 2003). Genetic heterogeneity among a population's individuals is a basic driving principle for sustainability to reduce the potential for deleterious population effects, including inbreeding depression. This genetic principle is applicable to all species, including Pacific lamprey, and provides organisms the ability to exhibit a selective response to environmental variability.

Another well-established premise for artificial propagation in salmonids is the use of locally-adapted broodstock. Such local stock may be comprised of individuals that are adapted to specific conditions in a basin, and subsequently exhibit higher fitness. However, in comparison to salmonids, Pacific lamprey do not appear to exhibit strict natal homing (Goodman et al. 2008; Hess et al. 2013; Spice et al. 2012). For this reason, unlike salmonids, the spatial scale that contains locally-adapted broodstock may be much broader for Pacific lamprey, and thus the specific watershed- or subbasin-of-origin of this broodstock may not be critical to the success of artificial propagation programs for Pacific lamprey.

Hess et al. (2013) concluded that although neutral genetic variation (i.e., gene variants detected have no direct effect on fitness) in Pacific lamprey is influenced by geography and adult phenotypes, there is high gene flow among individuals collected from the Columbia River, Oregon and California. However, Hess et al. (2013) and Lin et al. (2008) documented significant genetic differences among fish from different large-scale geographic regions but Lin et al. 2008 found no obvious geographical pattern of gene flow or differentiation in samples from the Pacific Northwest (i.e., Washington, Oregon and California). The choice of genetic marker may have some bearing on the results of the genetic studies that have been conducted on Pacific lamprey. For example, the findings of Lin et al. (2008) and Hess et al. (2013) were obtained using relatively large numbers of amplified fragment length polymorphism and single nucleotide polymorphism markers, respectively. These types of markers have high potential to represent adaptive variation from genomic regions under selection, which was one of the primary goals of the study by Hess et al. (2013). In contrast with patterns from neutral variation, adaptive variation was shown to drive relatively large genetic divergence between regions, even within the Columbia River between the lower river and interior tributaries (Hess et al. 2013).

Other genetic studies using putatively neutral markers (based on microsatellites and mitochondrial DNA) have provided evidence of high rates of gene flow across much of the range of Pacific lamprey with low geographic association among samples (Goodman et al. 2008; Spice et al. 2012). Results from Spice et al. (2012) suggest that most Pacific lamprey in the Pacific Northwest could be managed as a single unit. In contrast, Lin et al. (2008) stated that the scale

over which genetically significant management units are categorized (e.g., stocks, populations, distinct population segments) requires additional clarification through more study. Recently, however, the USFWS (Luzier et al. 2011) divided Pacific lamprey into ten Regional Management Units (RMUs). The division of lamprey stocks into regional units was not based on genetic information, but is intended to allow for a more refined level of life history and data collection from each RMU. At this time, the USFWS (2012) believes that “dividing management units into finer geographic scales would provide a risk-averse approach for conserving Pacific lamprey”.

Despite some conflicting results, genetic studies generally corroborate the pattern that rates of gene flow are high among Pacific lamprey, particularly in the Pacific Northwest. The pool of potential donor-stock for artificial propagation or translocation programs may therefore be larger for lamprey than, for example, salmon. Similar genetic composition could be viewed as an advantage because healthy donor-stocks could be obtained from any RMU and translocated, or seeded, into suitable watersheds throughout the Pacific Northwest.

Still, from the viewpoint of conservation management vs. supplementation, Hess et al. (2013) emphasize that, although lamprey are capable of high levels of gene flow across most of their range, it is important to maintain “local” diversity (a suitable geographic area has not yet been described), primarily those adaptive genetic variants that respond to localized conditions. This would indicate that broodstock management and collection protocols must be cognizant of the need to maintain the diversity of donor-stock when faced with the potential for artificial propagation (i.e., hatchery programs). Similarly, the “mining” of donor-stock associated with lamprey translocation programs should not cause a substantial decrease in abundance in any currently occupied subbasin (Ward et al. 2012).

## 3.1 Genetic Monitoring and Analysis

The potential risks of supplementation tools have been recognized, and measures to minimize risks are outlined in the lamprey translocation guidelines agreed to by the Columbia River Inter-Tribal Fish Commission (CRITFC 2011a; Ward et al. 2012). Although consideration should be given to potential disruption of stock structure and associated genetic adaptations from sources, the risk of adverse effects associated with the continued downward trend in abundance may outweigh the potential loss of some adaptive genetic variants in isolated areas (Ward et al. 2012). This is particularly true in areas where numbers are decreasing rapidly. In these areas, it is possible that so few adults find their way into the watersheds that they may have trouble finding mates and the potential for genetic founder effects is increased. Given general support among genetics findings that a single homogenous population of Pacific lamprey exists throughout the Columbia River and Pacific Northwest region, there is likely less risk in temporary supplementation to increase abundance and genetic diversity.

Part of the planned monitoring that is described in this Supplementation Research Framework includes a genetic analysis component that will provide a means for tracking genetic diversity and the fitness consequences (if any) that are associated with genetic variation of lamprey used for translocation/outplanting. Genetic analysis will allow us to directly measure reproductive success of translocated lamprey adults and/or outplanted larvae (e.g. via parental based tagging), as well as provide a way to assess the genetic background of each individual adult and test

whether this background affects reproductive success in a particular environment. The other advantage of this genetic analysis is that the age of the larvae can be quantified accurately based on parentage assignment, allowing us to further our understanding of the age structure of Pacific lamprey at various life stages.

# 4 Supplementation Research Framework

This section describes the Supplementation Research Framework that will be an integral component of the larger Pacific lamprey Regional RME Framework (Item 1 described in Section1.4; Figure 4-1.). Collective development of these documents is anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan, (2) Lamprey Conservation Agreement, and (3) Northwest Power and Conservation Council Fish and Wildlife Program. Each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be drafted in years 2016-2017 and a Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research scheduled to be completed in 2015. Translocation and artificial propagation continue to be tools necessary for learning, both in laboratory and the natural environment. Supplementation may be used as one method to address limiting factors and ultimately to help shape the management plan.

Because of the low returns of Pacific lamprey, including extirpation in some subbasins, and the assumption that natural recolonization will require a long time, the use of and monitoring of adult translocation and hatchery reared larval and juvenile lamprey in short and long-term supplementation efforts will be necessary. In the short-term translocation and propagation efforts would be used to reestablish lamprey in extirpated streams, maintain lamprey presence to attract upstream migrating spawning lamprey, to offset demographic concerns, and to bolster populations above migration barriers. In the long-term, artificially produced lamprey could be used to supplement CRB lamprey by dramatically increasing larval/juvenile numbers with the goal of effectively reversing declines.

Throughout the entire life history of Pacific lamprey, multiple threats have been recognized both within and outside of subbasins, including degraded habitat, passage barriers, degraded water quality, dewatering, and predation (CRITFC 2011a; Luzier et al. 2011). To varying degrees these threats are being addressed, although it will take considerable time before their impacts are fully understood and corrected; therefore, appropriate supplementation is necessary during this time.

Fishery managers recognize the importance for both restoration and research to be complimentary efforts in addressing threats. It is especially important to recognize the use of supplementation in areas where lamprey numbers are too low to actually determine the nature or extent of potential limiting factors. Examples include juvenile entrainment and passage through irrigation screens or adult passage over irrigation facilities. Hatchery reared fish may also be used to address basic questions about growth and survival in natural riverine environments. Managers have concluded that without use of translocation and propagation research as a tool, it is essentially impossible to understand potential environmental threats in many subbasins. Short-term focus should be on critical areas of research and longer-term application of supplementation in key areas.

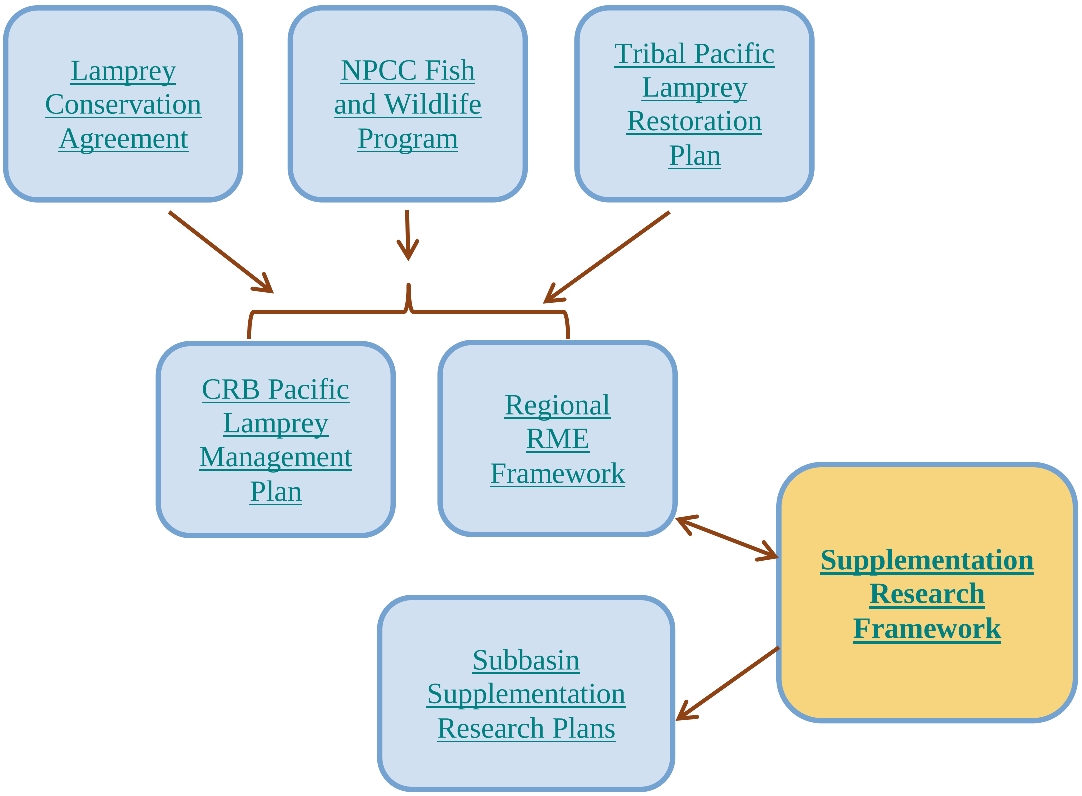


**Figure 4-1. Context of the Supplementation Research Framework relative to other existing and planned documents**

## 4.1 Regional RME Framework

The Regional Framework for Pacific Lamprey Research Monitoring, Evaluation, and Reporting in the Columbia River Basin (Regional RME Framework – Item 1 described in Section 1.4) will be guided by principles and concepts put forth by Luzier et al. (2011). The Regional RME Framework will also be informed by biologists with experience in lamprey biology. At this time, some of the elements of a Regional RME Framework cannot be implemented because of a lack of scientific tools needed to collect data (e.g., juvenile tags). Nevertheless, the Regional RME framework will identify appropriate RME questions and objectives, and the need to develop the tools necessary to address the questions and objectives.

### 4.1.1 Types of Regional RME Efforts

Several types of monitoring are needed to allow managers to make sound decisions:

- **Status and Trend Monitoring.** Status monitoring describes the current state or condition and limiting factors at any given time. Trend monitoring tracks these conditions to provide a measure of the increasing, decreasing, or steady state of a status measure through time. Status and trend monitoring includes the collection of standardized

information used to describe broad-scale trends over time. This information is the basis for evaluating the cumulative effects of actions on lamprey and their habitats.

- **Action Effectiveness Monitoring.** Action effectiveness monitoring is designed to determine whether a given action or suite of actions (e.g., propagation and translocation) achieved the desired effect or goal. This type of monitoring is research oriented and therefore requires elements of experimental design (e.g., controls or reference conditions) that are not critical to other types of monitoring. Consequently, action effectiveness monitoring is usually designed on a case-by-case basis. Action effectiveness monitoring provides funding entities with information on benefit/cost ratios and resource managers with information on what actions or types of actions improved environmental and biological conditions.

- **Implementation and Compliance Monitoring**. Implementation and compliance monitoring determines if actions were carried out as planned and meet established benchmarks. This is generally carried out as an administrative review and does not require any parameter measurements. Information recorded under this type of monitoring includes the types of actions implemented, how many were implemented, where they were implemented, and how much area or stream length was affected by the action. Success is determined by comparing field notes with what was specified in the plans or proposals. Implementation monitoring sets the stage for action effectiveness monitoring by demonstrating that the actions were implemented correctly and followed the proposed design.

- **Uncertainties Research**. Uncertainties research includes scientific investigations of critical assumptions and unknowns that constrain effective propagation and translocation. Uncertainties include unavailable pieces of information required for informed decision making as well as studies to establish or verify cause-and-effect and identification and analysis of limiting factors.

## 4.2 Supplementation Research Strategies

This Supplementation Research Framework covers the translocation of adults, the development of techniques to artificially propagate and rear larval and juvenile lamprey, and the outplanting of artificially propagated larvae or juveniles into Columbia River Basin watersheds to offset demographic concerns, to bolster populations above migration barriers, or to reestablish a presence of Pacific lamprey. It describes the RME recommended for assessing the status and trends of Pacific lamprey within subbasins and for evaluating the effectiveness of translocation and other actions implemented to restore Pacific lamprey within those subbasins. In addition, the Supplementation Research Framework identifies current efforts and additional RME needs. Although logistical and monetary limitations exist, this plan will focus on the common goal of assessing success in Pacific lamprey translocation and propagation.

### 4.2.1 Adult Translocation

#### 4.2.1.1 Background

Close et al. (1995) conceptualized the goal of lamprey translocation to "begin establishment or supplementation of lamprey in selected tributaries above Bonneville Dam where populations have been extirpated or are at extremely low levels." The overall goal of translocation is to restore natural production to self-sustaining levels.

Translocation programs in the CRB have been well documented by Close (1999), Close et al. (2009), and Ward et al. (2012). The approach for translocation efforts to date has been to collect adult Pacific lamprey at Bonneville, The Dalles, and John Day dams. Adults are then transported and held at facilities near release areas. Adults are tagged and treated at the holding facilities and released the following spring.

#### 4.2.1.2 Rationale and Assumptions

Although the best long-term sustainable option for increasing Pacific lamprey abundance and distribution may be improving the passage environment for adults and juveniles, translocation of adults may be the best immediate option to begin the process of rebuilding populations in areas of low abundance or extirpation. Translocation efforts are likely to increase production of larval lamprey in recipient subbasins, "seeding" underutilized rearing habitat and increasing pheromone cues to attract adults. Translocation and other restoration programs could therefore have a synergistic effect in breaking the downward cycle of Pacific lamprey abundance and recruitment.

Another potential benefit of translocation is expanded spatial distribution of Pacific lamprey, via occupation of subbasins in areas of low abundance or extirpation. Until passage is better understood and improved at mainstem dams, translocation from lower dams may also produce an escapement benefit for lamprey. These benefits may help decrease the risk of lamprey local extirpation by decreasing the overall impact of catastrophic events within a subbasin, or even within a larger portion of the Columbia River Basin.

Lamprey translocation may also produce ecosystem benefits. Because larvae are filter feeders and detritivores, increased production is expected to facilitate nutrient cycling in rivers where adult lampreys have been reintroduced. Other potential benefits include increased connectivity of marine with freshwater ecosystems, and delivery of marine-derived nutrients into upper reaches of the Columbia River Basin. Lamprey restoration will also increase the prey base available to native fish, avian, and mammalian predators.

#### 4.2.1.3 Critical Uncertainties

Critical uncertainties regarding translocation of adult Pacific lamprey that have been identified through monitoring of existing programs include:

- Survival of translocated adults.
- Spawning success.

- Viability and survival of eggs, larvae, and juveniles.

Potential risks (albeit unknown) from lamprey translocation often raised include:

- Disruption of population structure and associated genetic adaptations.
- Exposure to survival risks such as pathogens and disease.
- Decreased abundance in donor areas.

These potential risks have been recognized (Ward et al. 2011), and steps have been taken to avoid or reduce them by adherence to lamprey translocation guidelines agreed to by the Columbia River Inter-Tribal Fish Commission (CRITFC 2011a).

A remaining uncertainty may be the appropriate number of adults to release within a target location. The apparent lack of homing of Pacific lamprey to natal watersheds confounds attempts to address this uncertainty. Long-term efforts are needed to document the effect of increased larval abundance on returns of adults.

#### 4.2.1.4 Research and Monitoring Objectives

The four Columbia River treaty tribes have proposed creating a regional lamprey supplementation plan that includes adult translocation with the following general objectives (CRITFC 2011a):

- Continue translocation in accordance with tribal guidelines.
- Develop and implement lamprey translocation as a component of a regional supplementation plan.

Tribal translocation strategies will:

- Utilize historical and tribal records of lamprey distribution, abundance and habitat to help determine outplanting priorities.
- Use the best available knowledge to evaluate if translocation is necessary.
- Choose donor sources wisely and make efforts to minimize negative effects on donor groups.
- Monitor and improve collection, transport, and holding protocols and facilities.
- Evaluate and select target streams, release locations, and timing of releases using the best available knowledge.
- Closely monitor and evaluate translocations at a variety of spatial and temporal scales.
- Accurately record and sufficiently share translocation results with the region.

### 4.2.2 Larval and Juvenile Outplanting

#### 4.2.2.1 Background

The biological features of lamprey, especially after hatching, require new innovative ideas and methods to improve culture success. Formative work on lamprey propagation in Finland,

research on sea lamprey from the Great Lakes region, and research on Arctic lamprey from Japan provide important insights on how artificial propagation of Pacific lamprey could be used in the CRB. Some experimental work on the artificial propagation of Pacific lamprey has already been conducted within the CRB; however, the primary focus in the past has been on propagating small number of lamprey for research purposes and the processes and techniques applied were not scaled for aquacultural use.

In 2012, the YN and the CTUIR collaborated on the artificial propagation of Pacific lamprey. Over a 10-week period between April and June, 2012, 41 adults were spawned successfully primarily at Marion Drain and Prosser hatcheries. Some of the individuals (both male and female) spawned repeatedly, resulting in a total of 55 propagation events. Over 40% of the adults, however, did not mature in 2012 and were overwintered for another year. Fertilization and hatching success varied widely (0-99%). The success of fertilization and hatching depended chiefly on four variables: 1) seasonality; 2) quality of gametes; 3) water quality; and 4) incubation methods.

Many tribal and federal agencies experimented with larval rearing in 2012 using hatchery reared age 0+ larvae. Different feeds and substrate types were tested, and the effects of temperature and feeding regime on growth and survival were evaluated. Most studies demonstrated that larvae can attain positive growth and relatively high rates of survival under active dry yeast feed. However, a certain combination of feeds in addition to active dry yeast (such as hatch fry feeds or marine larvae feed) appeared to be potentially effective in producing even better growth and warrants further research. Larvae appeared to show preference for natural fine substrates, such as clay, silt, sand, detritus and straw. However, considering the enormous difficulty in separating larvae from clay/silt, detritus, and straw, fine sand appears to be the most promising substrate to date.

Protocols for rearing larvae and juveniles for extended periods of time (years) are lacking. Growing lamprey to larger sizes will be particularly challenging partly due to 1) the length of time they spend as larvae (3-7 years) and 2) their cryptic nature (i.e. burrowing under fine sediment), which makes any type of monitoring both very time-consuming and difficult.

#### 4.2.2.2 Rationale and Assumptions

Once developed, artificial propagation could be an important management tool to aid in the restoration of Pacific lamprey, especially in areas of low abundance or extirpation. A primary role of larval propagation and outplanting, besides increased larvae/juvenile production, would be to maintain and increase pheromone cues to attract returning adults. Increased numbers of larvae are likely needed to occupy available habitat, release pheromones, and begin reversing declines in numbers of returning adults.

Hatchery reared larval lamprey may also be valuable as study organisms. Larval lamprey behavior is secretive and larvae are elusive (i.e. burrowed in sediments), making them difficult to study in their natural environments. Rearing and evaluating lamprey in a controlled laboratory environment and connecting this work with controlled research in the natural environment may be the most effective way to better understand various life stages efficiently, both in time and expense.

Juvenile (macrophthalmia) outplanting may not be the most effective strategy for supplementation because larvae are needed in the streams to produce pheromones that attract adults and the economic cost of growing larvae for 3-7 years would also be substantial. Raising lamprey to the juvenile stage may have some benefits, however. For example, if the facility is in a suitable location, pheromones released by larvae being reared over long periods may serve to attract returning adults. Continued holding of fish may facilitate refinement of rearing techniques. Finally, survival rates of outplanted juveniles may be higher than that of larvae.

Hatchery-raised lamprey could also be used for other research programs other than re-stocking in streams. Very little is known about lamprey juvenile passage and migration, but the diminished abundance and distribution, and the unique size and shape of the lamprey make any kind of sizeable tagging studies extremely difficult, if not impossible, to implement. Therefore, artificial propagation of Pacific lamprey may be extremely valuable for research purposes to better understand their early life history and biology, and to meet the critical need of samples required for such studies. Hatchery lamprey could be raised to various life stages and used as test organisms for determining screen design, screening efficiencies, survival through hydroelectric projects, and other juvenile studies of critical importance.

Using hatchery reared fish in the natural environment provides several distinct research opportunities because lamprey could be placed in selected stream reaches or reservoir deltas at desired densities. For example, this type of lamprey placement allows for opportunities to test sampling protocols against a known sample. Larval lamprey placed in cages in certain streams could be evaluated to determine if their presence will attract adults via pheromones or their tolerance to certain levels of contaminant loads. In general, experiments using hatchery-raised lamprey will aid in the understanding of lamprey behavior and guide future restoration actions without the need to extract and harm existing lamprey from the natural environment.

#### 4.2.2.3 Critical Uncertainties

Substantial obstacles must be overcome to achieve a scale necessary for hatchery production. Critical knowledge gaps at the hatchery production level include:

- Optimal temperature regime for holding adults.
- Best management practice for successfully spawning and incubating lamprey.
- Disease and fish health issues specific to lamprey.
- Tolerance level of adults/eggs/larvae to disease/fungus controlling chemical treatments.
- Influence of rearing density on larval growth; larval food quality, quantity, and feeding methods.
- Methods to efficiently separate larvae from fine sediment for counting and monitoring.

Although many knowledge gaps exist at the hatchery production level, these questions can be answered relatively easily by the use of targeted experiments. In fact, from the first year of propagation efforts by the CRB tribes and federal agencies, many of these knowledge gaps are beginning to get answered (e.g. spawning and incubation techniques, chemical treatment effects, effective types of feed and substrate media).

Growing lamprey to larger sizes will be particularly challenging partly due to 1) the length of time they spend as larvae (3-7 years) and 2) their cryptic nature (i.e. burrowing under fine sediment), which makes any type of monitoring both time-consuming, difficult, and stressful for the larvae. For example, in a salmon hatchery, large mortality events are obvious to the hatchery personnel because the fish are directly visible in the water tanks. In the case of larval lamprey, even if a significant larvae mortality event occurs, this event may go unnoticed for some time because they all live under the sediment and remain invisible most of the time. As larvae increase in size, their weight density will continue to increase, most likely requiring more and more space to rear them successfully.

Significant critical uncertainties related to post hatchery production remain. The release of hatchery reared larvae into the natural environment has taken place in Finland, Japan and other countries, but very little monitoring has been conducted to successfully validate its effectiveness in increasing and boosting natural reproduction levels. Critical knowledge gaps post hatchery production include:

- Optimal release sites.
- Optimal larval release life stages (0+ ~ 7+ larvae).
- Optimal release density.
- Changes in growth and survival of hatchery reared larvae after release.
- Dispersal rates after release.
- Interactions with naturally produced larvae and juveniles.

In addition to larval habitat in mainstem and side channels of rivers and streams, potential release sites include salmon acclimation ponds, hatchery pollution abatement ponds, and irrigation diversions and canals. To determine the optimal larval release life stage, a much better understanding on the life stage survival model for Pacific lamprey and the corresponding "bottleneck" life stage is needed. If the primary bottleneck is in the egg incubation and prolarvae stage, being able to rear them past this stage should increase the larvae production immensely (at least in quantity). On the other hand, if the primary bottleneck takes place in later life stages as larvae, it would become crucial to rear them past this stage. The optimal density levels of the larval release also require more information on the life stage survival model. At what density of larval outplanting (per watershed size) are increases in larvae production noticeable? Can larval lamprey adapt quickly to the natural environment after being reared in the hatchery settings for over a year? How many of the larvae would stay put within the release site vs. others that disperse to other habitat? How would the outplanting affect naturally- produced larvae? Salmon and trout hatcheries have learned from 100+ years of experience. All these questions will require intense monitoring that will span multiple years.

### 4.2.2.4 Research and Monitoring Objectives

The four Columbia River treaty tribes proposed creating this Supplementation Research Framework with the following general objectives (CRITFC 2011a):

- Immediate evaluation of potential regional lamprey aquaculture facilities.
- Consolidation and synthesis of existing lamprey propagation information.
- Development and refinement of husbandry techniques for Pacific lamprey.

- Continued research on lamprey genetics, potential population substructure, and source locations.
- Assessment of appropriate release locations and strategies for hatchery reared lamprey within the region.
- Monitoring and evaluation of supplementation using hatchery reared lamprey.

These objectives are intended to answer basic questions on the feasibility of large scale lamprey propagation in the CRB. The next steps in research should focus on basic observations in nutrition, growth, rearing densities, survival, and habitat preferences. Preferably, efforts should build on previous propagation research on other lamprey species, especially related to collection of broodstock, fertilization techniques, incubation conditions, and release timing, for the efficient and cost-effective development of propagation programs in the CRB. The YN and the CTUIR have begun initial efforts for propagation starting the spring of 2012 by hatching and rearing several thousand Pacific lamprey larvae at their facilities. In 2013, propagation and rearing experiments ensued by the YN and CTUIR to assess critical questions, such as 1) how to improve fertilization and incubation rates, 2) how to maximize survival of newly hatched larvae during facility-to-facility transfer, 3) how to efficiently count eggs and hatched larvae, and 4) how to effectively feed and rear larvae in large tanks under high density (>50,000) conditions.

## 4.3 Monitoring and Evaluation Approaches

### 4.3.1 Adult Translocation

#### 4.3.1.1 Adult Survival

***Monitoring questions***

- How many translocated adults moved out of the release areas?
- How far and in what direction did translocated adults move following release?
- How many translocated adults moved to spawning areas?
- How did release timing and location affect spawn timing?
- What environmental factors (e.g., flows, temperature, etc.) may have caused translocated adults to leave the target areas?

***Performance metrics***

- Number of adults released
- Direction of movement
- Rate of movement
- Distance moved
- Adult maturation rate
- Estimated percentage of released adults that successfully reached spawning areas

Performance may be influenced by variables including water temperature and stream flow.

***Approach***

A tagging study (e.g., radio telemetry) is needed to determine the movement and habitat use of translocated adult Pacific lamprey. If water conditions allow and no lamprey are in the area, visual observations without tagging studies can be used to determine if translocated adults use the target spawning areas. This, however, is a less robust approach than using tagging studies.

***Analysis***

If a tagging study is used, the analyses are straightforward for estimating direction of movement (fraction moving upstream and downstream), rates of movement (distance moved per week), numbers leaving the target area, and numbers of adults spawning within the target area. Correlations between environmental factors (flows and temperatures), time and location of release, and spawn timing can be evaluated.

#### 4.3.1.2 Adult Spawning

***Monitoring questions***

- How many translocated adults constructed redds and engaged in reproduction within target areas?
- What was the distribution of spawners within target areas?
- What habitat conditions (e.g., flows, temperature, substrate, etc.) favored the construction of redds and reproductive success within target areas?
- How many adults successfully spawned and contributed offspring?
- What are the effects on spawning success of multi-year over-wintered adults?
- What are the effects of an individual's genetic background on spawning success?

***Performance metrics***

- Number and distribution of redds
- Number of adults engaged in reproduction
- Number of eggs per red
- Presence of live eggs and larvae within redds
- Number of live eggs and larvae within redds
- Number of offspring assigned back to translocated adults

Performance may be influenced by a number of variables including water temperature, stream flow, water velocity, water depth, cover, and substrate composition.

***Approach***

An important assumption of translocation is that the translocated Pacific lamprey are ready to spawn shortly after release. This means that the translocated adults will select suitable spawning sites, successfully find mates, construct redds, and reproduce. For indirect measures of reproduction, if water conditions do not allow for visual observations, a tagging study may be needed to determine the number and distribution of spawners within the target areas. If water conditions allow, visual observations can be used to determine the number, distribution, and

reproductive activities of translocated adults within the target areas. Ideally, spawning surveys should occur weekly throughout the spawning period (i.e., from time of release to the end of spawning). Field observations can be used to document redd construction and reproductive behavior. The location and timing of redds can be mapped using GPS. The size (width, length, and depth) of each redd can also be recorded. Habitat conditions (temperature, depths, velocities, cover, and substrate composition) can be measured at the locations of redds within the target areas. Stream flows can be downloaded from nearby gauging stations. Note that lamprey spawning surveys can be coupled with steelhead spawning surveys.

A genetic tagging study can be used to evaluate reproductive success metrics. Hess et al. (2014) have developed and evaluated a set of genetic markers for Pacific lamprey that can accurately assign offspring to their parents. Tissues from all translocated lamprey adults must be collected for this tagging approach to be possible to execute for efficient monitoring.

***Analysis***

Descriptive analyses can be used to describe the number, distribution, and spawning activities of translocated adult lamprey within the target areas. Correlation and regression techniques can be used to assess the relationships between habitat conditions and the abundance and distribution of redds in the target areas. These relationships can then be used by biologists to fine-tune their selection of appropriate release locations. Based on the distribution of redds, biologists can sample a random number of redds to determine the total number of eggs deposited per red; randomly sampling redds for the presence of viable eggs and larvae over a specified time interval (e.g., weekly). To the extent possible, biologists should count the total number of viable eggs and larvae within a redd to gain a better understanding of the natural survival mechanism during early life history (methods may need to be developed to measure viable eggs and larvae over time).

Because the sampling of redds can alter the survival of eggs and larvae over time, biologists will need to determine if sampling with or without replacement is appropriate. That is, should a given redd be sampled more than once over time? Ideally, the total number of redds sampled should be no more than 10% of the total redds within the target area. Habitat conditions (temperature, water depth, egg-pocket depth, redd size, velocities, and substrate composition) can be measured at the locations of redds within the target areas.

#### 4.3.1.3 Larval Survival and Growth

***Monitoring questions***

- Did translocated adults produce viable larvae in target areas?
- What fraction of the eggs survived to emergent larvae?
- What habitat conditions (e.g., flows, temperature, substrate, etc.) were associated with larvae survival and production?
- What is the survival rates for various age classes of larvae (i.e. 0+, 1+, 2+, 3+, etc.)
- Is genetic makeup associated with larval growth and survival?

***Performance metrics***

- Egg-to-larvae survival rates
- Larval survival and growth rates at various age classes
- Size, age, and abundance of larval lamprey identified as offspring from translocated adults

Performance may be influenced by a number of variables including water temperature, stream flow, water velocity, water depth, and substrate composition.

***Approach***

If translocation is to be successful in increasing the status of Pacific lamprey within a subbasin, then translocated adults must produce viable offspring. Therefore, measuring successful hatching and surviving larvae is critical to the assessment of translocation. If hatching and larvae production is successful, biologists will be equipped to re-establish lamprey in areas currently void of Pacific lamprey. Larval and juvenile lamprey of particular age classes will be able to be assigned back to translocated adults using genetic analyses. Offspring will be able to be assigned to adults translocated in 2013 and onwards.

***Analysis***

Descriptive analyses can be used to describe the mean number of eggs per redd, mean number of viable eggs and larvae per redd, and egg-to-larvae survival rates, as well as number of viable offspring per spawner pair. Correlation and regression techniques can be used to assess the relationships between habitat conditions and survival rates.

An important assumption of propagation is that outplanted larvae will use intended rearing areas over time. Biologists will identify suitable release sites based on rearing conditions within those sites. If biologists are able to identify suitable rearing areas that are used successfully by hatchery reared larvae, it may improve the status of Pacific lamprey within the subbasin. It will also be possible to track hatchery reared larvae via parentage analysis at various stages of maturity as they continue their continuous migration downstream.

### 4.3.1.4 Larval Abundance and Distribution

***Monitoring questions***

- How many larvae were produced by translocated adults?
- What size distribution is represented by each cohort of lamprey?
- How many larvae remained within the target areas over time?
- Did the distribution of larvae expand into areas outside the target areas?
- How did release timing and location affect the density and distribution of larval or juvenile lamprey within the target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval distribution and abundance?

***Performance metrics***

- Density of larvae (CPUE or fish/$m^2$)

- Distribution and abundance of larvae
- Presence and proportion of various size classes of larvae

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

***Approach***

Annual larval sampling within treated and untreated areas before and after supplementation activities will determine the relative abundance and size classes of larvae within the target areas. Parentage analysis will identify which larvae originated from which translocated adults, thereby providing a way to verify larvae were derived from translocation efforts and to measure distance traveled from last known spawner release site.

Electrofishing techniques modified for sampling larval lamprey may be the most appropriate method for estimating relative abundance, size classes and distribution. However, recent research from Europe shows that a significant proportion of lamprey populations (especially anadromous lamprey) can be found in deep water habitat that are not normally targeted with the standard electrofishing methods for lamprey. Alternative methods may need to be evaluated further (e.g. deep water shocking, suction dredging, passive traps, and infra-red cameras) to target these other areas that larvae may use extensively. Locations of juveniles can be mapped using GPS. Lamprey biologists will need to identify a protocol for sampling habitat conditions.

***Analysis***

A time series of the densities (CPUE or fish/$m^2$) of larval lamprey and numbers of juveniles can be constructed to show how densities and numbers changed before and after supplementation efforts. Distribution maps can be generated that show how the spatial extent of larvae expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and larval abundance and distribution.

### 4.3.1.5 Larval and Juvenile Outmigration

***Monitoring questions***

- How many larvae or juveniles transformed and migrated downstream?
- What ages are larvae or juveniles at particular maturation stages during their migration?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with outmigration?

***Performance metrics***

- Number of outmigrating larvae, and juveniles
- Number of PIT tagged larvae and juveniles
- Rate of movement
- Distance moved
- Genetic diversity of larvae and juveniles

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

***Approach***

Rotary screw traps or other traps can be used to estimate the number (or presence) of downstream migrating juveniles. Field research suggests that juveniles can be caught by electrofishing techniques as well, focusing on coarse sediment near Type I and Type II larval lamprey habitat in late summer / early fall season. Lamprey biologists will need to identify a modified protocol for electrofishing juveniles and their associated habitat conditions. Locations of juveniles can be mapped using GPS. Juveniles will be assigned to particular brood years of translocated adults via parentage analysis, and thereby provide an accurate age for each fish.

***Analysis***

A time series of the numbers of juveniles can be constructed to show how densities and numbers changed before and after supplementation. Distribution maps can be generated that show how the spatial extent of larvae and juveniles expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and transformer abundance and distribution. Parentage-based ages can be related to juvenile size and life-stage to refine our knowledge of size-at-age relationships.

#### 4.3.1.6 Adult Returns

***Monitoring questions***

- Are supplementation strategies influencing adult returns to specific streams and watersheds?
- What is the status and trend of returning adults in experimental and control streams and watersheds?
- What percentage of offspring derived from translocations return to the interior Columbia River as adults?

***Performance metrics***

- Number of returning adults
- Number of returning adults that were offspring of translocated lamprey
- Historical estimates of returning adults

Performance may be influenced by a number of variables including river conditions (e.g. water temperature, stream flow, water velocity) and basin-wide adult returns (e.g. adult counts at Bonneville Dam).

***Approach***

Addressing the adult life history stage will require a variety of monitoring techniques. Pacific lamprey do not appear to be philopatric (in the strict sense we use for salmonids), which makes associating changes in adult returns to specific supplementation strategies problematic. The

simplest approach will be to actively and passively monitor adult returns, in specific streams and watersheds, through a combination of active adult trapping, video and visual monitoring, or spawning/redd surveys. Many of these approaches require “bottleneck” locations (e.g. dams/diversions, waterfalls, manmade weirs) to facilitate passage/return estimates. Other approaches, such as spawning/redd surveys, may require significant manpower to complete.

Regardless of the approach used, any estimates of adult returns would need to be compared to historical estimates/counts to evaluate changes in adult returns in relation to specific supplementation strategies. Alternatively, if a long-term monitoring timeframe is utilized, in ~7+ years (around 2020) returning adults that were derived from these translocation efforts could conceivably be identified. These adults would be tissue sampled as they pass Bonneville Dam and identified as translocation offspring through parentage analysis, utilizing our translocation broodstock genetic dataset (brood years 2012-2015).

***Analysis***

Evaluating changes in adult returns will require a time series analysis of adult returns/estimates to specific streams and watersheds before, during, and after the implementation of supplementation strategies. Comparisons of adult returns/estimates before and after specific supplementation strategies would provide a qualitative assessment of adult returns. An assessment of adult returns in relation to supplementation strategies may be influenced by a number of variables including river conditions (e.g. water temperature, stream flow, water velocity) and basin-wide adult returns (e.g. adult counts at Bonneville Dam). These variables will need to be taken into account during analysis.

### 4.3.2 Larval and Juvenile Rearing

#### 4.3.2.1 Broodstock Survival

***Monitoring questions***

- How many adults survived and sexually matured in the second spring/summer season after collection?
- What water temperature regimes, water source (river vs. well water), and holding conditions (density, tank type and size, substrate, flow rates, diel light conditions, etc.) are optimal for increasing survival and sexual maturation?
- Do pheromones from larvae and adults (opposite sex) stimulate sexual maturation?
- Can sexual maturation be stimulated and synchronized using insulin-like growth factor and other hormonal chemicals?
- Under natural conditions, what proportions of adults spend more than a year to sexually mature?

***Performance metrics***

- Transportation and holding survival rates
- Sexual maturation rates
- Timing of sexual maturation
- Spawning rates (ability to successfully utilize gametes before they lose viability)

Performance may be influenced by a number of variables including water temperature, flow rates, water velocity, water depth, and substrate composition.

***Approach***

The primary goals of broodstock holding are to increase transportation and holding survival rates, increase sexual maturation rates, and enhance spawning success.

Efforts to collect, transport, and hold adult Pacific lamprey from the lower Columbia River have been largely successful with few observed mortalities. However, there are still important questions regarding the potential effects of artificial holding on the sexual maturation of adult lamprey. Although adults overwintering for multiple years may be a natural phenomenon, it is possible that the artificial holding conditions may negatively impact the rates of sexual maturation. It will be important to test and experiment the effects of various holding conditions (temperature, water source, lighting, etc.) strategically and systematically at various holding facilities to investigate the best conditions for successful sexual maturation.

Availability of larval and adult pheromone scents in the water may have an impact on this as well. An individual's genetic makeup may also affect its successful use in propagation. Sexually mature adults are often times covered with fungus and are extremely fragile and vulnerable and as a result, adults have a relatively short timeframe for successful spawning and propagation. If the sexual maturation is not in synchrony between males and females, gametes can often remain unused and go to waste. Insulin-like growth factor and other hormonal chemicals can be tested for its efficacy on synchronizing sexual maturation. It is important to note that what is learned from these propagation experiments will also help improve the holding conditions for adult lamprey that are part of the translocation programs.

***Analysis***

Correlation and regression techniques can be used to assess the relationships between holding conditions, genetic makeup, and rates of survival and sexual maturation. It is important to compare the survival and sexual maturation rates among all the facilities that hold the adults and from that determine the key factors that drive success (namely high rates of survival and sexual maturation). Every year, certain tank conditions can be modified strategically within and among the various facilities to evaluate the effects.

#### 4.3.2.2 Fertilization to Hatch Survival

***Monitoring questions***

- What spawning methods maximize the fertilization rates (methodology of gametes and water mixing, holding time, amount of water, chemical treatment, etc.)?
- What incubation methods maximize the hatching rates (McDonald jars, upwelling and downwelling jars, flow rates, chemical treatment, mesh size, etc.)?
- How long can gametes (eggs and milt) be preserved and remain viable using refrigeration, cryopreservation, etc.?
- How can eggs be quickly counted to evaluate production levels and survival rates?

***Performance metrics***

- Fertilization rates and successional egg development
- Hatching rates
- Genetic diversity and fitness
- Ability of incubation methods to separate gametes (so that fertilization and hatching rates can be assessed for each spawner group)

***Approach***

Maximizing the fertilization and hatching rates are fairly easy tasks, given that the propagation protocols that already exist for other lamprey species in other countries as well as salmon species in general can be emulated and fine-tuned. The Yakima Nation and CTUIR have worked collaboratively since 2012 to investigate fertilization and hatching success and many improvements in protocols have been made since then (see section 4.2.2 for more information). A wide variety of incubation methods were compared and contrasted in 2012 to evaluate the success rates of various incubation methods. In 2013, more in-depth questions related to propagation were investigated to continue to refine and improve fertilization and hatching success.

Genetic diversity of Pacific lamprey is influenced by two main sources: 1) the pool of adults that were originally collected from lower Columbia river dams and 2) the degree to which mixing of adults occur in propagation (for instance, 3x3 or higher breeding matrices of males and females can enhance genetic diversity of offspring). Genetic fitness will need to be evaluated on a long-term basis as more information is collected on survival rates and eventually return rates in future years. Lamprey eggs and newly hatched prolarvae are extremely small, allowing them to slide through the smallest gaps in incubation trays and tank dividers. If fertilization and hatching success are to be evaluated accurately for each spawner group, it is important to use an incubation method or holding vessels that minimize the unanticipated movement of eggs and prolarvae between trays and tank sections.

***Analysis***

Correlation and regression techniques can be used to assess the relationships between propagation and incubation conditions, genetic makeup, and rates of fertilization and hatching. Every year, certain elements of the protocols can be modified strategically to evaluate the effects on propagation success. Increasing the genetic diversity of off spring can be achieved by increasing the breeding matrices as well as the diversity of the source adult population. Subsequent genetic diversity of hatched larvae in the hatchery can be compared to that of hatched larvae from wild and/or translocated adults in the rivers and streams. Because of the limited number of adults and larvae present in many of the supplemented areas, striving to attain higher levels of genetic diversity appears important, but other genetic traits may be important fitness traits for survival in the upper Columbia reaches (such as large body lengths and weights) as well.

### 4.3.2.3 Hatch to Outplant Survival

***Monitoring questions***

- What are the best conditions for maximizing prolarvae and larvae survival (density, water temperature, cover material, lighting conditions, etc.)?
- What type of holding tanks (circular, trough, inlet and outlet styles, etc.) provide the best conditions for prolarvae and rearing larvae?
- What substrate media (clay, silt, sand, artificial media, etc.) will be optimal for survival, growth, and monitoring of larvae?
- What type of feeds will be optimal for survival, growth, and the overall health of larvae?
- How can larvae be separated from substrate media in a timely manner with the least amount of stress incurred to them for monitoring and transfer/transportation?
- How can larvae be quickly counted to evaluate survival and growth rates?
- What is the best way to maximize genetic diversity of the offspring?

***Performance metrics***

- Survival rates of prolarvae
- Survival and growth rates of feeding larvae
- Genetic diversity

***Approach***

Although experimental rearing of larvae in laboratory settings have been conducted for many decades, cases where lamprey were reared from eggs to larger larvae are rare. Based on the fact that Pacific lamprey has very high fecundity (~100,000 eggs per female), the survival rates of Pacific lamprey from egg to larva may be relatively low in the natural environment. In laboratory settings, however, there may be ways to greatly enhance the survival rates at this critical life history stage from eggs to larvae.

The YN, CTUIR, USGS, and USFWS have worked collaboratively since 2012 to investigate larval rearing as well as the survival between egg/prolarva and larva life stages. Life stages between egg and prolarva are fairly easy to monitor as they do not require fine substrate for survival and many of the conventional fish hatchery tanks and equipment can be used effectively with small minor modifications. However, once the larvae are ready to feed, it appears that the presence of fine sediment, a medium through which larvae burrow and feed, is vital for their survival. On the flip side, this means that larvae will remain invisible for the majority of time, and monitoring for survival and growth becomes considerably difficult.

Newly hatched prolarvae and young larvae are extremely small (6-10mm long) and refining ways to enumerate them quickly and efficiently is crucial in evaluating the hatching success and survival in general. In 2013, The YN has begun testing and calibrating XperCount device (an automated enumerating device for small fish/organisms by XpertSea, Inc - see http://www.xpertsea.com/ for more information) to find effective ways of counting these small larvae with minimal stress on fish.

Many questions still remain about appropriate feed for larvae in terms of survival, growth, and general fish health. Although active dry yeast has proven to be effective in attaining relatively high survival and growth within a short (<1 year) time frame, a certain combination of feeds in addition to active dry yeast (such as hatchfry feeds or marine larvae feeds) may be potentially effective in producing healthier fish and warrants further research. Protocols for rearing and monitoring larvae for extended periods of time (months and years) will need to be developed with ideally minimum handling impacts on larvae.

***Analysis***

Correlation and regression techniques can be used to assess the best methods to hold and rear prolarvae and larvae in terms of survival, growth, and general fish health. The variables of interest are tank settings, density, media substrate, feed type, feed amount and delivery system. Coordination and collaboration on these unique arrays of experiments among various agencies and tribes will be key to maximize our progress in this field of research. The genetic makeup of the surviving larvae will also be investigated to evaluate whether any natural selection is at work within the lab settings. Furthermore, genetic diversity of larvae in the hatchery can be compared to that of larvae from wild and/or translocated adults in the rivers and streams.

Various larvae extraction methods should also be compared and evaluated from the perspective of fish stress and survival as well as time efficiency. Unlike most other hatchery fish, lamprey larvae will need to be separated from the sediment in order to monitor them, so refining the methodology for this task will be important. Use of automated enumeration tools (such as XperCount) may be needed to effectively count and sort the hundreds of thousands of progeny produced from each female.

### 4.3.3 Larval and Juvenile Outplanting

#### 4.3.3.1 Larval Survival and Growth

***Monitoring questions***

- How do survival rates of hatchery reared larval lamprey compare to naturally-produced lamprey?
- Did release timing and location negatively affect the growth and survival of larval lamprey within target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval growth and survival?
- Is genetic makeup associated with larval growth and survival?

***Performance metrics***

- Size, age, and abundance of larval lamprey
- Number of immigrants and emigrants
- Survival and growth rates

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

### *Approach*

For propagation to be successful, released larvae need to grow and survive to the juvenile stage. Ideally, growth and survival rates would be compared to values for "wild" fish. If growth and survival are similar to or better than those measured for "wild" fish, propagation of larval lamprey would be considered a valid approach to improve the status of lamprey populations within subbasins. Growth and survival rates can be measured using parentage analysis. If all parents of hatchery reared larvae are genetically sampled, then routine sampling of the juveniles while they mature in the wild could be used to track the offspring of adults that were spawned for the propagation efforts. These offspring could then be compared to wild larvae in the same area though confirming the age classes of the wild larvae may be difficult.

Alternative techniques to assess growth and survival rates of larval lamprey are not currently available. Visible Implant Elastomer (VIE) markings have been tested for various size classes of juvenile and larval lamprey (down to 30mm size) and appears to be a promising technique for marking early life stage lamprey. VIE marks appear to last for a long time. Survival appears to be very high but effects on feeding and growth requires further investigation. Fin clips have also been used to mark larval and juvenile lamprey, but their impacts on both survival and growth have not been evaluated extensively to date. Genetic analysis may be the best available approach for monitoring movement of larvae in and out of sites, aging larvae, and assessing handling effects.

Annual larval sampling within treated and untreated areas before and after propagation will be needed to assess growth and survival rates. This work should be done within target areas and areas supporting natural production of Pacific lamprey. This will allow the comparison of growth and survival rates between the two areas, especially if mark and recapture studies can be incorporated into the sampling. Electrofishing techniques modified for sampling larval lamprey may be the most appropriate collection method for shallow water. Collected fish would be measured for length and weight, aged (method yet to be developed), and marked or tagged (standard method yet to be developed).  A separate study would be needed to determine the effects of shocking, handling, and marking/tagging on larval lamprey growth and survival. This work would likely be conducted in a laboratory. Finally, lamprey biologists will need to identify a protocol for sampling habitat conditions.

### *Analysis*

An appropriate model would be used to estimate growth and survival from mark-recapture data. These rates would then be compared between hatchery reared and naturally produced larvae. Alternatively, focus can be on sampling in areas where the hatchery reared and naturally produced larvae are well isolated from each other, if it is assumed that immigration and emigration rates are minimal between the sampling dates. Because data will be collected annually, a time series of annual growth and survival rates can be generated and compared between populations and laboratory studies. Correlation and regression techniques can be used to assess the relationships among habitat conditions, larval abundance, growth rates, and potentially survival rates.

Although techniques are not currently standardized for continuously measuring growth and survival rates, length, weight, and condition factors can be compared among areas or groups of fish. In addition, using correlation and regression techniques, these factors can be evaluated to see if they are associated with densities (density-dependent effects) and habitat conditions.

#### 4.3.3.2 Larval Abundance and Distribution

***Monitoring questions***

- How many larvae remained within the target areas over time?
- Did the distribution of released larvae expand into areas outside the target areas?
- Did release timing and location negatively affect the density and distribution of larval or juvenile lamprey within the target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval distribution and abundance?

***Performance metrics***

- Density of larvae (CPUE or fish/$m^2$)
- Distribution and abundance of larvae
- Presence and proportion of various size classes of larvae

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

***Approach***

An important assumption of propagation is that planted larvae will use intended rearing areas over time. Biologists will identify suitable release sites based on rearing conditions within those sites. If habitat is not suitable for rearing, hatchery reared larvae may leave the area or die. Even if the habitat is suitable, larvae may naturally migrate downstream over time. If biologists are able to identify suitable rearing areas that are used successfully by hatchery reared larvae, it may improve the status of Pacific lamprey within the subbasin.

Annual larval sampling within treated and untreated areas before and after propagation will determine the relative abundance of larvae within the target areas. Electrofishing techniques modified for sampling larval lamprey may be the most appropriate method for estimating relative abundance and distribution in shallow water. Locations of juveniles can be mapped using GPS. Lamprey biologists will need to identify a protocol for sampling habitat conditions.

***Analysis***

A time series of the densities (CPUE or fish/$m^2$) of larval lamprey and numbers of juveniles can be constructed to show how densities and numbers changed before and after the propagation and release of larvae. Direct assessment of the abundance and distribution of planted larvae can be implemented via parentage analysis to identify offspring of adults that were spawned in the hatchery. Distribution maps can be generated that show how the spatial extent of larvae expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and larval abundance and distribution.

#### 4.3.3.3 Larval and Juvenile Outmigration

See Section 4.3.1.5 for information on monitoring questions, performance metrics, approach and analysis.

#### 4.3.3.4 Adult Returns

See Section 4.3.1.6 for information on monitoring questions, performance metrics, approach and analysis.

### 4.3.4 Experimental Controls

For supplementation to be successful, larvae produced by translocated adults or released from hatcheries need to survive, grow, and eventually transform and migrate. Ideally, survival, growth, and transformation rates would be compared to values for areas not being supplemented. If survival, growth, and transformation rates are similar to or better than those measured for areas not being supplemented, then translocation or propagation would be considered a valid approach to improve the status of lamprey populations within subbasins. Feasible approaches may range from simple comparisons of adult returns among areas to actual comparisons of larval survival, growth and transformation among areas. Non-supplemented "control" areas might be distinct watersheds within a subbasin being supplemented elsewhere, or a nearby subbasin considered a suitable control. The use of experimental controls is implicit in most of the approaches described above.

### 4.3.5 Genetic Monitoring and Analysis

Recently, a set of 96 high-throughput genetic assays (single nucleotide polymorphisms, SNPs) have been developed for Pacific lamprey and have been demonstrated to perform the following three critical functions: 1) species identification, 2) parentage assignment, and 3) characterization of adaptive variation (Hess et al. 2014). These functions have important implications for the conservation of Pacific lamprey, and have already been applied successfully to specific management questions.

For example, 1) species identification via genetic analysis has been utilized to document a natural recolonization of Pacific lamprey in a tributary in which this species was thought to be extirpated (Hess et al. 2014). The putative Pacific lamprey larvae that were collected were all 0-year age class, which is a particularly challenging age class to morphologically distinguish Pacific lamprey from other species such as Western brook lamprey, however in this case all larvae were confirmed as Pacific lamprey.

2) Parentage assignment has been utilized to verify reproductive success of translocated adults that had been released in 2007 into Newsome Creek (Snake River Basin). A smolt trap was used in 2012 to collect over a hundred juvenile lamprey of which nearly 100% were successfully assigned back to their parents that had been translocated in 2007 (Hess et al. 2014). Therefore, types of information that parentage assignment can provide includes a direct measure of reproductive success of a group of adults (e.g. number of viable offspring per spawner pair) and an accurate method for aging offspring. This latter piece of information is particularly critical for refining our understanding of the relationship between larval size and age distributions, and the age-timing of juvenile lamprey life-stage transformations (i.e. ammocoete to macropthalmia).

3) Adaptive variation that was found to be associated with morphology, run-timing, and geography (Hess et al. 2013) can be characterized using the 96 high-throughput assays, and was demonstrated to reflect differences in body-size and run-timing among adults collected at Willamette Falls in the Lower Columbia River. Specific adaptive genetic markers will be characterized in the adults used for supplementation to assess how the genotypes of individuals may help predict their reproductive success at particular supplementation sites. Therefore, these three central functions of the 96 SNPs will provide critical pieces of information needed to implement effective monitoring of these Pacific lamprey conservation efforts.

# 5 Supplementation Research Plans for Individual Subbasins –General Outline

This section provides a template for Subbasin Supplementation Plans that will be integral components of the Regional RME Framework. Development of these plans is anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan (CRITFC 2011a), (2) USFWS Conservation Agreement for Pacific Lamprey (Lamprey Conservation Agreement; USFWS 2012) and (3) Northwest Power and Conservation Council Fish and Wildlife Program (NPCC 2009). In total, each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be developed in years 2016-2017 and a Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research scheduled to be completed in 2015. Plans provide information specific to a subbasin regarding lamprey status, limiting factors, ongoing and planed actions, and rationale for those actions. Plans describe supplementation actions and RME actions associated with supplementation, including metrics, parameters, etc. Although plans will vary in scope and content among subbasins, each plan should provide a minimum of information described here to facilitate consistency and continuity of important methods, analysis, and reporting formats. An example plan for the Yakima River Subbasin is provided for further guidance in Appendix D.

## 5.1 Introduction

### 5.1.1 Subbasin overview

Provide general information about the subbasin such as location, drainage size, annual and seasonal discharge, major topographic features, and important human population centers. Include information about major natural lakes and reservoirs, diversions, and other facilities potentially affecting passage or habitat quantity/quality. Briefly describe changes from the natural seasonal hydrograph, if any, and how changes in passage, habitat, and the hydrograph have affected Pacific lamprey.

### 5.1.2 Importance of Lamprey in the Ecosystem and as a Cultural Resource

Describe importance of Pacific lamprey to the ecosystem and tribal culture within the subbasin. Provide information on historic harvest sites, numbers, etc. if possible.

### 5.1.3 Brief Historic and Current Status and USFWS Findings for Subbasins

Briefly summarize subbasin-specific information from the 2011 USFWS Conservation Assessment. Include information on potential population groupings and historic and current status and trends. If available, include information on limiting factors and critical uncertainties. Summarize information in tables as appropriate.

### 5.1.4 Ultimate Goals and Vision: Natural Production and Harvest

State the overall goals or vision of the supplementation research plan. Demonstrate how these are consistent or complimentary with those of existing plans or programs. Examples may include the Tribal Restoration Plan, the Conservation Agreement, NPCC subbasin plans, or goals or plans of pertinent management entities.

## 5.2 Summary of Pacific Lamprey Status in the Subbasins

### 5.2.1 Adult Abundance, Run Timing, and Spawning Locations

Summarize as much historical and current information as possible to document information on adult Pacific lamprey abundance and distribution in the subbasin. Use tables as appropriate. Discuss the implications of continuing downward trends when relevant. Summarize information on run timing if available.

### 5.2.2 Juvenile Abundance and Run Timing

Summarize as much historical and current information as possible to document information on juvenile Pacific lamprey abundance and distribution in the subbasin. Use tables as appropriate. Discuss the implications of continuing downward trends when relevant. Summarize information on migration timing if available.

### 5.2.3 Ammocoete Abundance and Distribution

Summarize as much historical and current information as possible to document information on ammocoete abundance, distribution, and habitat use in the subbasin. Use tables as appropriate. Note if information is specific to Pacific lamprey or includes brook lamprey. Discuss the implications of continuing downward trends when relevant.

## 5.3 Analysis Units (Optional)

Provide justification for partitioning Pacific lamprey within the subbasin into analysis units if applicable. Preference would be to adopt USFWS groupings. Additional justification for groupings may include management areas, passage constraints, differences in habitat quality/quantity, or others. Provide a map of the subbasin highlighting the various analysis units.

### 5.3.1 Analysis Unit Descriptions

Use subsections to define and describe each analysis unit. These should be referenced from existing documents if possible to avoid the need to define new geographic units. Include geographic bounds (e.g., watersheds included), and general descriptions of Pacific lamprey abundance and distribution.

## 5.4 Summary of Pacific Lamprey Primary Limiting Factors

Describe known limiting factors and critical uncertainties for Pacific lamprey in the subbasin. Use a different subsection for each analysis unit if applicable. For each unit, describe factors for adults, juveniles, and larvae when possible. Use tables to summarize information. Example of limiting factors may include passage at dams and diversions (including juvenile or ammocoete entrainment), water quality, habitat quantity/quality, and others.

## 5.5 Lamprey Supplementation Research Actions over the Next 5-10 Years

Describe both ongoing and anticipated supplementation RME actions. Provide sufficient detail to fully describe and justify actions. Ensure that critical uncertainties, key hypotheses, and general monitoring strategies have been described. Include a summary of potential comparisons to assist in evaluating effectiveness of supplementation actions (Table 5-1 and Table 5-2). Describe any cross-regional efforts that are addressed. Examples of potential actions for the Grande Ronde, Tucannon, Walla Walla, Umatilla, and John Day subbasins, including comparisons and timelines, are provided (Table 5-3).

**Table 5-1. Numerical codes for monitoring and evaluating supplementation research strategies**. Strategies are described in Section 4.3 of the Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin; codes reflect the section number in the Framework document.

| Translocation | | Hatchery | | Outplanting | |
|---|---|---|---|---|---|
| **4.3.1** | Adult Translocation | **4.3.2** | Larval and Juvenile Rearing | **4.3.3** | Larval and Juvenile Outplanting |
| **4.3.1.1** | Adult Survival | **4.3.2.1** | Broodstock survival | **4.3.3.1** | Larval Survival and Growth |
| **4.3.1.2** | Adult Spawning | **4.3.2.2** | Fertilization to hatch survival | **4.3.3.2** | Larval Abundance and Distribution |
| **4.3.1.3** | Larval Survival and Growth | **4.3.2.3** | Hatch to outplant survival | **4.3.3.3** | Larval and Juvenile Outmigration |
| **4.3.1.4** | Larval Abundance and Distribution | | | **4.3.3.4** | Adult Returns |
| **4.3.1.5** | Larval and Juvenile Outmigration | | | | |
| **4.3.1.6** | Adult Returns | | | | |

**Table 5-2. Comparison chart displaying all potential comparison pairs of the different supplementation and research strategies.** T = Translocation; larval/juvenile lamprey from translocated adults. H = Hatchery; larval/juvenile lamprey born and reared in a hatchery environment. O = Outplanting; larval/juvenile lamprey hatchery reared and released into the natural environment. C = Control; larval/juvenile lamprey born and rearing in the natural environment.

| Comparison | Translocation | Hatchery | Outplanting | Control |
|---|---|---|---|---|
| Translocation | TxT | HxT | OxT | CxT |
| Hatchery | TxH | HxH | OxH | CxH |
| Outplanting | TxO | HxO | OxO | CxO |
| Control | TxC | HxC | OxC | CxC |

**Table 5-3. Lamprey supplementation research actions over the next 5-10 years within the Umatilla River Subbasin. See Table 5-1 and Table 5-2 for the monitoring and evaluation (M&E) and comparison codes.**

| Location | Supplementation Research Strategy | | | | | | | | Start Timeline | End Timeline |
|---|---|---|---|---|---|---|---|---|---|---|
| | Adult Translocation (T) | | Hatchery Rearing (H) | | Larval and Juvenile Outplanting (O) | | Control (C) | | | |
| | M&E Approach | Compariso n | M&E Approach | Comparison | M&E Approach | Comparison | M&E Approach | Comparison | | |
| Mainstem Umatilla River | 4.3.1.1 – 4.3.1.5 | TxC<br>TxH<br>TxT | -- | -- | -- | -- | -- | -- | Ongoing | 1-3 years<br>5+ years<br>1-3 years |
| Upper Maxwell Diversion | -- | -- | -- | -- | 4.3.3.1 - 4.3.3.2 | OxH<br>OxO | -- | -- | Ongoing | 1-3 years<br>1-3 years |

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# Appendix A. INVENTORY OF ARTIFICIAL PROPAGATION FACILITIES AND RIVERINE NURSERY AREAS ABOVE MCNARY DAM

**ADULT TRANSLOCATION SITES – GRANDE RONDE SUBBASIN**

| Subbasin | Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|---|
| Grande Ronde River | Minam StateRecreation Area Campground | Wallowa River, Rkm 13.4, accessed via Minam State Park Road<br>Lat: 45.636264°<br>Long: -117.728667° | Oregon State Parks | Riffle, pool and glide habitats adjacent; easy access from public road/land | Currently extirpated above Troy, OR | Redd surveys planned upstream and downstream of site; utilize existing screw trap efforts (ODFW or NPT); establish long-term juvenile sediment sampling index sites in lower Wallowa River | CTUIR will focus adult translocation in the Grande Ronde River basin. Adults have been released at this site since 2011; plans are to continue releases and monitor spawning success and population trend through time. |
| Grande Ronde River | Starkey/Upper Grande Ronde River above La Grande, OR | Grande Ronde River, Rkm TBD, accessed via Grand Ronde River Road/NF-51<br>Lat: TBD<br>Long: TBD | Private or USFS, depending on location chosen | Pool-riffle complexes; high in system; easy access from public road adjacent to river | Currently extirpated above Troy, OR | Redd surveys planned upstream and downstream of site; utilize existing screw trap efforts (above La Grande and in lower river near Troy), establish long-term juvenile sediment sampling index sites in Grande Ronde River below site | CTUIR will focus adult translocation in the Grande Ronde River basin. CTUIR will initiate adult releases and monitor spawning success and population trend through time. |
| Grande Ronde River | Catherine Creek near Union, OR | Catherine Creek, Rkm TBD, accessed via SR 203, SR 237 or Cove Highway<br>Lat: TBD<br>Long: TBD | Private - agricultural | Low gradient sinuous channels through agricultural matrix, with fine sediments. | Currently extirpated above Troy, OR | Sediment sampling could be used to document any existing population and potential for natural recolonization in tributary basin of Grande Ronde River. | Control site in basin without supplementation. |
| Grande Ronde River | Lookingglass Creek | Lookingglass Creek, Rkm TBD, accessed via Lookingglass Road<br>Lat: TBD<br>Long: TBD | ODFW | Confined riffle-run channel affected by road development and other adjacent structures, including the Lookingglass Creek Hatchery. | Currently extirpated above Troy, OR | Sediment sampling could be used to document existing population and potential for natural recolonization in tributary basin of Grande Ronde River. | Control site in basin without supplementation. |
| | | | | | | | |

**JUVENILE RELEASE/REARING SITES – WALLA WALLA AND TUCANNON SUBBASINS**

| Subbasin | Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|---|
| Walla Walla River | Touchet River | Touchet River, Rkms TBD, access via Ice Harbor Drive/SR 124 and/or S Touchet Road<br>Upper Touchet (above Dayton), approx.:<br>Lat: 46.278088°<br>Long: -117.953322°<br>Lower Touchet (below Prescott), approx.:<br>Lat: 46.294721°<br>Long: -118.340461°<br>Mouth at Walla Walla River:<br>Lat: 46.034036°<br>Long: -118.683803° | National Forest above Dayton, WA (Asotin County); private below, would need to obtain landowner permission in the lower river. | Upper Touchet River – above Dayton, WA (Asotin Co.): steelhead habitat that may be representative of typical lamprey spawning habitat; unconfined channel that meanders through a matrix of forest and lightly developed land.<br>Lower Touchet River – below Prescott, WA: channel remains relatively unconfined and meanders through an agricultural and partially undeveloped landscape; anticipate finer sediments, need more baseline conditions assessment. | Currently extirpated | Fisheries biologists believe there is an existing screw trap somewhere in the area– additional details/research needed. Objective would be to monitor the upper and lower river simultaneously, and attempt to distinguish between the pro-larvae and larger larvae outplanting strategies. | CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Walla Walla system. For the Touchet River, two different approaches to juvenile supplementation are proposed with the goal of evaluating differences in cost-benefit. These two strategies are: (1) outplanting pro-larvae, with minimal artificial rearing investment, higher up in the system, and (2) outplanting larger larvae, reared in the artificial environment for 1-2 years, lower in the system. |
| Walla Walla River | Mill Creek | Mill Creek above Bennington Lake Diversion, Rkm TBD, access via Mill Creek Road<br>Bennington Lake Diversion:<br>Lat: 46.079697°<br>Long: -118.254212° | Private up to National Forest boundary; would need to obtain landowner permission to access private portion of river. | Mill Creek is not channelized and includes meandering areas and backwater habitats above the Bennington Lake diversion. | Currently extirpated | Fisheries biologists believe there is an existing screw trap somewhere in the area– additional details/research needed. If used as a control site, monitoring would focus on the existing population and could be used to identify natural recolonization from adjacent streams as the population rebounds. | CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Walla Walla River system. For Mill Creek, the strategy will focus on outplanting pro-larvae with minimal artificial rearing investment above Bennington Lake diversion. An alternate strategy may be to use Mill Creek as a control system without outplanting. This may be a good strategy for Mill Creek because it is anticipated to be less productive than other streams in the Walla Walla River subbasin. |
| Walla Walla River | South Fork Walla Walla | South Fork Walla Walla River near existing acclimation pond, Rkm TBD, access via South Fork Walla Walla River Road<br>Acclimation Pond:<br>Lat: 45.859123°<br>Long: -118.222371° | Likely private unless outplanting occurs on the CTUIR/BPA property (acclimation pond) or upstream in National Forest | River is somewhat confined in narrow valley, with existing road and low levels of land development. | Currently extirpated | There are three known existing traps in the mainstem Walla Walla River below the confluence between the North and South Forks that are operated by CTUIR and could be used to monitor fish outmigration from the South Fork Walla Walla River. One of these traps is located where Walla Walla River Road/US 603 crosses the river. Another is located where Old Milton Highway/CO 448 crosses the river. The third is located off US 12 approximately 9 km upstream from the mouth of the Walla Walla River. | CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Walla Walla River system. For South Fork Walla Walla River, the strategy will focus on outplanting pro-larvae with minimal artificial rearing investment above Milton-Freewater, OR, and up to the vicinity of the existing South Fork Walla Walla River Acclimation Pond. |
| Walla Walla River | Lower mainstem Walla Walla | Walla Walla River between confluence with Touchet River and mouth at Columbia River, Rkm TBD, access via US 12<br>Confluence with Touchet River:<br>Lat: 46.034036°<br>Long: -118.683803°<br>Mouth at Columbia River:<br>Lat: 46.060571°<br>Long: -118.910810° | Private | Fine sediments and backwater conditions in lower river | Currently extirpated | An existing screw trap operated by CTUIR is located off US 12 approximately 9 km upstream from the mouth of the Walla Walla River. | CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Walla Walla River system. For the lower Walla Walla River, the strategy will focus on outplanting larger larvae, reared in the artificial environment for 1-2 years. |

| Subbasin | Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|---|
| Tucannon River | Tucannon River | Tucannon River near Wooten State Fish Hatchery, Rkm TBD, access via Tucannon Road<br>Wooten State Fish Hatchery:<br>Lat: 46.320471°<br>Long: -117.662954° | ODFW, private, or National Forest | Fine sediments are only present in the lowest reach of this river; in general, this basin has larger substrate. | Small remnant population, in decline and inadequate population replacement; limited captures in screw trap. | There is an existing screw trap in the lower river. Monitoring in the lower river may also include sediment sampling. Lower river monitoring could establish a baseline until outplanted juveniles higher in the system work their way down with time after outplanting. | CTUIR will evaluate the strategy of artificial propagation and outplanting juveniles as a supplementation tool in the Tucannon River subbasin. Only one outplanting strategy is proposed in this basin due to limited geography and habitat conditions (larger substrates). The strategy will focus on outplanting larger larvae, reared in the artificial environment for 1-2 years. A targeted survey will be performed to identify appropriate outplanting locations. Outplanting locations will be targeted to match steelhead habitat and/or existing lamprey spawning grounds, if they can be identified. |

**PROPAGATION FACILITIES – WALLA WALLA, TUCANNON, AND GRAND RONDE SUBBASINS**

| Subbasin | Site | Location | Owner | Current Use | Available Resources | Facility Features | Monitoring Opportunities | Other Benefits | Potential Concerns |
|---|---|---|---|---|---|---|---|---|---|
| Walla Walla River | South Fork Walla Walla Acclimation Pond | South Fork Walla Walla River<br>Rkm 8.49<br>Lat: 45.860102°<br>Long: -118.221686° | CTUIR/BPA | Adult holding and spawning of Spring Chinook; hold lamprey (May-Nov) for translocation and propagation programs before moving to Umatilla basin. | 5 Holding ponds (one dedicated for lamprey currently); potential to expand for larval incubation and rearing with hatchery addition anticipated in 2014 | Planned expansion as a hatchery in 2014 for incubation and rearing of Spring Chinook; excellent water quality/temp | Propagation and rearing studies, adult behavior experiments | Potential use for artificial propagation and outplanting, evaluating strategies for juvenile outplanting, and/or larval rearing. Will be expanded to become hatchery facility. | Space limitations – lamprey program may be expelled; two construction alternatives for hatchery expansion – one includes lamprey, one does not. |
| Walla Walla River | Water and Environmental Center (WEC) Laboratory at Walla Walla Community College (WWCC) | Near confluence of Titus Creek and Mill Creek<br>Lat: 46.077803°<br>Long: -118.274385° | WWCC | This new facility is oriented toward lamprey and mussels applied research, but is also available for a variety of other fishery research uses, including tagging of wild salmon. | A multi-lateral agreement (MLA) is in place between WWCC and CTUIR for office space and laboratory use. | Facility includes: circular ponds; raceways; aquatic laboratory facilities; and holding, spawning and early life history rearing facilities. | Laboratory resources are available for adult holding prior to spawning, incubation and early rearing. Juveniles reared at the lab can be outplanted into the upper and lower Walla Walla River, Mill Creek, and the Touchet River. | Abundant and diverse water sources (City water, Titus Creek runs through facility and may be tapped, Mill Creek runs adjacent to facility, existing plans to develop a new deep well). | N/A |
| Tucannon River | Tucannon Hatchery | Tucannon River<br>Lat: 46.320471°<br>Long: -117.662954° | WDFW | Spring Chinook, summer steelhead, rainbow trout | UNKNOWN | Potential use for adult holding, spawning and/or rearing | Potential to outplant in adjacent habitat reaches, and then monitor movement and/or return. | TBD | State-owned; no current agreement in place for lamprey use. |
| Grande Ronde River | Lookingglass Hatchery | Lookingglass Creek<br>Lat: 45.731528°<br>Long: -117.864519° | ODFW | Spring Chinook | Adult holding and circular ponds, rearing ponds | Potential use for adult holding, spawning and/or rearing | Potential to outplant in adjacent habitat reaches, and then monitor movement and/or return. Existing screw trap just downstream of the hatchery. | TBD | State-owned; no current agreement in place for lamprey use. |

**ADULT TRANSLOCATION SITES – YAKIMA SUBBASIN**

| Assessment Unit | Site | Location | Property Owner | Site Features | Population Status (2009-2012 Yakama Nation surveys) | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|---|
| Upper Yakima | Wenas | Wenas Creek near S Wenas Rd, Rkm 5.8<br>Lat: 46.713113° Long: -120.541115° | Private (rural) | Potential research site – single-thread channel. Very low flows, Wenas Creek over-allocated and highly regulated at dam by water users | Currently extirpated | Need | Need |
| | Taneum | Taneum Creek off W Taneum Rd, Rkm 5.0<br>Elk Meadows<br>Lat: 47.084974° Long: -120.757281° | Rocky Mtn. Elk Foundation Lands | Single thread, low gradient channel through cattle/elk pasture at canyon exit. Access off W. Taneum Rd via Thorp Cemetery Rd., exit off I-90 via S. Thorp Hwy | Currently extirpated | Instream flow needs. Flow-based geomorphic channel change analysis. | Downstream a short distance, KRD spillway flows into Taneum Cr. Potential flow-management/analysis site upstream vs. downstream. USBR/SOAC, KRD, and other irrigation district support/coordination would be required. |
| | Teanaway | Teanaway River off W Fork Teanaway Rd, Rkm 20.1<br>Lat: 47.256387° Long: -120.897924° | American Forest Land Company – Forest Service | Single thread, moderate gradient channel through ponderosa pine and doulas fir forest. Access via W. Fork Teanaway Rd. Stream in reasonable condition. Some impacts from prior timber land use. Some sediment loading from upstream slides. | Unknown | Need | Need |
| | Cle Elum | Cle Elum River downstream of Cle Elum Dam, Rkm 12.0<br>Lat: 47.244197° Long: -121.067785° | Need | Large single-thread river immediately downstream from spillway. Access via Cle Elum Dam. | Small population verified in 2012 | Potential to collect adults at Cle Elum spillway. Potential to configure macropthalmia collection system at, above or below spillway if lamprey are restored to upper Cle Elum (above lake). | Cle Elum River core monitoring station |
| Middle Yakima | Lower Ahtanum | Ahtanum Creek off Goodman Rd, Rkm 4.0, Union Gap area & La Salle<br>Lat: 46.547672° Long: -120.495850° | Mixed: private, school | Single thread, accessible via Goodman Rd, S. 42nd Ave and S. 62nd Ave. | Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek | Some electrofishing completed at site to verify population. Additional sampling possible | Population supplementation and document canal entrainment |
| | Mid Ahtanum | Ahtanum Creek off S 79th Ave, Rkm 16.5<br>Lat: 46.541407° Long: -120.610602° | Mostly private | Single thread, accessible via Lynch Ln., Carson Rd., Ahtanum Rd., Marks Rd., Stanton Rd., Wiley Rd., S. 90th Ave., and S. 74th Ave. | Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek | Need | Population supplementation and document canal entrainment |
| | Upper Ahtanum | Ahtanum Creek off Lynch Lane, Rkm 29.9<br>Tampico - At forks of N. Fk. And S. Fk Ahtanum<br>Lat: 46.528279° Long: -120.747768° | Mixed private – forest land | Braided channel through partially wooded floodplain. Access primarily from S. Fork Ahtanum Rd., south from Tampico. | Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek | Need | Population supplementation and document canal entrainment |
| Lower Yakima | Simcoe Creek | Simcoe Creek off Barks Rd, Rkm 2.0, White Swan<br>Lat: 46.386613° Long: -120.628231° | Mixed: Tribal, private | Single thread, intermittent. Accessible mostly at bridges: e.g. White Swan Rd., Wesley Rd. | Currently extirpated | Need | Population supplementation |
| Naches-Tieton | Lower Naches | Naches River near Cowiche Diversion, Rkm 3.8<br>Mapped as 40th Ave Exit<br>Lat: 46.626020° Long: -120.560948° | Private (rural) | Side Channel floodplain habitat and ponds on south (R) bank of Naches River. | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Population supplementation, document canal entrainment, and address flow management impacts |

| Assessment Unit | Site | Location | Property Owner | Site Features | Population Status (2009-2012 Yakama Nation surveys) | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|---|
| | Mid Naches | Naches River at S Naches Rd bridge, Rkm 21.7<br>Naches, Wa, S. Naches Rd.<br>Lat: 46.724084° Long: -120.699823° | Private-rural and quasi-municipal (Naches) | Channel downstream from S. Naches Rd. bridge is single thread with multiple side channels. Accessible off S. Naches Rd., Lewis Rd. immediately south of US -12 | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Population supplementation, document canal entrainment, and address flow management impacts |
| | Upper Naches | Naches River off SR 410, Rkm 38.9<br>Lat: 46.789604° Long: -120.871210° | Mixed private – national forest | Higher gradient, coarser substrate, cold water – may be less suitable to Pacific lamprey. | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Population supplementation, document canal entrainment, and address flow management impacts |
| Satus-Toppenish | Lower Satus | Satus Creek at Plank Road, Rkm 12.8<br>Lat: 46.290402° Long: -120.221004° | Mixed, Yakama Nation and private | Lower Satus Creek is a low-gradient single-thread channel located within the historic Yakima River floodplain, bisecting irrigated land, shrub-steppe uplands, and wetlands located in the Satus Wildlife Area. Accessible through wildlife area and public roads. | Small population verified in lower Satus Creek | Ease of access to Yakama Nation lands at Satus Cr. – Yakima R. confluence makes for opportune juvenile, macropthalmia and adult monitoring location. | Population supplementation & translocation evaluation site. Potential juvenile release sites in Satus Wildlife Area and adjacent WDFW lands. |
| | Upper Satus | Satus Creek at Rd 148, Rkm 31.0<br>Lat: 46.255659° Long: -120.394332° | Yakama Nation Forest Lands | Single thread, intermittent. Accessible off US-97 | Currently extirpated | Need | Population supplementation |
| | Lower Toppenish | Toppenish Creek near Lateral A Rd, Rkm 37.3<br>Lat: 46.325093° Long: -120.481040° | Mixed: Private, Federal (e.g. USFWS) | Lower Toppenish Creek is a low-gradient single-thread channel located within the historic Yakima River floodplain, bisecting irrigated land, shrub-steppe uplands, and wetlands. | Currently extirpated | Existing trapping for salmonids in lower Toppenish. Could augment with lamprey traps. | Population supplementation and document canal entrainment |
| | Upper Toppenish | Toppenish Creek at Fort Rd, Rkm 56.8<br>Lat: 46.375283° Long: -120.641224° | Mixed: Tribal, private, forested | Substantial areas of restoration, access to these sites and potentially others. Mostly open space shrub-steppe or agriculture | Currently extirpated | Need | Population supplementation and document canal entrainment |

**JUVENILE RELEASE/REARING SITES – YAKIMA SUBBASIN**

| Assessment Unit | Site | Location | Property Owner | Site Features | Population Status (2009-2012 Yakama Nation surveys) | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|---|
| Upper Yakima | Wenas Creek | Wenas Creek near S Wenas Rd, Rkm 5.8<br>Lat: 46.713113° Long: -120.541115° | Need | Research site? | Currently extirpated | Need | Supplement local population, evaluate survival, growth, density, dispersion and habitat use |
| | Lower Wilson | Wilson Creek off Thrall Rd, Rkm 2.0<br>Lat: 46.930942° Long: -120.503684° | Need | Need | Currently extirpated | Need | Need |
| | Lower Reecer | Reecer Creek off W Dolarway Rd, Rkm 0.25 – 1.6<br>Lat: 46.999895° Long: -120.575643° | Need | Need | Unknown | Need | Need |
| | Holmes Rearing Ponds | Yakima River off Oneil Rd, Rkm 260.7<br>Lat: 47.041405° Long: -120.628567° | Need | Good habitat for juvenile rearing, proximal to spawning habitat, coho spawning channel located above the rearing ponds | Currently extirpated | Need | Supplement local population, evaluate survival, growth, density, dispersion and habitat use |
| | Gladmar Park Side Channels | Yakima River off Gladmar Park Rd, Rkm 262.7<br>Lat: 47.050235° Long: -120.644894° | Need | Need | Small population verified in one location near Cle Elum in 2012 | Need | Need |
| | Teanum Creek | Taneum Creek off W Taneum Rd, Rkm 10.1<br>Lat: 47.090062° Long: -120.813649° | Need | Need | Small population verified in one location near Cle Elum in 2012 | Need | Supplement local population, evaluate survival, growth, density, dispersion and habitat use |
| | Church Property | Yakima River off SR 10/Airport Rd, Rkm 291.5<br>Lat: 47.172134° Long: -120.857112° | Need | Need | Small population verified in one location near Cle Elum in 2012 | Need | Need |
| | Easton Side Channels | Yakima River off Shady Glen Dr, Rkm 322.0<br>Lat: 47.222670° Long: -121.128635° | Need | Need | Small population verified in one location near Cle Elum in 2012 | Need | Need |
| | Cle Elum Side Channels | Yakima River off Iron Horse Trail, Rkm 306.6<br>Lat: 47.174812° Long: -121.009934° | Need | Need | Small population verified in one location near Cle Elum in 2012 | Need | Supplement local population, evaluate survival, growth, density, dispersion and habitat use |
| Middle Yakima | Upper Ahtanum – Forks | Ahtanum Creek off Ahtanum Rd, Rkm 39.4<br>Lat: 46.523441° Long: -120.853438° | Need | Need | Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek | Need | Need |
| | Lower Ahtanum | Ahtanum Creek off McCullough Rd, Rkm 13.2<br>Lat: 46.551420° Long: -120.579333° | Need | Need | Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek | Need | Need |
| | Lower Ahtanum – La Salle | Ahtanum Creek off Goodman Rd, Rkm 4.3<br>Lat: 46.547440° Long: -120.498270° | Need | Need | Small population verified in lower Ahtanum Creek and in Yakima River near mouth of Ahtanum Creek | Need | Need |
| Lower Yakima | Wapato Dam | Yakima River downstream of Wapato Dam, Rkm 175.0<br>Lat: 46.519073° Long: -120.471495° | Need | Need | Presence verified | Need | Need |
| Naches-Tieton | Stills Pond by Gleed | Naches River off McCormick Rd, Rkm 9.4<br>Lat: 46.650052° Long: -120.611270° | Need | Need | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Need |
| | Naches Trout Hatchery Side Channel | Naches River off Young Grade Rd, Rkm 10.5<br>Lat: 46.654728° Long: -120.627931° | Need | Need | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Need |
| | Eschbach Park | Naches River off S Naches Rd, Rkm 13.2<br>Lat: 46.672399° Long: -120.646605° | Yakima County | Good habitat for juvenile rearing, good access from S Naches Rd | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Supplement local population, evaluate survival, growth, density, dispersion and habitat use |

| Assessment Unit | Site | Location | Property Owner | Site Features | Population Status (2009-2012 Yakama Nation surveys) | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|---|
| | Cowichie Creek Mouth | Cowiche Creek off Clover Ln, Rkm 0.4<br>Lat: 46.628131° Long: -120.573250° | Need | Need | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Need |
| | 40th Ave Exit Side Channel | Naches River near 40th Street, Rkm 3.0<br>Lat: 46.624622° Long: -120.550643° | Need | Need | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Need |
| | Naches River Side Channel | Naches River off Lewis Rd, Rkm 20.8<br>Lat: 46.719707° Long: -120.692676° | Need | Need | Small population verified in Naches River and in Yakima River near mouth of Naches River | Need | Need |

**PROPAGATION FACILITIES – YAKIMA SUBBASIN**

| Assessment Unit | Site | Location | Owner | Current Use | Available Resources | Facility Features | Monitoring Opportunities | Other Benefits | Potential Concerns |
|---|---|---|---|---|---|---|---|---|---|
| Upper Yakima | Cle Elum Hatchery | Yakima River Rkm 303.0 | Yakama Nation | Spring Chinook rearing | Existing raceways not being utilized, spawning channel, natural side channel for potential rearing | Water temperature modulation, high water quality | Propagation; rearing and feeding of larvae; Tests on adult and juvenile fish behavior | Located high in the watershed, good rearing habitat available in adjacent side channel, potential source of pheromone attraction into prime spawning reach | Potential interactions between spring Chinook and lamprey. |
| | Holmes Acclimation Ponds | Yakima River Rkm 260.7 | Yakama Nation | Floodplain mitigation – pasture, residence | Currently being developed for coho program and has both spawning channels and rearing ponds | 50 ac land area. Potential 12.6 ac available for facility development, approx. 4 ac wetland/floodplain meander scroll | Test rearing potential of salmon acclimation ponds; spawning recruitment relationship | Water rights on property acquired. Grant applications suggested water is to go to instream flow. Convert some to fish production? | Can coho and lamprey program goals both be achieved at this location? |
| Lower Yakima | Marion Drain | Yakima River Rkm 134.4 | Yakama Nation | None | Current design includes construction of buildings and ponds for lamprey propagation program | Existing well water on site, infiltration gallery proposed | Collection of macropthalmia and returning adults | Potential for rearing in adjacent riverine wetland areas; proximal to Yakama Nation office | Potential attraction of adults towards Marion Drain; requires investment and development of infrastructure. |
| | Prosser Hatchery | Yakima River Rkm 74.4 | Yakama Nation | Kelt re-conditioning, Spring/ Summer/ Fall Chinook, Coho | Adequate space to implement proposed upgrades for lamprey propagation; existing spawning channel; sediment pond available for rearing; experienced staff on site | Surface and well water | Propagation; rearing and feeding of larvae; Tests on adult and juvenile fish behavior; effects of contaminants | High water quality; efficiency - potential to re-use sturgeon water; adjacent stream potentially available for modification as rearing habitat | Low in watershed; lack of good spawning and rearing habitat in immediate vicinity |
| | Yakima Groundwater Recharge Channel | Yakima River Rkm 182.4 | City of Yakima | None | City of Yakima is studying feasibility of running treated water from a treatment facility into a constructed channel for groundwater recharge | Surface water (through inlet) | Test rearing potential of restored side channels | Great pilot site to assess survival/movement over multiple years | Can lamprey survive year round in the restored side channel? |

# Appendix B. Comments on Previous Framework Draft by ODFW, WDFW, IDFG, and USFWS

# 1 Introduction

## 1.1 Background

Pacific lamprey (*Entosphenus tridentatus*) is an anadromous fish species that has occupied freshwater rivers of western North American for the last 350 million years. These ancient fish are distinct from other fish within their range – lampreys are jawless, have no scales, and lack paired fins. Since pre-historic times, Native Americans have utilized lamprey for important subsistence, ceremonial, and medicinal purposes. Pacific lamprey are also important ecologically because they provide marine-derived nutrients to the freshwater riverine environment and the aquatic and terrestrial food web (Beamish 1980; Brown et al. 2009) and provide a high-calorie prey source for various marine and freshwater species.
Today, Pacific lamprey return to the Columbia River Basin (CRB) at a fraction of their historical numbers; daytime counts of adult Pacific lamprey at Bonneville Dam have declined from an estimated 400,000 in the 1960's and 1970's to lows of approximately 20,000 in 2009 and 2010 (CRITFC 2011a). At Willamette Falls, a traditional harvest location on the Willamette River, estimates of harvest declined from about 400,000 in the 1940's to about 4,000 in 2001 (Ward 2001).
Recent studies on this alarming trend of Pacific lamprey decline in the CRB cite the construction of hydroelectric and flood control dams, irrigation and municipal water diversions, habitat degradation and loss, poor water quality, excessive predation, contaminants, ocean cycles, prey-species availability, and targeted chemical eradication as major contributors (Close et al. 1995; CRITFC 2011a; Luzier et al. 2011; Murauskas et al. 2012). Despite recent implementation of passage improvements at mainstem and tributary dams, habitat improvements, and adult lamprey translocation efforts, (CRITFC 2011a; Luzier et al. 2011; Ward et al. 2012), adult returns remain relatively low and spatial distribution is increasingly limited to the lower portions of the CRB. Pacific lamprey have been extirpated from many subbasins in the interior CRB (Close et al. 1995; USFWS 2007; Luzier et al. 2011). Considering their low numbers and their apparent value to the ecological health of the CRB, the time to address and recover lamprey stocks is now. Ecological effects include reductions in marine derived nutrients and the potential prey base.

The absence of lamprey in the interior CRB also represents a significant cultural loss (Close et al. 1995). The decline of lamprey has a number of cultural impacts, including: (1) loss of tribal heritage, (2) loss of fishing opportunities in traditional areas, and (3) necessity to travel great distances to the lower CRB for ever-decreasing lamprey harvest opportunities. As a consequence of reduced or eliminated harvest in the interior CRB, young tribal members are losing historically important legends associated with lamprey because they have not learned harvest and preparation methods.
Because of the long, complex, and poorly understood life history of Pacific lamprey, existing environmental conditions in the CRB, and scarcity of data, it remains unclear how quickly lamprey will recolonize extirpated streams, especially in the upper reaches of the CRB. Passage for adult lamprey is low (adult passage at mainstem dams hovers around 50%; Keefer et al. 2012), so natural recolonization of upper reaches may require extensive time, perhaps decades, considering that lamprey life history spans approximately 10 years. Efforts to utilize alternative management strategies such as supplementation to aggressively maintain and reestablish Pacific lamprey in specific locations have recently increased.

**Comment [JAE1]:** Is this true? I was not aware that targeted chemical eradication of PL had occurred in the CRB. What documentation do we have? I thought chemical eradication only occurred in the Great Lakes region to control invasive Sea Lamprey that bypassed Niagra Falls through the Welland Lock/Canal.

**Comment [DBJ2]:** An important goal of the supplementation program would be to boost adult returns to the interior CRB to allow for more tribal harvest for food and cultural use of lampreys, which has been severely reduced in recent years. If supplementation is successful and millions of captive-bred larvae are planted in the interior CRB, it essentially increases the rearing capacity of the species and will likely increase the number of adults returning to spawn in the Pacific Northwest. However, current data suggest that Pacific lamprey do not home to their natal spawning grounds as do salmon, rather they will mix with the largely panmictic population of the Pacific Northwest. Only a fraction of the increase of adults will even attempt to access the interior CRB; and because of dams hindering upstream passage, only a tiny fraction of those will make it to the interior CRB. This suggests that supplementation in interior CRB may provide little bang for the buck in adult returns in this region. This research framework draft should be clearer about the connection between supplementation and expectations of adult returns in the interior CRB.

**Comment [DBJ3]:** So is the conservation objective of this research to implement supplementation actions? Or is it to inform future/current conservation actions in an adaptive and structured decision-making process? Maybe insert a paragraph here that really outlines this body of RME relative to risk reduction strategies such as dam passage and habitat restoration. Define here why lamprey supplementation is different than salmonid supplementation, where the later is seen as a short –term experiment to be implemented once the factors of decline are addressed.

**Comment [DBJ4]:** Alternative to what?

-unsure about upstream recolonization rates, passage is bad (and there are other issues), effort is occurring to improve, many upstream locations have no lamprey, difficult to assess passage issues for upstream/downstream movement, this may require short-term actions to accurately assess issues—which will require fish, also in the long-term recolonization/seeding of streams will require fish—supplementation—both of these actions will require fish,--(1) propagation of fish, (2) translocation of fish, (3) monitoring and evaluation strategies
This document is a "framework" for monitoring and evaluating potential short and long-term supplementation approaches
Goal of the framework—develop a RME framework for implementing short and long-term supplementation approaches to (1) improve status in certain subbasins, maintain presences, bypass difficult migration corridors, assess upstream movements = **Translocation**, (2) maintain presence, assess passage/habitat issues, develop release strategies, = **release of art. prop. fish**, (3) improve status, significantly increase larval/juvenile output, recolonize extirpated streams, = **release of art. prop./full scale hatchery fish**

**Comment [DBJ5]:** As we discussed in the meeting, perhaps this is a place where you communicate co-manager buy-in and decisions process (i.e. jurisdictions, regional goals, existing plans/agreements, allowances under scientific take permits, other potential permitting issues, etc.).

## 1.2 Supplementation Approaches

Pacific lamprey supplementation is defined here as an interim production facilitation strategy that supports region-wide efforts to reduce known threats to self-sustaining (natural) productivity. Facilitation actions include either the translocation of surplus adults from one watershed to a watershed with poor adult recruitment, or artificial propagation of larvae (ammocoetes) and juveniles (macrophthalmia) in a hatcheryfor release into a watershed that is underseeded. . . Section 5 of this Supplementation Research Framework describes guidance on how supplementation can be incorporated into subbasin-specific plans for lamprey recovery. Initial trials and accompanying monitoring and evaluation activities will better inform fish managers on how to use supplementation as a restoration tool.

**Comment [DBJ6]:** As a general rationale for the use of artificial production:
- it could beneficially help with reintroductions in upriver tributaries where lamprey are extinct.
-it could supply a source of lampreys for research so the researchers throughout the basin could stop or cut back on use of wild lampreys.
- there are low risks to planting artificially-produced lampreys in a basin where they are extinct. The lampreys might be wasted, but they won't cause a risk.

**Comment [DBJ7]:** Need a paragraph here on the risks/considerations involved in taking adult fish from a productive watershed and putting them into one that by definition has some lamprey issues. That is a risk and regional co-managers may have concern about best investment of wild adults.

### 1.2.1 Adult Translocation

Translocation is defined as the collection of adult Pacific lamprey from one location and transport for release into another location where they are extirpated or scarce (Ward et al. 2012). Translocation has been successfully implemented by several treaty tribes in the Mid-to Upper Columbia River and Snake River basins, though well-designed post-reintroduction monitoring programs are imperative to documenting success (Close et al. 2009; Ward et al. 2012). In the short term, these efforts are designed to increase larval abundance and maintain a larval connection, through pheromone signals, to returning spawning adults. Translocation is not designed to be a long-term restoration strategy but rather a short-term, stop-gap measure to maintain lamprey presence while known limiting factors and critical uncertainties are addressed. Although monitoring and evaluation of these efforts has yielded substantial information about effectiveness and has contributed to critical life history information for lamprey, it remains unclear whether efforts will result in increased adult returns in the future.

**Comment [DBJ8]:** Good; but what are the criteria to stop doing it?

### 1.2.2 Larval Outplanting

A second strategy to improve the status of Pacific lamprey within a subbasin is to outplant larval Pacific lamprey into targeted areas. This requires successful collection, holding, spawning, incubation, and rearing of Pacific lamprey in a hatchery environment. It also requires the identification of suitable locations for the release of larval lamprey. Research on propagation of lamprey in hatchery settings began in the 1980s in Finland to address declines of an important commercial fishery. Over time, the success of lamprey propagation progressed to a level in Finland where fisheries managers were able to produce 17 million larvae per year for release into the Perhonjoki River between 1997 and 2009 (CRITFC 2011b). Unfortunately, very little post-release monitoring has been conducted in Finland or other countries.

### 1.2.3 Juvenile Outplanting

The third strategy to improve the status of Pacific lamprey within a subbasin is to outplant older larval and juvenile Pacific lamprey into targeted areas. Protocols for rearing larvae for extended periods of time (years) to produce juvenile are lacking. In addition, the benefits of rearing fish to the juvenile stage may be difficult to assess because fish ready to immediately transform and migrate may not release the pheromones thought to attract returning adults

## 1.3 Research and Monitoring Needs

Because of the low returns of lamprey and the assumption that successful natural recolonization will require a long-term strategy, CRB Tribes and regional agencies have increasing interest in beginning research on the use of artificially propagated larval and juvenile lamprey in short and long-term supplementation efforts (CRITFC 2011a; USFWS 2012). In the short term, artificially produced larvae and juveniles would be used as a research tool to evaluate critical uncertainties and limiting factors of the species as well as its potential use in supplementing the locally extirpated populations. Many important questions regarding the biology of Pacific lamprey remain unanswered to date, such as the age classes of all three life stages (ammocoetes, macrophthalmia, adults), the natural annual growth and survival rates of larvae, and the general migration behavior of larvae before transforming to macrophthalmia. All these questions are absolutely essential in developing a life stage survival model for Pacific lamprey which will lead to better conservation and management of the species. Through the use of artificial production and genetics analysis tools, we have the opportunity to make incredible advancements in these unanswered biological questions.

Besides laboratory use, some larval lamprey will be established in extirpated streams to evaluate important questions related to the viability of the local population (i.e. limiting factors, passage barriers, pheromones). If larvae and juveniles are absent or functionally absent in these extirpated or near extirpated regions, there is virtually no way to identify and resolve the region-specific threats for the species. For instance, if irrigation diversions are a potential serious threat to migrating larval and juvenile lamprey, without the presence of larval lamprey either in the system or alternatively in lab settings, nothing can be effectively tested and evaluated to seek mitigation or resolution of the problem.

Artificially produced lamprey may also be used to supplement CRB lamprey by dramatically increasing larval/juvenile numbers, albeit in the short-term, with the goal of effectively compensating for the natural declines in adult returns. By doing this, we will not only allow the species to function its natural ecological purposes in these extirpated streams and rivers, but it will also provide an opportunity to evaluate important

**Comment [DBJ9]:** So the goal/objective is to improve the status within a subbasin, and I assume this is without doing any harm to the status in other basins?

**Comment [SMN10]:** Time-line? And what is the long-term strategy?

DW: Reference the USFWS Conservation Template and the Tribal Restoration Plan. Tribal plan says "sustainable harvestable levels" by 2050

**Comment [BM11]:** Again need to check point of view within this document—who is the WE

**Comment [H12]:** Hatchery propagation

**Comment [SMN13]:** Long-term is repeated throughout this document but I am unclear on what sort of timeline we are talking about or how we will use this framework to inform long-term thinking/strategies.

**Comment [H14]:** Assumes that hatchery larvae will successfully migrate and return

**Comment [DBJ15]:** These are interesting research questions but supplementation is not necessary to pursue these questions. For example, lifestage survival models using parentage-based genetic analysis could be developed anywhere spawning or migrating adults can be captured (like Smith River falls, Umpqua River Basin); and different types of irrigation diversion screens are tested in lab studies (e.g., Rose and Mesa 2012) using larval lampreys that can be readily collected from areas of larval abundance in the wild using relatively simple capture techniques.

-Another consideration is density dependent effects-i.e. survival might be higher if you have 2 lamprey per basin than 100 lamprey per basin-i.e. spread out the breeders to maximize juvenile survival ... [1]

**Comment [H16]:** I don't think the model should be the focus. The focus should be on identifying the bottleneck to increased adult returns. The model is a tool for evaluating conservation strategies.

**Comment [H17]:** I agree but restoration should focus on the major limiting factors. For example if upstream adult passage is the primary concern ... [2]

overarching biological questions, such as stream selection criteria for returning spawning adults. For example, we can effectually evaluate whether these larvae can attract upstream migrating spawning lamprey and contribute to increased recruitment, which is a vital management question.
Finally, if Pacific lamprey numbers continue to decline in the near future, there may be a need for conservation hatchery to protect the viability of the species and its remaining genetic diversity. The techniques and methods required for a successful conservation hatchery do not develop in a short time span, especially for an exceptionally cryptic and surreptitious species such as lamprey. It is important that we begin learning and advancing conservation hatchery techniques and methods as soon as possible, so that they are available when needed. This will also help us advance our knowledge on many of the important existing knowledge gaps in biology.

Supplementation of Pacific lamprey has potential benefits and risks. Taking no action also has risks. Potential risks of lamprey supplementation are not all known, but may include disruption of any connection between stock structure and particular subbasins (genetic risk), moving fish to areas with substantial limiting factors, introduction of pathogens and disease, and decreases in abundance from donor areas. Risks of taking no action include maintaining and increasing areas of extirpation, enhancing potential for "Founders Effects" in watersheds with low return rates, continued loss of ecological role served by lamprey, and continued loss of cultural heritage.

Before supplementation of Pacific lamprey with artificially propagated fish can be used, it is important to develop and assess this type of strategy to the extent possible. Preliminary work includes (1) the development of basic propagation and rearing techniques for lamprey, (2) an assessment of the cost/benefits of releasing artificially propagated fish into the environment, and (3) the development of consistent and standard protocols for monitoring and evaluating artificial propagation releases. In short, before supplementation with artificially propagated lamprey can be utilized, basic research needs to occur to (1) refine existing supplementation methods (translocation), (2) develop new methods (artificial propagation), (3) assess feasibility of artificial propagation, (4) identify existing facilities and prospective new facility locations within the CRB to support development and implementation of artificial propagation, (5) identify natural riverine features within the CRB to provide spawning and rearing sites for artificially propagated pre-adult Pacific lamprey, and (6) develop and refine research, monitoring, and evaluation (RME) methods for long-term supplementation strategies. It is important to understand the inherent risks (generally associated with genetics) of supplementation, and be mindful of two important concepts: "do no harm" and "risk management" for both the donor and recipient areas.

For these reasons, a significant planning effort, led by the CRITFC tribes, has been undertaken by regional fishery managers to guide the use of Pacific lamprey supplementation as a short-term research and long-term restoration tool in the CRB. Three distinct, yet inter-related products will be developed over time:

1. Regional Framework for Pacific Lamprey Research, Monitoring, Evaluation and Reporting in the Columbia River Basin (RME Framework) which will encompass a broad scope of ongoing and needed research, monitoring and restoration activities;

2. Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin (Supplementation Research Framework) which will focus specifically on coordination and continuity in research and reporting of information associated with emerging and active lamprey restoration strategies such as propagation, reintroduction, translocation, and augmentation; and

**Comment [SMN18]:** What are we doing to address the threats? I.e. passage at mainstem dams?

**Comment [BM19]:** Perhaps in the early paragraphs we cite something that highlights all of the potential/important threats to lamprey survival—USFWS assessment, CRBLTWG critical uncertainties

**Comment [SMN20]:** I think it is premature to state the need for a conservation hatchery bc we really don't know if artificial propagation is do-able. Might be better stated that research is needed to determine if conservation hatcheries are a viable recovery tool for lamprey.

**Comment [DBJ21]:** Conserving the remaining genetic diversity and overall viability of the species assumes that the Pacific lamprey is facing an imminent loss of genetic diversity and the viability of the species is actually threatened. If the interior CRB is really part of a panmictic population that include Oregon and Washington, as the genet ... [3]

**Comment [H22]:** This is absolutely critical to develop culture techniques prior to dangerously low abundance.

**Comment [SMN23]:** I struggle with discussion of supplementation risks when we haven't discussed specific threats - perhaps that level of detail w ... [4]

**Comment [DBJ24]:** This research framework summarizes some of the valid risks of supplementation thorough artificial propagati ... [5]

**Comment [H25]:** Hatchery

**Comment [H26]:** This section is about artificially propagated lamprey so the translocation is out of place.

**Comment [H27]:** Are these captive reared to maturation or captive broodstock?

**Comment [SMN28]:** One focus of this framework is to research & develop long-term supplementation strategies. I know we at grou ... [6]

**Comment [SMN29]:** Is the intent of all products to be adopted by all fisheries managers? I.e. tribal and non-tribal? Need to define process for ... [7]

3. Pacific Lamprey Restoration and Supplementation Research Subbasin Plans (Subbasin Supplementation Research Plans) which will summarize ongoing and proposed lamprey restoration activities in CRB subbasins within the context of the RME Framework and the Supplementation Research Framework described above such that consistency and continuity of important methods, analysis and reporting formats can be achieved.

This document focuses on the Supplementation Research Framework and a template for Subbasin Supplementation Research Plans (Items 2 and 3), which will be integral components of the larger RME Framework (Item 1). Collectively, these documents are anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan (CRITFC 2011a), (2) USFWS Conservation Agreement for Pacific Lamprey (Lamprey Conservation Agreement; USFWS 2012) and (3) Northwest Power and Conservation Council (NPCC) Fish and Wildlife Program (NPCC 2009). In total, each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be developed in years 2016-2017.

# 2 Pacific Lamprey Genetic Structure

Influence on genetic integrity is a primary concern for all supplementation efforts, but the field of regional genetic study of Pacific lamprey is still in its infancy. Although much more work is needed to better understand lamprey genetics, compared to salmonids, lamprey appear to exhibit low genetic differentiation among regional stocks, and its population structure reflects a single broadly distributed population across much of its range in the Pacific Northwest (e.g., Goodman et al. 2008, Spice et al. 2012). The need for genetic diversity in artificial salmonid propagation and rearing programs has been well documented. With salmon, collecting broodstock across the entire run is advised to maintain the genetic diversity of supplemented populations (Cuenco et al. 1993; Bilby et al. 2003). Genetic heterogeneity among a population's individuals is a basic driving principle for sustainability to reduce the potential for deleterious population effects, including inbreeding depression. This genetic principle is applicable to all species, including Pacific lamprey, and provides organisms the ability to exhibit a selective response to environmental variability.

Another well-established premise for artificial propagation in salmonids is the use of locally-adapted broodstock. Such local stock may be comprised of individuals that are adapted to specific conditions in a basin, and subsequently exhibit higher fitness. However, in comparison to salmonids, Pacific lamprey do not appear to exhibit strict natal homing (Goodman et al. 2008; Hess et al. 2013; Spice et al. 2012). For this reason, unlike salmonids, the spatial scale that contains locally-adapted broodstock may be much broader for Pacific lamprey, and thus the specific watershed- or subbasin-of-origin of this broodstock may not be critical to the success of artificial propagation programs for Pacific lamprey.

Hess et al. (2013) concluded that although neutral genetic variation (i.e., gene variants detected have no direct effect on fitness) in Pacific lamprey is influenced by geography and adult phenotypes, there is high gene flow among individuals collected from the Columbia River, Oregon and California. However, Hess et al. (2013) and Lin et al. (2008) documented significant genetic differences among fish from different large-scale geographic regions but Lin et al. 2008 found no obvious geographical pattern of gene flow or differentiation in samples from the Pacific Northwest

(i.e., Washington, Oregon and California). The choice of genetic marker may have some bearing on the results of the genetic studies that have been conducted on Pacific lamprey. For example, the findings of Lin et al. (2008) and Hess et al. (2013) were obtained using relatively large numbers of amplified fragment length polymorphism and single nucleotide polymorphism markers, respectively. These types of markers have high potential to represent adaptive variation from genomic regions under selection, which was one of the primary goals of the study by Hess et al. (2013). In contrast with patterns from neutral variation, adaptive variation was shown to drive relatively large genetic divergence between regions, even within the Columbia River between the lower river and interior tributaries (Hess et al. 2013).

Other genetic studies using putatively neutral markers (based on microsatellites and mitochondrial DNA) have provided evidence of high rates of gene flow across much of the range of Pacific lamprey with low geographic association among samples (Goodman et al. 2008; Spice et al. 2012). Results from Spice et al. (2012) suggest that most Pacific lamprey in the Pacific Northwest could be managed as a single unit. In contrast, Lin et al. (2008) stated that the scale over which genetically significant management units are categorized (e.g., stocks, populations, distinct population segments) requires additional clarification through more study. Recently, however, the USFWS (Luzier et al. 2011) divided Pacific lamprey into ten Regional Management Units (RMUs). The division of lamprey stocks into regional units was not based on genetic information, but is intended to allow for a more refined level of life history and data collection from each RMU. At this time, the USFWS (2012) believes that "dividing management units into finer geographic scales would provide a risk-averse approach for conserving Pacific lamprey".
Despite some conflicting results, genetic studies generally corroborate the pattern that rates of gene flow are high among Pacific lamprey, particularly in the Pacific Northwest. The pool of potential donor-stock for artificial propagation or translocation programs may therefore be larger for lamprey than, for example, salmon. Similar genetic composition could be viewed as an advantage because healthy donor-stocks could be obtained from any RMU and translocated, or seeded, into suitable watersheds throughout the Pacific Northwest.

Still, from the viewpoint of conservation management vs. supplementation, Hess et al. (2013) emphasize that, although lamprey are capable of high levels of gene flow across most of their range, it is important to maintain "local" diversity (a suitable geographic area has not yet been described), primarily those adaptive genetic variants that respond to localized conditions. This would indicate that broodstock management and collection protocols must be cognizant of the need to maintain the diversity of donor-stock when faced with the potential for artificial propagation (i.e., hatchery programs). Similarly, the "mining" of donor-stock associated with lamprey translocation programs should not cause a substantial decrease in abundance in any currently occupied subbasin (Ward et al. 2012).

## 2.1 Genetic monitoring and analysis

The potential risks of supplementation tools have been recognized, and measures to minimize risks are outlined in the lamprey translocation guidelines agreed to by the Columbia River Inter-Tribal Fish Commission (CRITFC 2011a; Ward et al. 2012). Although consideration should be given to potential disruption of stock structure and associated genetic adaptations from sources, the risk of adverse effects associated with the continued downward trend in abundance may outweigh the potential loss of some adaptive genetic variants in isolated areas (Ward et al. 2012) This is particularly true in areas where numbers are decreasing rapidly. In these areas, it is possible that so few adults find their way into the watersheds that they may have trouble finding mates and the potential for genetic founder effects is increased. Given general support among

**Comment [SMN30]:** I have not had a chance to review this document.

genetics findings that a single homogenous population of Pacific lamprey exists throughout the Columbia River and Pacific Northwest region, there is likely less risk in temporary supplementation to increase abundance and genetic diversity.

Part of the planned monitoring that is described in this framework includes a genetic analysis component that will provide a means for tracking genetic diversity and the fitness consequences (if any) that are associated with genetic variation of lamprey used for translocation/outplanting. Genetic analysis will allow us to directly measure reproductive success of translocated lamprey adults and/or outplanted larvae (e.g. via parentage assignment of putative offspring), as well as provide a way to assess the genetic background of each individual adult and test whether this background affects reproductive success in a particular environment. The other advantage of this genetic analysis is that the age of the larvae can be quantified accurately based on parentage assignment, allowing us to further our understanding of the age structure of Pacific lamprey at various life stages.

**Comment [H31]:** Parental Based Tagging.

**Comment [H32]:** If all spawning adults in a population are known.

# 3 Purpose, Need and Scope for Supplementation Research Framework

## 3.1 Purpose

A framework is an organized foundation or structure that supports an intended area of research or the development of strategies that focus on the achievement of specific objectives. The framework typically consists of concepts, existing data and information, and various theories related to a particular research topic that, when assembled, form the basis of understanding. Relative to fisheries research and management, this foundation determines how information is interpreted, what problems are identified, and a range of appropriate solutions (Independent Scientific Group 1996) to achieve the ecological conditions necessary to meet specific goals and objectives. Lichatowich (1998) compares a conceptual foundation (i.e., framework) to the process of assembling a puzzle, where the foundation is the cover of the puzzle box, displaying what the fully assembled puzzle should look like.

As applied to Pacific lamprey supplementation research and ultimately the recovery of Pacific lamprey in the CRB, the USFWS and various state and tribal entities have developed visions for fully recovered Pacific lamprey. In the recent Lamprey Conservation Agreement, the ultimate future vision for lamprey is the "long-term persistence of Pacific lamprey… throughout their historic range in the United States". This vision is consistent with that of the Tribal Pacific Lamprey Restoration Plan, which states that lamprey should be restored to sustainable, harvestable levels throughout their range by 2050. To this end, the development of this Supplementation Research Framework requires input from various stakeholders to ensure consistency in purpose, approach, analysis and reporting.

The purpose of this Supplementation Research Framework is to initiate the development of a regionally coordinated and long-term RME and reporting plan directed towards the implementation of supplementation and recovery actions for Pacific lamprey within the CRB. Additionally, this Supplementation Research Framework intends to "standardize" key elements of supplementation RME and reporting so that findings associated with status and trends and other important objectives can be reported in a common and consistent format. Finally, the Supplementation Research Framework provides specific guidance for the development of Subbasin Supplementation Research Plans.

The development of this regional Supplementation Research Framework is needed to coordinate supplementation RME on both a regional and local level. The Supplementation Research Framework will provide consistency and serve as a communication and management tool for stakeholders to remain focused on the overall goals of the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement.

This Supplementation Research Framework will be updated over time as new, pertinent information becomes available. Importantly, this Supplementation Research Framework is intended to serve as a foundation and template for consistency in the development of more specific Subbasin Supplementation Research Plans. Findings associated with local planning and activities informed by this Supplementation Research Framework will provide sufficient information to update the Tribal Pacific Lamprey Restoration Plan. This can ensure the consistency among

**Comment [SMN33]:** Likely missed it but what is the reporting plan?

**Comment [SMN34]:** On page 16 Section 3.3 the Scope of the framework is described as narrow in time (5years) and space (a few select basins) so how does that fit with long-term RME?

**Comment [H35]:** Separate R, M &E

**Comment [SMN36]:** Might be worth spelling out a process i.e. 5-year review of framework.

stakeholders in providing a more cohesive foundation for lamprey recovery in the CRB over the next five years, leading to the development of the Columbia River Basin Pacific Lamprey Management Plan. This management plan, envisioned to be developed in 2016– 2017, will (1) update the Tribal Pacific Lamprey Restoration Plan (2) provide guidance for activities undertaken through the Lamprey Conservation Agreement and (3) direct future funding through the NPCC Fish and Wildlife Program. Contributors to this Supplementation Research Framework clearly recognize that because of our lack of knowledge and resources, this is a "work- in progress" and will be revisited and updated periodically to incorporate new findings and reflect management direction.

## 3.2 Need

### 3.2.1 Pacific lamprey are in low abundance or extirpated in many mid to upper watersheds, especially above McNary Dam.

Abundance of Pacific lamprey has declined throughout the CRB, and counts decline rapidly from downstream to upstream areas (Table 1). Although counts at dams are incomplete, they serve as the only long-term index of Pacific lamprey abundance in the CRB. Annual cumulative daytime counts at Bonneville Dam prior to 1970 were regularly at least 50,000, with occasional peaks approaching 400,000 (Kostow 2002). Counts prior to 1970 at McNary Dam were generally in the few tens of thousands, but have decreased to less than 1,000.

In the Umatilla River, anecdotal information indicates that Pacific lamprey were historically abundant, with harvest occurring throughout the subbasin (Ward et al. 2012). Observations by tribal members and state and federal fisheries agency personnel (Jackson and Kissner 1997) indicate that lamprey were so abundant as to be a nuisance in the Umatilla River Subbasin. Abundance decreased precipitously in the late 1960s and early 1970s following treatments, and very few lamprey were observed in the subbasin during surveys conducted in the 1990s (Ward et al. 2012).

**Comment [JAE37]:** Rotenone treatments intentionally targeting lamprey? Clarify what the rotenone treatments were for…directly or indirectly killed lamprey.

Few counts of Pacific lamprey at Snake River dams are available prior to the 1990's; however, counts ranged from approximately 5,000 to 7,000 at Ice Harbor dam from 1967 through 1969 (Fish Passage Center 2013). Recent counts have been under 1,000 fish at Ice Harbor Dam and under 100 fish at Lower Granite Dam (Table 1).

Although long-term information from dam counts in the Snake River is not available, information summarized by Cochnauer and Claire (2009) from the Clearwater Subbasin indicates a precipitous decline in Pacific lamprey abundance and distribution. The number of kilometers occupied by Pacific lamprey declined by an estimated 66% between 1960 and 2006. Counts at Lewiston Dam, near the mouth of the Clearwater River, decreased from over 5,000 in 1950 to zero by 1972, after which the dam was removed and lamprey once again had access to the upper drainage. Pacific lamprey ammocoetes and macrophthalmia were collected in Lolo Creek from 1994 through 2003; however, continued sampling failed to capture any lamprey from 2004 through 2006.

Anecdotal accounts indicate lamprey were historically plentiful in the Yakama Nation Ceded Lands, specifically in the Yakima River where adult lamprey were harvested locally at least till the 1960s and early 70s (Yakama Nation and GeoEngineers, Inc. 2012). Current adult lamprey

occurrence data for the Yakima River Subbasin is based primarily upon observations at fishways at Prosser and Roza dams. At Prosser Dam, the number of adult lamprey counted at the fishway was low from 2000 to 2013, ranging from zero in 2000 to a high of 87 in 2003. In most years less than 20 adults pass Prosser Dam. No adults have been observed at Roza Dam since the counting program began (Yakama Nation and GeoEngineers, Inc. 2012). Recent abundance data indicates very low, numbers of larvae and juveniles throughout the subbasin as well. From 2000 to 2012, outmigrating larval and juvenile lamprey counts (unconfirmed species) from Chandler Canal Fish Collection Facility in lower Yakima River ranged between 18 and 1,450 (43% subsampling) with a mean annual count of 317.

In the upper Columbia River, numbers of Pacific lamprey passing Wells Dam (furthest upstream facility on the mainstem Columbia River with passage) each year have been declining, with some recent adult counts below ten per year (Table 1). Counts were over 1,400 fish as recently as 2004.

### 3.2.2 Pacific lamprey in some subbasins may need to be supplemented so that recovery can occur in a timeframe consistent with aggressive restoration plans.

Brian, ODFW technical staff offers the comments below on natural colonization, and passage at dams but not sure best place for you to address them:

- **One of the fundamental rationale's for supplementation is the assumption that natural recolonization will take too long. This assumption is not backed by any data and is indeed contradicted by the one case study cited. The assumption is likely based on the fact that adults are attracted to larval pheromones; the assumption being that if there are no larvae rearing in a particular watershed, there is nothing to attract adults to that watershed. However, there are other factors besides larval pheromones likely attracting adults to spawn such as discharge, temperature, presence of Western brook lamprey rearing, presence of other maturing Pacific lamprey adults, and so on (Keefer et al. 2013).**

- **Moreover, the one example of actual natural recolonization mentioned in this document happened relatively rapidly and the authors disingenuously refer to it as a "natural reintroduction." The case study comes from Hess et al. (in prep), and looks to be a really interesting paper for more than this reason. Hess et al. sampled the upper Hood River shortly (<3 years) after the removal of Powerdale Dam, which was considered a lamprey barrier, and found only age-0 Pacific lamprey. The lack of other age classes (and no Western brook larvae) suggests this was a recent, rapid recolonization of an area that did not have rearing larvae as an attractant.**

- **Given that very little is known about natural recolonization rates of Pacific lamprey, one might expect that this topic would be a high priority in their research framework. However, this framework does not propose to evaluate**

**natural recolonization rates and the factors affecting them even though there are plenty of rivers in this region where dams have been removed in the last 15 years that could serve as study watersheds. Here is a partial list (from American Rivers) of Washington and Oregon watersheds where occupancy estimation studies could improve our understanding of Pacific lamprey recolonization rates: Sandy River (Marmot Dam, 2007), Hood River (Powerdale Dam, 2010), White Salmon River (Condit Dam, 2012), Trout Creek (Wind River, Emerald Dam, 2010), Elwha River (Elwha and Glines Canyon Dams, 2013), Clackamas River, Cowlitz River, Lewis River, Rogue River (Gold Ray Dam, 2010; Savage Rapids Dam, 2009), South Fork Necanicum River (Diversion Dam, 2012), South Fork Siletz River (Valsetz Dam, 2012), Birch Creek (Taylor Dam, 2012), Elk Creek (Elk Creek Dam, 2009), Calapooia River (Brownsville Dam, 2007), South Fork Klaskanine River (SF Klaskanine Dam, 2007), Dinner Creek (Dinner Creek Dam, 2003), Little Applegate River (Buck & Jones Diversion Dam, 2003), Wagner Creek (2003), Beaver Creek (Byrne Diversioin Dam, 2002), Evans Creek (Maple Gulch Diversion Dam, 2002; Alphonso Dam, 1999), Ashland Creek (2000).**

- Another rationale for supplementation is that improving passage at mainstem dams will take too much time to meet the ambitious restoration goals set by tribal and regional conservation plans. And once passage is improved and a greater proportion of adults make it to the interior CRB, rearing populations need to be in place to attract these adults. In their effort to establish a supplementation program, the authors might be losing sight of how bad passage is at the dams. Here is a table that shows how pitiful it is, based on PIT and radiotelemetry data from and collected by Keefer et al. (2013):
-

| | Probability of upstream passage success at individual lower CRB dams | | | | |
|---|---|---|---|---|---|
| | Bonneville | Dalles | John Day | McNary | Total |
| Mean | 0.40 | 0.56 | 0.40 | 0.65 | 0.06 |
| Low | 0.37 | 0.50 | 0.27 | 0.50 | 0.02 |
| High | 0.43 | 0.72 | 0.55 | 0.80 | 0.14 |

-
- Based on these data, during a mean year, the probability that adults trying to access the interior CRB will successfully pass these four mainstem dams is 6%. Year after year, almost 95% of the migratory adult population headed for the interior CRB is blocked by these dams. This does not account for the upper CRB and lower Snake River dams. Until passage at dams is dramatically improved, supplementation may have little effect on the status of Pacific lamprey in the interior CRB.

Given the precipitous decline in Pacific lamprey abundance, particularly in the upper reaches of the CRB, it is unlikely that large-scale restoration and passage improvement activities, though necessary for long-term sustainability, will result in increased abundance or distribution at a rate sufficient to offset continuing declines and preclude further extirpations. Pacific lamprey supplementation has therefore been identified as a recovery action that should occur concurrently with improvements in fish passage, water quality, and habitat (CRITFC 2011a; Luzier et al. 2011; USFWS 2012; Ward et al. 2012; Yakama Nation and GeoEngineers 2012).

Potential supplementation tools include translocation of adults and reintroduction of larvae or juveniles using artificial propagation. Translocation can be used to bypass corridors where migration is impeded or blocked, increase number of spawning adults, increase larval abundance and distribution, and provide pheromones for potential attraction of additional adults. Artificial propagation may be needed in some areas to increase larval abundance and provide pheromones. Both supplementation techniques are intended to be used while simultaneously improving known factors that limit productivity of lamprey in these specific watersheds. The goal is that self-sustaining natural productivity will provide meaningful ecological contributions and traditional tribal harvest. Research is needed to determine the feasibility of these approaches and to monitor and evaluate results.

Table 1. Counts of adult Pacific lamprey at Columbia and Snake River dams, 2002-12. Counts are during the day only at most dams. Priest Rapids and Wells dams have 24-hour counts. Counts at Lower Granite dam have been conducted 24 hours a day since 2009.

| | Lower Columbia River | | Snake River | | Mid-Columbia River | |
|---|---|---|---|---|---|---|
| Year | Bonneville Dam | McNary Dam | Ice Harbor Dam | Lower Granite Dam | Priest Rapids Dam | Wells Dam |
| 2002 | 100,476 | 11,282 | 1,127 | 128 | 4,007 | 338 |
| 2003 | 117,029 | 13,325 | 1,702 | 282 | 4,339 | 261 |
| 2004 | 61,780 | 5,888 | 805 | 117 | 2,647 | 1,408 |
| 2005 | 26,664 | 4,158 | 461 | 40 | 2,598 | 291 |
| 2006 | 38,938 | 2,456 | 277 | 35 | 4,381 | 212 |
| 2007 | 19,313 | 3,454 | 290 | 34 | 6,593 | 21 |
| 2008 | 14,562 | 1,530 | 264 | 61 | 5,083 | 7 |
| 2009 | 8,622 | 676 | 57 | 12 | 2,714 | 9 |
| 2010 | 11,183 | 825 | 114 | 15 | 1,114 | 2 |
| 2011 | 18,305 | 868 | 269 | 48 | 3,868 | 1 |
| 2012 | 29,224 | 970 | 484 | 48 | 4,025 | 3 |

**Comment [JAE38]:** Use a footnote to explain that the higher count at Priest Rapids, relative to McNary, is because lamprey that use the navigation lock at McNary are not counted. There is no nav lock at PRD, so all lamprey must pass the fish ladder counting window. That is why there has not been a noticeable decline in counts at PRD since 2002. The lower CR and Snake R. dams all have navigation locks that bypass lamprey around the counting stations.

Supplementation is intended to be a short term action to boost Pacific lamprey numbers and make other restoration actions more meaningful. Research needs related to supplementation identified by the USFWS (Luzier et al. 2011) include evaluating the risks and benefits of translocation, evaluating techniques for artificial propagation, and evaluating if artificial propagation can be used to "jump start" ammocoete production in appropriate watersheds.

Supplementation would increase larval or juvenile abundance in seeded watersheds or stream reaches. Not only would these actions re-establish juveniles back into the local ecology, they may improve pheromone attraction of returning adults. Emerging evidence strongly suggests an association between juvenile lamprey pheromones and adult returns (Sorensen et al. 2005; Lin et al. 2008; Close et al. 2009; Spice et al. 2012). Adult Pacific lamprey, like sea lamprey (*Petromyzon marinus*), may be attracted to spawning sites by pheromones released by ammocoetes (Lin et al. 2008).

**Comment [DBJ39]:** The goal of attracting adults to specific watersheds by supplementing them with larvae will likely have some effect since adults are indeed attracted to larval pheromones. If other factors, such as discharge or temperature, don't obscure the effect of greater numbers of larvae in a watershed, supplementation is likely to only improve the particular watershed where the treatment has occurred. Since there are relatively small numbers of adults reaching the interior CRB and they don't home to natal watersheds, a gain in a supplemented watershed may not represent an increase of adults since it is likely to detract from another watershed that didn't receive a larval supplement.

(However, more lamprey might be tempted to attempt upstream passage both pre and post passage improvements thereby increasing actual numbers in the UCB)

## 3.2.3 Supplementation research and use as a recovery and management tool will provide valuable insights into lamprey biology and ecology.

In consideration of low numbers of adult lamprey, alternative management strategies must be employed as stop-gap measures to slow extirpation and re-establish genetic variability within local areas throughout the CRB. During this time, supplementation research should be implemented and important attributes, such as local genetic diversity must be monitored so that if/when supplementation is determined to move forward at a larger scale, the working knowledge will have increased to better plan and implement future management actions. As supplementation research is implemented in specific areas, monitoring and evaluation to determine action effectiveness of adult translocation, artificial propagation method development, and larval and juvenile reintroduction, will provide valuable insights into lamprey biology and ecology as well as provide the opportunity to research known and potential limiting factors and critical uncertainties.

**Comment [SMN40]:** Assuming these areas have been identified? How were they defined? How will we define additional areas? i.e. is there a process?

Translocation efforts to date have resulted directly in successful transportation and holding techniques for adult Pacific lamprey. Successful holding and releases of adults have resulted in increased larval abundance (Ward et al. 2012), which has in turn increased knowledge of larval distribution and migration timing. In addition, by radio-tagging translocated adults, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Yakama Nation / USFWS have been able to collect information on adult passage at low-elevation diversion dams, providing insights on placement of lamprey passage structures such as the structure completed at Threemile Dam in the Umatilla River in 2009, and passage improvements currently being planned at Prosser Dam in the Yakima River. Ongoing translocation and future propagation research will have broad application in addressing other factors potentially limiting lamprey in the tributary environment including the effects of irrigation entrainment, flow management (ramping rates), emerging and legacy contaminants, and habitat availability.

Knowledge to be gained from evaluating lamprey artificial propagation includes information related to rearing techniques and with post-release monitoring. Development and evaluation of artificial propagation techniques will increase knowledge of laboratory protocols, growth and survival, food preferences, habitat needs, and possibly changes in morphology associated with metamorphosis. Monitoring of larval or juvenile releases will provide information on growth and survival in the wild, distribution including downstream movement, and outmigration timing.

Monitoring of supplementation activities may also provide opportunities to increase understanding of known limiting factors and critical uncertainties. These may include larval and juvenile passage at specific facilities, contaminant accumulation and effects, and predation. If larval pheromones guide adults to spawning sites, supplementation would encourage natural production in suitable spawning and rearing areas. Research is currently being conducted to isolate these pheromones and investigate how they may be used to improve adult returns (Yakama Nation and GeoEngineers, Inc. 2012). Investigations such as these are important to initiate at this time so that, if need be, this management strategy can be confidently implemented when necessary.

### 3.2.4 A regional Supplementation Research Framework will provide for a more comprehensive and systematic research and monitoring strategy and will contribute to greater consistency in data analysis and reporting.

A successful, economical and rapid recovery of Pacific lamprey will require regionally coordinated efforts from tribes, federal and state fishery agencies, and others involved in conducting or funding lamprey restoration efforts. An important component of this coordination is consistency in protocols, data collection and reporting metrics. The need for this coordination was clearly identified in both the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement. Both documents clearly established a context for coordinated action among stakeholders across the CRB towards conservation actions, funding and RME.

## 3.3 Scope

The scope of this Supplementation Research Framework is intentionally narrow in both time (5 years) and space (only a few key CRB subbasins) due primarily to the conservative nature of this initial effort and budgeting constraints. Actions guided by this Supplementation Research Framework are expected initially to focus on addressing important management questions, limiting factors, and critical uncertainties identified in both the Tribal Pacific Lamprey Restoration Plan and the Lamprey Conservation Agreement. With regard to supplementation research, the Supplementation Research Framework will provide guidance to address Objective 3 of Tribal Pacific Lamprey Restoration Plan, *Supplementation/Augmentation*, and Objective 7 of the Lamprey Conservation Agreement, *Restore Pacific Lamprey of the RMUs*. The Supplementation Research Framework and associated Subbasin Supplementation Research Plans are integral components of the larger RME Framework.

**Comment [SMN41]:** 'Long-term' is repeated throughout this document. How does the 5-year scope fit with long-term planning & research?

**Comment [SMN42]:** How were these basins selected?

The Supplementation Research Framework is further expected to guide consistent analysis methods and reporting formats for research and monitoring tools in the context of Objectives 5 and 6 of the Lamprey Conservation Agreement (*Identify and characterize Pacific lamprey for the RMUs* and *Identify, secure and enhance watershed conditions contained in the RMUs*) and Objective 6 of the Tribal Pacific Lamprey Restoration Plan (Research, Monitoring, and Evaluation).

Through adaptive management this Supplementation Research Framework will expand, with the intention of maintaining its relative simplicity. Many critical uncertainties about Pacific lamprey remain and fishery managers expect that continued RME activities will likely modify the overall

**Comment [SMN43]:** Okay- so how will adaptive management work? Annual review of supplementation techniques? 5-year review of framework? Answer some research questions, ask more?

**Comment [SMN44]:** Expand how? To more basins? Longer time frame? Different supplementation techniques?

objectives and methods. For this reason, managers choose to maintain relative simplicity in the approach. Considering budgets, existing capacity, and the state of knowledge, it is not practical at this time to construct a Supplementation Research Framework overly burdened with details built upon speculation and uncertainty. Simply based on a 10-year life history of Pacific lamprey, managers recognize many important objectives may require a decade and longer to achieve.

**Comment [SMN45]:** So why the 5-year scope?

# 4 Supplementation RME Framework

Comment [SMN46]: A simple flow chart showing all the relevant documents and how they are linked as far as Supplementation might be a handy visual esp for those that aren't familiar with all the different plans.

This section describes the Supplementation Research Framework that will be an integral component of the larger Pacific lamprey RME Framework (Item 1 described in Section 1.4). Collective development of these documents is anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan, (2) Lamprey Conservation Agreement, and (3) Northwest Power and Conservation Council Fish and Wildlife Program. Each of these activities will be important contributions towards the development of a Columbia River Basin Pacific Lamprey Management Plan, intended to be drafted in years 2016-2017.
Translocation and propagation continue to be tools necessary for learning, both in laboratory and the natural environment. Supplementation may be used as one method to address limiting factors and ultimately to help shape the management plan.

Because of the low returns of Pacific lamprey, including extirpation in some subbasins, and the assumption that natural recolonization will require a long time, the use and monitoring of adult translocation and artificially propagated larval and juvenile lamprey in short and long-term supplementation efforts will be necessary. In the short term, translocation and propagation efforts would be used to reestablish lamprey in extirpated streams and maintain lamprey presence to attract upstream migrating spawning lamprey. In the long term, artificially produced lamprey could be used to supplement CRB lamprey by dramatically increasing larval/juvenile numbers with the goal of effectively reversing declines.

Within key research areas, multiple threats recognized, both within and outside of subbasins, include degraded habitat, passage barriers, degraded water quality, dewatering, and predation (CRITFC 2011a; Luzier et al. 2011). To varying degrees these threats are being addressed, although it will take considerable time before their impacts are fully understood and corrected; therefore, appropriate supplementation is necessary during this time.

Fishery managers recognize the importance for both restoration and research to be complimentary efforts in addressing threats. It is especially important to recognize the use of supplementation in areas where lamprey numbers are too low to actually determine the nature or extent of potential limiting factors. Examples include juvenile entrainment and passage through irrigation screens or adult passage over irrigation facilities. Propagated fish may also be used to address basic questions about growth and survival in natural riverine environments. Managers have concluded that without use of translocation and propagation research as a tool, it is essentially impossible to understand potential environmental threats in many subbasins. Short term focus should be on critical areas of research and longer-term application of supplementation in key areas.

## 4.1 Regional RME Framework

The larger scale Regional Framework for Pacific Lamprey Research Monitoring, Evaluation, and Reporting in the Columbia River Basin (RME Framework – Item 1 described in Section 1.4) will be guided by principles and concepts put forth by Luzier et al. (2011).

The RME Framework will also be informed by biologists with experience in lamprey biology. At this time, some of the elements of a comprehensive RME Framework cannot be implemented because of a lack of scientific tools needed to collect data (e.g., juvenile tags). Nevertheless, the framework will identify appropriate RME questions and objectives, and the need to develop the tools necessary to address the questions and objectives.

### 4.1.1 Types of RME Efforts

Several types of monitoring are needed to allow managers to make sound decisions:

- **Status and Trend Monitoring.** Status monitoring describes the current state or condition and limiting factors at any given time. Trend monitoring tracks these conditions to provide a measure of the increasing, decreasing, or steady state of a status measure through time. Status and trend monitoring includes the collection of standardized information used to describe broad-scale trends over time. This information is the basis for evaluating the cumulative effects of actions on lamprey and their habitats.

- **Action Effectiveness Monitoring.** Action effectiveness monitoring is designed to determine whether a given action or suite of actions (e.g., propagation and translocation) achieved the desired effect or goal. This type of monitoring is research oriented and therefore requires elements of experimental design (e.g., controls or reference conditions) that are not critical to other types of monitoring. Consequently, action effectiveness monitoring is usually designed on a case-by-case basis. Action effectiveness monitoring provides funding entities with information on benefit/cost ratios and resource managers with information on what actions or types of actions improved environmental and biological conditions.

- **Implementation and Compliance Monitoring.** Implementation and compliance monitoring determines if actions were carried out as planned and meet established benchmarks. This is generally carried out as an administrative review and does not require any parameter measurements. Information recorded under this type of monitoring includes the types of actions implemented, how many were implemented, where they were implemented, and how much area or stream length was affected by the action. Success is determined by comparing field notes with what was specified in the plans or proposals. Implementation monitoring sets the stage for action effectiveness monitoring by demonstrating that the actions were implemented correctly and followed the proposed design.

- **Uncertainties Research.** Uncertainties research includes scientific investigations of critical assumptions and unknowns that constrain effective propagation and translocation. Uncertainties include unavailable pieces of information required for informed decision making as well as studies to establish or verify cause-and-effect and identification and analysis of limiting factors.

## 4.2 Supplementation Research Strategies

This supplementation research Framework covers the translocation and artificial propagation of Pacific lamprey within the Columbia River basin. It describes the RME recommended for assessing the status and trends of Pacific lamprey within subbasins and for evaluating the effectiveness of translocation and other actions implemented to restore Pacific lamprey within those subbasins. In addition, this plan identifies current efforts and additional RME needs. Although logistical and monetary limitations exist, this plan will focus on the common goal of assessing success in Pacific lamprey translocation and propagation.

Comment [JAE47]: To match "Action Effectiveness Monitoring" described on the previous page.

### 4.2.1 Adult Translocation

#### 4.2.1.1 Background

Close et al. (1995) conceptualized the goal of lamprey translocation to "begin establishment or supplementation of lamprey in selected tributaries above Bonneville Dam where populations have been extirpated or are at extremely low levels." The overall goal of translocation is to restore natural production to self-sustaining levels.

Translocation programs in the CRB have been well documented by Close (1999), Close et al. (2009), and Ward et al. (2012). The approach for translocation efforts to date has been to collect adult Pacific lamprey at Bonneville, The Dalles, and John Day dams. Adults are then transported and held at facilities near release areas. Adults are tagged and treated at the holding facilities and released the following spring.

#### 4.2.1.2 Rationale and Assumptions

Although the best long-term sustainable option for increasing Pacific lamprey abundance and distribution may be improving the passage environment for adults and juveniles, translocation of adults may be the best immediate option to begin the process of rebuilding populations in depressed subbasins. Translocation efforts are likely to increase production of larval lamprey in recipient subbasins, "seeding" underutilized rearing habitat and increasing pheromone cues to attract adults. Translocation and other restoration programs could therefore have a synergistic effect in breaking the downward cycle of Pacific lamprey abundance and recruitment.

Another potential benefit of translocation is expanded spatial distribution of Pacific lamprey, via occupation of subbasins where they have been severely depressed or extirpated. Until passage is better understood and improved at mainstem dams, translocation from lower dams may also produce an escapement benefit for lamprey. These benefits may help decrease the risk of lamprey local extirpation by decreasing the overall impact of catastrophic events within a subbasin, or even within a larger portion of the Columbia River Basin.

Lamprey translocation may also produce ecosystem benefits. Because ammocoetes are filter feeders and detritivores, increased production is expected to facilitate nutrient cycling in rivers where adult lamprey have been reintroduced. Other potential benefits include increased connectivity of marine with freshwater ecosystems, and delivery of marine-derived nutrients into upper reaches of the Columbia River Basin. Lamprey restoration will also increase the prey base available to native fish, avian, and mammalian predators.

**Comment [JAE48]:** True, but don't over sell this ecological benefit, particularly in the near-term. Overall abundance of adult lamprey is low and total biomass is miniscule compared to salmon and steelhead because each adult only weighs about 1 pound. It takes 30 lamprey carcasses to be equivalent to a single 30 lbs. fall chinook carcass. I suggest you be "up front" about the biomass disparity.

### 4.2.1.3 Critical Uncertainties

Critical uncertainties regarding translocation of adult Pacific lamprey that have been identified through monitoring of existing programs include:

- Survival of translocated adults
- Spawning success
- Viability and survival of eggs, larvae, and juveniles

Potential risks (albeit unknown) from lamprey translocation often raised include:

- Disruption of population structure and associated genetic adaptations
- Exposure to survival risks such as pathogens and disease
- Decreased abundance in donor areas.

These potential risks have been recognized (Ward et al. 2011), and steps have been taken to avoid or reduce them by adherence to lamprey translocation guidelines agreed to by the Columbia River Inter-Tribal Fish Commission (CRITFC 2011a)).

**Comment [JAE49]:** Provide the translocation guidelines as an appendix to the Supplementation Research Framework.

A remaining uncertainty may be the appropriate number of adults to release within a target location. The apparent lack of homing of Pacific lamprey to natal watersheds confounds attempts to address this uncertainty. Long-term efforts are needed to document the effect of increased larval abundance on returns of adults.

### 4.2.1.4 Research and Monitoring Objectives

The four Columbia River treaty tribes have proposed creating a regional lamprey supplementation plan that includes adult translocation with the following general objectives (CRITFC 2011a):

- Continue translocation in accordance with tribal guidelines.
- Develop and implement lamprey translocation as a component of a regional supplementation plan.

Tribal translocation strategies will:

- Utilize historical and tribal records of lamprey distribution, abundance and habitat to help determine outplanting priorities.
- Use the best available knowledge to evaluate if translocation is necessary.
- Choose donor sources wisely and make efforts to minimize negative effects on donor groups.
- Monitor and improve collection, transport, and holding protocols and facilities.

- Evaluate and select target streams, release locations, and timing of releases using the best available knowledge.
- Closely monitor and evaluate translocations at a variety of spatial and temporal scales.
- Accurately record and sufficiently share translocation results with the region.

**Comment [JAE50]:** These are all good strategies for implementing regional-level translocation in a consistent manner.

## 4.2.2 Larval and Juvenile Outplanting

### 4.2.2.1 Background

The biological features of lamprey (especially after hatching) require new innovative ideas and methods to improve culture success. Formative work on lamprey propagation in Finland, research on sea lamprey from the Great Lakes region, and research on Arctic lamprey from Japan provide important insights on how artificial propagation of Pacific lamprey could be used in the CRB. Some experimental work on the artificial propagation of Pacific lamprey has already been conducted within the CRB; however, the primary focus in the past has been on propagating small number of lamprey for research purposes and the processes and techniques applied were not scaled for aquacultural use.

In 2012, the Yakama Nation and Umatilla Tribe joined forces and collaborated on the artificial propagation of Pacific lamprey. Over a 10-week period between April and June, 2012, 41 adults were spawned successfully primarily at Marion Drain and Prosser hatcheries. Some of the individuals (both male and female) spawned repeatedly, resulting in a total of 55 propagation events. Over 40% of the adults, however, did not mature in 2012 and were overwintered for another year. Fertilization and hatching success varied widely (0-99%). The success of fertilization and hatching depended chiefly on four variables: 1) seasonality; 2) quality of gametes; 3) water quality; and 4) incubation methods.

**Comment [JAE51]:** What do you mean by this? Maturity of the fish? the month of the year that fish matured?

Many tribal and federal agencies experimented with larval rearing in 2012 using propagated age 0+ larvae. Different feeds and substrate types were tested, and the effects of temperature and feeding regime on growth and survival were evaluated. Most studies demonstrated that larvae can attain positive growth and relatively high rates of survival under active dry yeast feed. However, a certain combination of feeds in addition to active dry yeast (such as hatch fry feeds or marine larvae feed) appeared to be potentially effective in producing even better growth and warrants further research. Larvae appeared to show preference for natural fine substrates, such as clay, silt, sand, detritus and straw. However, considering the enormous difficulty in separating larvae from clay/silt, detritus, and straw, fine sand appears to be the most promising substrate to date.

Protocols for rearing larvae and juveniles for extended periods of time (years) are lacking. Growing lamprey to larger sizes will be particularly challenging partly due to 1) the length of time they spend as larvae (3-7 years) and 2) their cryptic nature (i.e. burrowing under fine sediment), which makes any type of monitoring both very time-consuming and difficult.

#### 4.2.2.1 Rationale and Assumptions

Once developed, artificial propagation could be an important management action to aid in the restoration of Pacific lamprey, especially in areas of low abundance or extirpation. A primary role of larval propagation and outplanting besides increased larvae/juvenile production would be to maintain and increase pheromone cues to attract returning adults. Increased numbers of larvae are likely needed to occupy available habitat, release pheromones, and begin reversing declines in numbers of returning adults.

Comment [JAE52]: Due to the difficulty in propagating large numbers of larvae or larger juveniles, artificial synthesis of lamprey pheromone in a biochemistry lab deserves serious consideration.

Propagated larval lamprey may also be valuable as study organisms. Larval lamprey behavior is secretive and larvae are elusive (i.e. burrowed in sediments), making them difficult to study in their natural environments. Rearing and evaluating lamprey in a controlled laboratory environment and connecting this work with controlled research in the natural environment may be the most effective way to better understand various life stages efficiently, both in time and expense.

Juvenile (macrophthalmia) outplanting may not be the most effective strategy for supplementation because larvae are needed in the streams to produce pheromones that attract adults and the economic cost of growing larvae for 3-7 years would also be substantial. Raising lamprey to the juvenile stage may have some benefits, however. For example, if the facility is in a suitable location, pheromones released by larvae being reared over long periods may serve to attract returning adults. Continued holding of fish may facilitate refinement of rearing techniques. Finally, survival rates of outplanted juveniles are most likely going to be higher than that of larvae.

Hatchery-raised lamprey could also be used for other research programs other than re-stocking in streams. Very little is known about lamprey juvenile passage and migration, but the diminished abundance and distribution, and the unique size and shape of the lamprey make any kind of sizeable tagging studies extremely difficult, if not impossible, to implement. Therefore, artificial propagation of Pacific lamprey may be extremely valuable for research purposes to better understand their early life history and biology, and to meet the critical need of samples required for such studies. Hatchery lamprey could be raised to various life stages and used as test organisms for determining screen design, screening efficiencies, survival through hydroelectric projects, and other juvenile studies of critical importance.

Using propagated fish in the natural environment provides several distinct research opportunities because lamprey could be placed in selected stream reaches or reservoir deltas at desired densities. For example, this type of lamprey placement allows for opportunities to test sampling protocols against a known sample. Larval lamprey placed in cages in certain streams could evaluate if their presence will attract adults via pheromones, or alternatively, their tolerance to certain levels of contaminant loads. In general, experiments using hatchery-raised lamprey will aid in the understanding of lamprey behavior and guide future restoration actions without the need to extract and harm existing lamprey from the natural environment.

#### 4.2.2.2 Critical Uncertainties

Substantial obstacles must be overcome to achieve a scale necessary for hatchery production. Critical knowledge gaps at the hatchery production level include

- Optimal temperature regime for holding adults
- Best management practice for successfully spawning and incubating lamprey
- Disease and fish health issues specific to lamprey
- Tolerance level of adults/eggs/larvae to disease/fungus controlling chemical treatments
- Influence of rearing density on larval growth; larval food quality, quantity, and feeding methods
- Methods to efficiently separate larvae from fine sediment for counting and monitoring

Although many knowledge gaps exist at the hatchery production level, these questions can be answered relatively easily by the use of targeted experiments. In fact, from the first year of propagation efforts by the CRB tribes and federal agencies, many of these knowledge gaps are beginning to get answered (such as spawning and incubation techniques, chemical treatment effects, effective types of feed and substrate media, etc.).

Growing lamprey to larger sizes will be particularly challenging partly due to 1) the length of time they spend as larvae (3-7 years) and 2) their cryptic nature (i.e. burrowing under fine sediment), which makes any type of monitoring both time-consuming, difficult, and stressful for the larvae. For example, in a salmon hatchery, large mortality events are obvious to the hatchery personnel because the fish are directly visible in the water tanks. In the case of larval lamprey, even if a significant larvae mortality event occurs, this event may go unnoticed for some time because they all live under the sediment and remain invisible most of the time. As larvae increase in size, their weight density will continue to increase, most likely requiring more and more space to rear them successfully.

Significant critical uncertainties related to post hatchery production remain. The release of propagated larvae into the natural environment has taken place in Finland, Japan and other countries, but very little monitoring has been conducted to successfully validate its effectiveness in increasing and boosting natural reproduction levels. Critical knowledge gaps post hatchery production include

- Optimal release sites
- Optimal larval release life stages (0+ ~ 7+ larvae)
- Optimal release density
- Changes in growth and survival of propagated larvae after release
- Dispersal rates after release
- Interactions with naturally produced larvae and juveniles.

In addition to larval habitat in mainstem and side channels of rivers and streams, potential release sites include salmon acclimation ponds, hatchery pollution abatement ponds, and irrigation diversions and canals. To determine the optimal larval release life stage, we will need to have a much better understanding on the life stage survival model for Pacific lamprey and the corresponding "bottleneck" life stage. If the primary bottleneck is in the egg incubation and prolarvae stage, being able to rear them past this stage should increase the larvae production immensely (at least in quantity). On the other hand, if the primary bottleneck takes place in later life stages as larvae, it would become crucial to rear them past this stage. The optimal density levels of the larval release also require more information on the life stage survival model. At what density of larval outplanting (per watershed size) are we able to see noticeable increases in larvae production? Can larval lamprey adapt quickly to the natural environment after being reared in the hatchery settings for over a year? How many of the larvae would stay put within the release site vs. others that disperse to other habitat? How would the outplanting affect naturally produced larvae? Salmon and trout hatcheries have learned from 100+ years of experience. All these questions will require intense monitoring that will span multiple years.

#### 4.2.2.3 Research and Monitoring Objectives

The four Columbia River treaty tribes proposed creating this Framework with the following general objectives (CRITFC 2011a):

- Immediate evaluation of potential regional lamprey aquaculture facilities.
- Consolidation and synthesis of existing lamprey propagation information.
- Development and refinement of husbandry techniques for Pacific lamprey.
- Continued research on lamprey genetics, potential population substructure, and source locations.
- Assessment of appropriate release locations and strategies for propagated lamprey within the region.
- Monitoring and evaluation of supplementation using artificially propagated lamprey.

These objectives are intended to answer basic questions on the feasibility of large scale lamprey propagation in the northwest. The next steps in research should focus on basic observations in nutrition, growth, rearing densities, survival, and habitat preferences. Preferably, efforts should build on previous propagation research on other lamprey species, especially related to collection of brood stock, fertilization techniques, incubation conditions, and release timing, for the efficient and cost-effective development of propagation programs in the CRB. The Yakama Nation and the CTUIR has begun initial efforts for propagation starting the spring of 2012 by hatching and rearing several thousand Pacific lamprey larvae at their facilities. In 2013, propagation and rearing experiments ensued by the Yakama Nation and CTUIR to assess critical questions, such as 1) how to improve fertilization and incubation rates, 2) how to maximize survival of newly hatched larvae during facility-to-facility transfer, 3) how to efficiently count eggs and hatched larvae, and 4) how to effectively feed and rear larvae in large tanks under high density (>50,000) conditions.

## 4.3 Monitoring and Evaluation Approaches

### 4.3.1 Adult Translocation

#### 4.3.1.1 Adult Survival

***Monitoring questions***

- How many translocated adults moved out of the release areas?
- How far and in what direction did translocated adults move following release?
- How many translocated adults moved to spawning areas?
- How did release timing and location affect spawn timing?
- What environmental factors (e.g., flows, temperature, etc.) may have caused translocated adults to leave the target areas?

***Performance metrics***

- Number of adults released
- Direction of movement
- Rate of movement
- Distance moved
- Adult maturation rate
- Estimated percentage of released adults that successfully reached spawning areas

Performance may be influenced by variables including water temperature and stream flow.

***Approach***

A tagging study (e.g., radio telemetry) is needed to determine the movement and habitat use of translocated adult Pacific lamprey. If water conditions allow and no lamprey are in the area, visual observations without tagging studies can be used to determine if translocated adults use the target spawning areas. This, however, is a less robust approach than using tagging studies.

***Analysis***

If a tagging study is used, the analyses are straightforward for estimating direction of movement (fraction moving upstream and downstream), rates of movement (distance moved per week), numbers leaving the target area, and numbers of adults spawning within the target area. Correlations between environmental factors (flows and temperatures), time and location of release, and spawn timing can be evaluated.

#### 4.3.1.2 Adult Spawning

***Monitoring questions***

- How many translocated adults constructed redds and engaged in reproduction within target areas?
- What was the distribution of spawners within target areas?
- What habitat conditions (e.g., flows, temperature, substrate, etc.) favored the construction of redds and reproductive success within target areas?
- How many adults successfully spawned and contributed offspring?
- What are the effects on spawning success of multi-year over-wintered adults?
- What are the effects of an individual's genetic background on spawning success?

***Performance metrics***

- Number and distribution of redds
- Number of adults engaged in reproduction
- Number of eggs per red
- Presence of live eggs and larvae within redds
- Number of live eggs and larvae within redds
- Number of offspring assigned back to translocated adults

Performance may be influenced by a number of variables including water temperature, stream flow, water velocity, water depth, cover, and substrate composition.

***Approach***

An important assumption of translocation is that the translocated Pacific lamprey are ready to spawn shortly after release. This means that the translocated adults will successfully find mates, select suitable spawning sites, construct redds, and reproduce. For indirect measures of reproduction, if water conditions do not allow for visual observations, a tagging study may be needed to determine the number and distribution of spawners within the target areas. If water conditions allow, visual observations can be used to determine the number, distribution, and reproductive activities of translocated adults within the target areas. Ideally, spawning surveys should occur weekly throughout the spawning period (i.e., from time of release to the end of spawning). Field observations can be used to document redd construction and reproductive behavior. The location and timing of redds can be mapped using GPS. The size (width, length, and depth) of each redd can also be recorded. Habitat conditions (temperature, depths, velocities, cover, and substrate composition) can be measured at the locations of redds within the target areas. Stream flows can be downloaded from nearby gauging stations. Note that lamprey spawning surveys can be coupled with steelhead spawning surveys.

A genetic tagging study can be used to evaluate reproductive success metrics. Hess et al. (in prep) have developed and evaluated a set of genetic markers for Pacific lamprey that can accurately assign offspring to their parents. Tissues from ALL translocated lamprey adults must be collected for this tagging approach to be possible to execute for efficient monitoring.

*Analysis*

Descriptive analyses can be used to describe the number, distribution, and spawning activities of translocated adult lamprey within the target areas. Correlation and regression techniques can be used to assess the relationships between habitat conditions and the abundance and distribution of redds in the target areas. These relationships can then be used by biologists to fine-tune their selection of appropriate release locations. Based on the distribution of redds, biologists can sample a random number of redds to determine the total number of eggs deposited per red; randomly sampling redds for the presence of viable eggs and larvae over a specified time interval (e.g., weekly). To the extent possible, biologists should count the total number of viable eggs and larvae within a redd to gain a better understanding of the natural survival mechanism during early life history (methods may need to be developed to measure viable eggs and larvae over time).

Because the sampling of redds can alter the survival of eggs and larvae over time, biologists will need to determine if sampling with or without replacement is appropriate. That is, should a given redd be sampled more than once over time? Ideally, the total number of redds sampled should be no more than 10% of the total redds within the target area. Habitat conditions (temperature, water depth, egg-pocket depth, redd size, velocities, and substrate composition) can be measured at the locations of redds within the target areas.

#### 4.3.1.3 Larval Survival and Growth

*Monitoring questions*

- Did translocated adults produce viable larvae in target areas?
- What fraction of the eggs survived to emergent larvae?
- What habitat conditions (e.g., flows, temperature, substrate, etc.) were associated with larvae survival and production?
- What is the survival rates for various age classes of larvae (i.e. 0+, 1+, 2+, 3+,etc.)
- Is genetic makeup associated with larval growth and survival?

*Performance metrics*

- Egg-to-larvae survival rates
- Larval survival and growth rates at various age classes
- Size, age, and abundance of larval lamprey identified as offspring from translocated adults

Performance may be influenced by a number of variables including water temperature, stream flow, water velocity, water depth, and substrate composition.

***Approach***

If translocation is to be successful in increasing the status of Pacific lamprey within a subbasin, then translocated adults must produce viable offspring. Therefore, measuring successful hatching and surviving larvae is critical to the assessment of translocation. If hatching and larvae production is successful, biologists will be equipped to re-establish lamprey in areas currently void of Pacific lamprey. Larval and juvenile lamprey of particular age classes will be able to be assigned back to translocated adults using genetic analyses. Offspring will be able to be assigned to adults translocated in 2013 and onwards.

***Analysis***

Descriptive analyses can be used to describe the mean number of eggs per redd, mean number of viable eggs and larvae per redd, and egg-to-larvae survival rates, as well as number of viable offspring per spawner pair. Correlation and regression techniques can be used to assess the relationships between habitat conditions and survival rates.
An important assumption of propagation is that planted larvae will use intended rearing areas over time. Biologists will identify suitable release sites based on rearing conditions within those sites. If biologists are able to identify suitable rearing areas that are used successfully by propagated larvae, it may improve the status of Pacific lamprey within the subbasin. It will also be possible to track propagated larvae via parentage analysis at various stages of maturity as they continue their continuous migration downstream.

### 4.3.1.4 Larval Abundance and Distribution

***Monitoring questions***

- How many larvae were produced by translocated adults?
- What size distribution is represented by each cohort of lamprey?
- How many larvae remained within the target areas over time?
- Did the distribution of larvae expand into areas outside the target areas?
- How did release timing and location affect the density and distribution of larval or juvenile lamprey within the target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval distribution and abundance?

***Performance metrics***

- Density of larvae (CPUE or fish/$m^2$)
- Distribution and abundance of larvae
- Presence and proportion of various size classes of larvae

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

***Approach***
Annual larval sampling within treated and untreated areas before and after supplementation activities will determine the relative abundance and size classes of larvae within the target areas. Parentage analysis will identify which larvae originated from which translocated adults, thereby providing a way to verify larvae were derived from translocation efforts and to measure distance traveled from last known spawner release site.

Electrofishing techniques modified for sampling larval lamprey may be the most appropriate method for estimating relative abundance, size classes and distribution. However, recent research from Europe shows that a significant proportion of lamprey populations (especially anadromous lamprey) can be found in deep water habitat that are not normally targeted with the standard electrofishing methods for lamprey. Alternative methods may need to be evaluated further (such as deep water shocking, suction dredging, passive traps, and infra-red cameras) to target these other areas that larvae may use extensively. Locations of juveniles can be mapped using GPS. Lamprey biologists will need to identify a protocol for sampling habitat conditions.

***Analysis***
A time series of the densities (CPUE or fish/$m^2$) of larval lamprey and numbers of transformers can be constructed to show how densities and numbers changed before and after supplementation efforts. Distribution maps can be generated that show how the spatial extent of larvae expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and larval abundance and distribution.

#### 4.3.1.5 Larval and Juvenile Outmigration

***Monitoring questions***
- How many larvae or juveniles transformed and migrated downstream?
- What ages are larvae or juveniles at particular maturation stages during their migration?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with outmigration?

***Performance metrics***

- Number of outmigrating larvae and transformers
- Rate of movement
- Distance moved
- Genetic diversity of larvae and macrophthalmia

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

***Approach***
Rotary screw traps or other traps can be used to estimate the number (or presence) of downstream migrating transformers. Field research suggests that transformers can be caught by electrofishing techniques as well, focusing on coarse sediment near Type I and Type II larval lamprey habitat in late summer / early fall season. Lamprey biologists will need to identify a modified protocol for electrofishing transformers and their associated habitat conditions. Locations of juveniles can be mapped using GPS. Juveniles will be assigned to particular brood years of translocated adults via parentage analysis, and thereby provide an accurate age for each fish.

***Analysis***
A time series of the numbers of transformers can be constructed to show how densities and numbers changed before and after supplementation. Distribution maps can be generated that show how the spatial extent of larvae and transformers expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and transformer abundance and distribution. Parentage-based ages can be related to juvenile size and life-stage to refine our knowledge of size-at-age relationships.

#### 4.3.1.6 Adult Returns

***Monitoring questions***

- Are supplementation strategies influencing adult returns to specific streams and watersheds?
- What is the status and trend of returning adults in experimental and control streams and watersheds?
- What percentage of offspring derived from translocations return to the interior Columbia River as adults?

***Performance metrics***

- Number of returning adults
- Number of returning adults that were offspring of translocated lamprey
- Historical estimates of returning adults

Performance may be influenced by a number of variables including river conditions (e.g. water temperature, stream flow, water velocity) and basin-wide adult returns (e.g. adult counts at Bonneville Dam).

***Approach***

Addressing the adult life history stage will require a variety of monitoring techniques. Pacific lamprey do not appear to be philopatric (in the strict sense we use for salmonids), which makes associating changes in adult returns to specific supplementation strategies problematic. The simplest

approach will be to actively and passively monitor adult returns, in specific streams and watersheds, through a combination of active adult trapping, video and visual monitoring, or spawning/redd surveys. Many of these approaches require "bottleneck" locations (e.g. dams/diversions, waterfalls, manmade weirs) to facilitate passage/return estimates. Other approaches, such as spawning/redd surveys, may require significant manpower to complete.

Regardless of the approach used, any estimates of adult returns would need to be compared to historical estimates/counts to evaluate changes in adult returns in relation to specific supplementation strategies. Alternatively, if a long-term monitoring timeframe is utilized, in ~7+ years (around 2019) we could conceivably begin identifying returning adults that were derived from these translocation efforts. These adults would be tissue sampled as they pass Bonneville Dam and identified as translocation offspring through parentage analysis, utilizing our translocation broodstock genetic dataset (broodyears 2012-2015).

***Analysis***

Evaluating changes in adult returns will require a time series analysis of adult returns/estimates to specific streams and watersheds before, during, and after the implementation of supplementation strategies. Comparisons of adult returns/estimates before and after specific supplementation strategies would provide a qualitative assessment of adult returns. An assessment of adult returns in relation to supplementation strategies may be influenced by a number of variables including river conditions (e.g. water temperature, stream flow, water velocity) and basin-wide adult returns (e.g. adult counts at Bonneville Dam). These variables will need to be taken into account during analysis.

## 4.3.2 Larval and Juvenile Rearing

### 4.3.2.1 Broodstock survival

***Monitoring questions***

- How many adults survived and sexually matured in the second spring/summer season after collection?
- What water temperature regimes, water source (river vs. well water), and holding conditions (density, tank type and size, substrate, flow rates, diel light conditions, etc.) are optimal for increasing survival and sexual maturation?
- Does pheromone from larvae and adults (opposite sex) stimulate sexual maturation?
- Can sexual maturation be stimulated and synchronized using insulin-like growth factor and other hormonal chemicals?
- Under natural conditions, what proportions of adults spend more than a year to sexually mature?

***Performance metrics***

- Transportation and holding survival rates
- Sexual maturation rates
- Timing of sexual maturation

- Spawning rates (ability to successfully utilize gametes before they lose viability)

Performance may be influenced by a number of variables including water temperature, flow rates, water velocity, water depth, and substrate composition.

***Approach***
The primary goals of broodstock holding is to increase transportation and holding survival rates, increase sexual maturation rates, and enhance spawning success.

Efforts to collect, transport, and hold adult Pacific lamprey from the lower Columbia River have been largely successful with few observed mortalities. However, there are still important questions regarding the potential effects of artificial holding on the sexual maturation of adult lamprey. Although adults overwintering for multiple years may be a natural phenomenon, it is likely that the artificial holding conditions may negatively impact the rates of sexual maturation. It will be important to test and experiment the effects of various holding conditions (temperature, water source, lighting, etc.) strategically and systematically at various holding facilities to investigate the best conditions for successful sexual maturation.

Availability of larval and adult pheromone scents in the water may have an impact on this as well. An individual's genetic makeup may also affect its successful use in propagation. Sexually mature adults are often times covered with fungus and are extremely fragile and vulnerable and as a result, adults have a relatively short timeframe for successful spawning and propagation. If the sexual maturation is not in synchrony between males and females, gametes can often remain unused and go to waste. Insulin-like growth factor and other hormonal chemicals can be tested for its efficacy on synchronizing sexual maturation. It is important to note that what we learn from these propagation experiments will also help us improve the holding conditions for adult lamprey that are part of the translocation programs.

***Analysis***
Correlation and regression techniques can be used to assess the relationships between holding conditions, genetic makeup, and rates of survival and sexual maturation. It is important to compare the survival and sexual maturation rates among all the facilities that hold the adults and from that determine the key factors that drive success (namely high rates of survival and sexual maturation). Every year, certain tank conditions can be modified strategically within and among the various facilities to evaluate the effects.

#### 4.3.2.2 Fertilization to hatch survival

***Monitoring questions***
- What spawning methods maximize the fertilization rates (methodology of gametes and water mixing, holding time, amount of water, chemical treatment, etc.)?
- What incubation methods maximize the hatching rates (McDonald jars, upwelling and downwelling jars, flow rates, chemical treatment, mesh size, etc.)?

- How long can gametes (eggs and milt) be preserved and remain viable using refrigeration, cryopreservation, etc.?
- How can we quickly count egg numbers to evaluate production levels and survival rates

***Performance metrics***

- Fertilization rates and successional egg development
- Hatching rates
- Genetic diversity and fitness

Ability of incubation methods to separate gametes (so that fertilization and hatching rates can be assessed for each spawner group)

***Approach***

Maximizing the fertilization and hatching rates are fairly easy tasks, given that we can emulate and fine tune the propagation protocols that already exist for other lamprey species in other countries as well as salmon species in general. The Yakima Nation and CTUIR have worked collaboratively since 2012 to investigate fertilization and hatching success and many improvements in protocols have been made since then (see section 4.2.2 for more information). A wide variety of incubation methods were compared and contrasted in 2012 to evaluate the success rates of various incubation methods. In 2013, more in-depth questions related to propagation were investigated to continue to refine and improve fertilization and hatching success.

Genetic diversity of Pacific lamprey is influenced by two main sources: 1) the pool of adults that were originally collected from lower Columbia river dams and 2) the degree to which mixing of adults occur in propagation (for instance, 3x3 or higher breeding matrices of males and females can enhance genetic diversity of offspring). Genetic fitness will need to be evaluated on a long-term basis as we collect more information on survival rates and eventually return rates in future years. Lamprey eggs and newly hatched prolarvae are extremely small, allowing them to slide through the smallest gaps in incubation trays and tank dividers. If we were to evaluate fertilization and hatching success accurately for each spawner group, it is important that we use an incubation method or holding vessels that minimize the unanticipated movement of eggs and prolarvae between trays and tank sections.

***Analysis***

Correlation and regression techniques can be used to assess the relationships between propagation and incubation conditions, genetic makeup, and rates of fertilization and hatching. Every year, certain elements of the protocols can be modified strategically to evaluate the effects on propagation success. Increasing the genetic diversity of off spring can be achieved by increasing the breeding matrices as well as the diversity of the source adult population. Subsequent genetic diversity of hatched larvae in the hatchery can be compared to that of hatched larvae from wild and/or translocated adults in the rivers and streams. Due to the limited number of adults and larvae present in many of the supplemented areas, striving to attain higher levels of genetic diversity appear important, but we may also discover later that certain genetic traits may be important fitness traits for survival in the upper Columbia reaches (such as large body lengths and weights).

#### 4.3.2.3 Hatch to outplant survival

***Monitoring questions***

- What is the best conditions for maximizing prolarvae and larvae survival (density, water temperature, cover material, lighting conditions, etc.)?
- What type of holding tanks (circular, trough, inlet and outlet styles, etc.) provide the best conditions for prolarvae and rearing larvae?
- What substrate media (clay, silt, sand, artificial media, etc.) will be optimal for survival, growth, and monitoring of larvae?
- What type of feeds will be optimal for survival, growth, and the overall health of larvae?
- How can larvae be separated from substrate media in a timely manner with the least amount of stress incurred to them for monitoring and transfer/transportation?
- How can we quickly count larvae to evaluate survival and growth rates?
- What is the best way to maximize genetic diversity of the offspring?

***Performance metrics***

- Survival rates of prolarvae
- Survival and growth rates of feeding larvae
- Genetic diversity

***Approach***

Although experimental rearing of larvae in laboratory settings have been conducted for many decades, cases where lamprey were reared from eggs to larger larvae are rare. Based on the fact that Pacific lamprey has very high fecundity (~100,000 eggs per female), the survival rates of Pacific lamprey from egg to larva may be relatively low in the natural environment. In laboratory settings, however, there may be ways to greatly enhance the survival rates at this critical life history stage from eggs to larvae.

The Yakima Nation, CTUIR, USGS, and USFWS have worked collaboratively since 2012 to investigate larval rearing as well as the survival between egg/prolarva and larva life stages. Life stages between egg and prolarva is fairly easy to monitor as they do not require fine substrate for survival and many of the conventional fish hatchery tanks and equipment can be used effectively with small minor modifications. However, once the larvae is ready to feed, it appears that the presence of fine sediment, a medium through which larvae burrow and feed, is vital for their survival. On the flip side, this means that larvae will remain invisible for the majority of time, and monitoring for survival and growth becomes considerably difficult.

Newly hatched prolarvae and young larvae are extremely small (6~10mm long) and refining ways to enumerate them quickly and efficiently is crucial in evaluating the hatching success and survival in general. In 2013, The Yakama Nation has begun testing and calibrating XperCount device (an automated enumerating device for small fish/organisms by XpertSea, Inc - see http://www.xpertsea.com/ for more information) to find effective ways of counting these small larvae with minimal stress on fish.

Many questions still remain about appropriate feed for larvae in terms of survival, growth, and general fish health. Although active dry yeast has proven to be effective in attaining relatively high survival and growth within a short (<1 year) time frame, a certain combination of feeds in addition to active dry yeast (such as hatchfry feeds or marine larvae feeds) may be potentially effective in producing healthier fish and warrants further research. Protocols for rearing and monitoring larvae for extended periods of time (months and years) will need to be developed with ideally minimum handling impacts on larvae.

***Analysis***
Correlation and regression techniques can be used to assess the best methods to hold and rear prolarvae and larvae in terms of survival, growth, and general fish health. The variables of interest are tank settings, density, media substrate, feed type, feed amount and delivery system. Coordination and collaboration on these unique arrays of experiments among various agencies and tribes will be key to maximize our progress in this field of research. The genetic makeup of the surviving larvae will also be investigated to evaluate whether any natural selection is at work within the lab settings. Furthermore, genetic diversity of larvae in the hatchery can be compared to that of larvae from wild and/or translocated adults in the rivers and streams.
Various larvae extraction methods should also be compared and evaluated from the perspective of fish stress and survival as well as time efficiency. Unlike most other hatchery fish, lamprey larvae will need to be separated from the sediment in order to monitor them, so refining the methodology for this task will be important. Use of automated enumeration tools (such as XperCount) may be needed to effectively count and sort the hundreds of thousands of progeny produced from each female.

### 4.3.3 Larval and Juvenile Outplanting

#### 4.3.3.1 Larval Survival and Growth

***Monitoring questions***

- How do the survival rates of propagated larval lamprey compare to naturally-produced lamprey?
- Did release timing and location negatively affect the growth and survival of larval lamprey within target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval growth and survival?
- Is genetic makeup associated with larval growth and survival?

***Performance metrics***

- Size, age, and abundance of larval lamprey
- Number of immigrants and emigrants
- Survival and growth rates

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

***Approach***
For propagation to be successful, released larvae need to grow and survive to the juvenile stage. Ideally, growth and survival rates would be compared to values for "wild" fish. If growth and survival are similar to or better than those measured for "wild" fish, propagation of larval lamprey would be considered a valid approach to improve the status of lamprey populations within subbasins. Growth and survival rates can be measured using parentage analysis. If all parents of propagated larvae are genetically sampled, then routine sampling of the juveniles while they mature in the wild could be used to track the offspring of adults that were spawned for the propagation efforts. These offspring could then be compared to wild larvae in the same area though confirming the age classes of the wild larvae may be difficult.

Alternative techniques to assess growth and survival rates of larval lamprey are not currently available. Visible Implant Elastomer (VIE) markings have been tested for various size classes of juvenile and larval lamprey (down to 30mm size) and appears to be a promising technique for marking early life stage lamprey. VIE marks appear to last for a long term. Survival appears to be very high but effects on feeding and growth requires further investigation. Fin clips have also been used to mark larval and juvenile lamprey, but their impacts on both survival and growth have not been evaluated extensively to date. Genetic analysis may be the best available approach for monitoring movement of larvae in and out of sites, aging larvae, and assessing handling effects.

Annual larval sampling within treated and untreated areas before and after propagation will be needed to assess growth and survival rates. This work should be done within target areas and areas supporting natural production of Pacific lamprey. This will allow the comparison of growth and survival rates between the two areas, especially if mark and recapture studies can be incorporated into the sampling. Electrofishing techniques modified for sampling larval lamprey may be the most appropriate collection method for shallow water. Collected fish would be measured for length and weight, aged (method yet to be developed), and marked or tagged (standard method yet to be developed). A separate study would be needed to determine the effects of shocking, handling, and marking/tagging on larval lamprey growth and survival. This work would likely be conducted in a laboratory. Finally, lamprey biologists will need to identify a protocol for sampling habitat conditions.

***Analysis***
An appropriate model would be used to estimate growth and survival from mark-recapture data. These rates would then be compared between propagated and naturally produced larvae. Alternatively, we can also focus sampling in areas where the propagated and naturally produced larvae are well isolated from each other, if we can assume that immigration and emigration rates are minimal between the sampling dates. Because data will be collected annually, a time series of annual growth and survival rates can be generated and compared between populations and laboratory studies. Correlation and regression techniques can be used to assess the relationships among habitat conditions, larval abundance, growth rates, and potentially survival rates.

Although techniques are not currently standardized for continuously measuring growth and survival rates, length, weight, and condition factors can be compared among areas or groups of fish. In addition, using correlation and regression techniques, these factors can be evaluated to see if they are associated with densities (density-dependent effects) and habitat conditions.

#### 4.3.3.2 Larval Abundance and Distribution

***Monitoring questions***

- How many larvae remained within the target areas over time?
- Did the distribution of released larvae expand into areas outside the target areas?
- Did release timing and location negatively affect the density and distribution of larval or juvenile lamprey within the target areas?
- What habitat conditions (e.g., flows, water quality, temperature, substrate, velocities, depths, etc.) were associated with larval distribution and abundance?

***Performance metrics***

- Density of larvae (CPUE or fish/$m^2$)
- Distribution and abundance of larvae
- Presence and proportion of various size classes of larvae

Performance may be influenced by a number of variables including water temperature, stream flow, water quality, water velocity, water depth, substrate composition, and riparian condition.

***Approach***

An important assumption of propagation is that planted larvae will use intended rearing areas over time. Biologists will identify suitable release sites based on rearing conditions within those sites. If habitat is not suitable for rearing, propagated larvae may leave the area or die. Even if the habitat is suitable, larvae may naturally migrate downstream over time. If biologists are able to identify suitable rearing areas that are used successfully by propagated larvae, it may improve the status of Pacific lamprey within the subbasin.

Annual larval sampling within treated and untreated areas before and after propagation will determine the relative abundance of larvae within the target areas. Electrofishing techniques modified for sampling larval lamprey may be the most appropriate method for estimating relative abundance and distribution in shallow water. Locations of juveniles can be mapped using GPS. Lamprey biologists will need to identify a protocol for sampling habitat conditions.

***Analysis***

A time series of the densities (CPUE or fish/$m^2$) of larval lamprey and numbers of transformers can be constructed to show how densities and numbers changed before and after the propagation and release of larvae. Direct assessment of the abundance and distribution of planted larvae can be implemented via parentage analysis to identify offspring of adults that were spawned in the hatchery. Distribution maps can be generated that show how the spatial extent of larvae expanded or contracted over time. Correlation and regression techniques can be used to assess the relationships between habitat conditions and larval abundance and distribution.

#### 4.3.3.3 Larval and Juvenile Outmigration

See Section 4.3.1.5 for information on monitoring questions, performance metrics, approach and analysis.

#### 4.3.3.4 Adult Returns

See Section 4.3.1.6 for information on monitoring questions, performance metrics, approach and analysis.

### 4.3.4 Experimental Controls

For supplementation to be successful, larvae produced by translocated adults or released from hatcheries need to survive, grow, and eventually transform and migrate. Ideally, survival, growth, and transformation rates would be compared to values for areas not being supplemented. If survival, growth, and transformation rates are similar to or better than those measured for areas not being supplemented, then translocation or propagation would be considered a valid approach to improve the status of lamprey populations within subbasins. Feasible approaches may range from simple comparisons of adult returns among areas to actual comparisons of larval survival, growth and transformation among areas. Non-supplemented "control" areas might be distinct watersheds within a subbasin being supplemented elsewhere, or a nearby subbasin considered a suitable control. The use of experimental controls is implicit in most of the approaches described above.

### 4.3.5 Genetic Monitoring and Analysis

Recently, a set of 96 high-throughput genetic assays (single nucleotide polymorphisms, SNPs) have been developed for Pacific lamprey and have been demonstrated to perform the following three critical functions: 1) species identification, 2) parentage assignment, and 3) characterization of adaptive variation (Hess et al. in prep). These functions have important implications for the conservation of Pacific lamprey, and have already been applied successfully to specific management questions. For example, 1) species identification via genetic analysis has been utilized to document a natural reintroduction of Pacific lamprey in a tributary in which this species was thought to be extirpated (Hess et al. in prep). The putative Pacific lamprey larvae that were collected were all 0-year age class, which is a particularly challenging age class to morphologically distinguish Pacific lamprey from other species such as Western brook lamprey, however in this case all larvae were confirmed as Pacific lamprey. 2) Parentage assignment has been utilized to verify reproductive success of translocated adults that had been released in 2007 into Newsome Creek (Snake River Basin). A smolt trap was used in 2012 to collect over a hundred juvenile lamprey of which nearly 100% were successfully assigned back to their parents that had been translocated in 2007 (Hess et al. in prep). Therefore, types of information that parentage assignment can provide includes a direct measure of reproductive success of a group of adults (e.g. number of viable offspring per spawner pair) and an accurate method for aging offspring. This latter piece of information is particularly critical for refining our understanding of the relationship between larval size and age distributions, and the age-timing of juvenile lamprey life-stage transformations (i.e. ammocoete to macropthalmia). 3) Adaptive variation that was found to be associated with morphology, run-timing, and geography (Hess et al. 2013) can be characterized using the 96 high-

throughput assays, and was demonstrated to reflect differences in body-size and run-timing among adults collected at Willamette Falls in the Lower Columbia River. Specific adaptive genetic markers will be characterized in the adults used for supplementation to assess how the genotypes of individuals may help predict their reproductive success at particular supplementation sites. Therefore, these three central functions of the 96 SNPs will provide critical pieces of information needed to implement effective monitoring of these Pacific lamprey conservation efforts.

# 5 Supplementation Research Plans for Ceded Area Subbasins -- General Outline

Comment [H53]: Why is this limited to Ceded Area Subbasins? If this is a Tribal/State/Private document then the Outline should be generic to a Subbasin, Watershed etc.

This section provides a template for Subbasin Supplementation Plans that will be integral components of the RME Framework. Development of these plans is anticipated to guide future activities and funding associated with periodic updates for the (1) Tribal Pacific Lamprey Restoration Plan (CRITFC 2011a), (2) USFWS Conservation Agreement for Pacific Lamprey (Lamprey Conservation Agreement; USFWS 2012) and (3) Northwest Power and Conservation Council Fish and Wildlife Program (NPCC 2009). Plans provide information specific to a subbasin regarding lamprey status, limiting factors, ongoing and planed actions, and rationale for those actions. Plans describe supplementation actions and RME actions associated with supplementation, including metrics, parameters, etc. Although plans will vary in scope and content among subbasins, each plan should provide a minimum of information described here to facilitate consistency and continuity of important methods, analysis, and reporting formats. An example plan for the Yakama River Subbasin is provided for further guidance in Appendix A.

## 5.1 Introduction

### 5.1.1 Subbasin Overview

Provide general information about the subbasin such as location, drainage size, annual and seasonal discharge, major topographic features, and important human population centers. Include information about major natural lakes and reservoirs, diversions, and other facilities potentially affecting passage or habitat quantity/quality. Briefly describe changes from the natural seasonal hydrograph, if any, and how changes in passage, habitat, and the hydrograph have affected Pacific lamprey.

### 5.1.2 Importance of lamprey in the ecosystem and as a cultural resource

Describe importance of Pacific lamprey to the ecosystem and tribal culture within the subbasin. Provide information on historic harvest sites, numbers, etc. if possible.

### 5.1.3 Brief Historic and Current status and USFWS findings for subbasins

Briefly summarize subbasin-specific information from the 2011 USFWS Conservation Assessment. Include information on potential population groupings and historic and current status and trends. If available, include information on limiting factors and critical uncertainties. Summarize information in tables as appropriate.

### 5.1.4 Ultimate goals and vision: natural production and harvest

State the overall goals or vision of the supplementation research plan. Demonstrate how these are consistent or complimentary with those of existing plans or programs. Examples may include the Tribal Restoration Plan, the Conservation Agreement, NPCC subbasin plans, or goals or plans of pertinent management entities.

## 5.2 Summary of Pacific Lamprey Status in the Subbasins

### 5.2.1 Adult abundance, run timing, and spawning locations

Summarize as much historical and current information as possible to document information on adult Pacific lamprey abundance and distribution in the subbasin. Use tables as appropriate. Discuss the implications of continuing downward trends when relevant. Summarize information on run timing if available.

### 5.2.2 Juvenile abundance and run timing (focusing on macrophthalmia)

Summarize as much historical and current information as possible to document information on juvenile Pacific lamprey abundance and distribution in the subbasin. Use tables as appropriate. Discuss the implications of continuing downward trends when relevant. Summarize information on migration timing if available.

### 5.2.3 Ammocoete abundance and distribution

Summarize as much historical and current information as possible to document information on ammocoete abundance, distribution, and habitat use in the subbasin. Use tables as appropriate. Note if information is specific to Pacific lamprey or includes brook lamprey. Discuss the implications of continuing downward trends when relevant.

## 5.3 Analysis Units (Optional)

Provide justification for partitioning Pacific lamprey within the subbasin into analysis units if applicable. Preference would be to adopt USFWS groupings. Additional justification for groupings may include management areas, passage constraints, differences in habitat quality/quantity, or others. Provide a map of the subbasin highlighting the various analysis units.

### 5.3.1 Analysis unit descriptions

Use subsections to define and describe each analysis unit. These should be referenced from existing documents if possible to avoid the need to define new geographic units. Include geographic bounds (e.g., watersheds included), and general descriptions of Pacific lamprey abundance and distribution.

## 5.4 Summary of Pacific Lamprey Primary Limiting Factors

Describe known limiting factors and critical uncertainties for Pacific lamprey in the subbasin. Use a different subsection for each analysis unit if applicable. For each unit, describe factors for adults, juveniles, and ammocoetes when possible. Use tables to summarize information. Example of limiting factors may include passage at dams and diversions (including juvenile or ammocoete entrainment), water quality, habitat quantity/quality, and others.

## 5.5 Lamprey Supplementation Research Actions over the Next 5-10 Years

Describe both ongoing and anticipated supplementation RME actions. Provide sufficient detail to fully describe and justify actions. Ensure that critical uncertainties, key hypotheses, and general monitoring strategies have been described. Include a summary of potential comparisons to assist in evaluating effectiveness of supplementation actions (Table 5-1). Describe any cross-regional efforts that are addressed. Examples of potential actions for the Grande Ronde, Tucannon, Walla Walla, Umatilla, and John Day subbasins, including comparisons and timelines, are provided (Table 5-3).

**Table 5-1. Numerical codes for monitoring and evaluating the three supplementation research strategies described in section 4.3 of the *Framework for Pacific Lamprey Supplementation Research in the Columbia River* Basin.**

| 4.3.1 | Adult Translocation | 4.3.2 | Larval and Juvenile Rearing | 4.3.3 | Larval and Juvenile Outplanting |
|---|---|---|---|---|---|
| 4.3.**1.1** | Adult Survival | 4.3.**2.1** | Broodstock survival | 4.3.**3.1** | Larval Growth and Survival |
| 4.3.**1.2** | Adult Spawning | 4.3.**2.2** | Fertilization to hatch survival | 4.3.**3.2** | Larval Abundance and Distribution |
| 4.3.**1.3** | Larval Survival and Growth | 4.3.**2.3** | Hatch to outplant survival | 4.3.**3.3** | Larval and Juvenile Outmigration |
| 4.3.**1.4** | Larval Abundance and Distribution | | | 4.3.**3.4** | Adult Returns |

| | | | | | |
|---|---|---|---|---|---|
| 4.3.**1.5** | Larval and Juvenile Outmigration | | | | |
| 4.3.**1.6** | Adult Returns | | | | |

**Table 5-2. Comparison chart displaying all potential comparison pairs of the different supplementation and research strategies. T = Translocation; larval/juvenile lamprey from translocated adults. P = Propagation; larval/juvenile lamprey born and reared in a hatchery environment. O = Outplanting; larval/juvenile lamprey artificially propagated and released into the natural environment. C = Control; larval/juvenile lamprey born and rearing in the natural environment.**

| Comparison | Translocation | Hatchery | Outplanting | Control |
|---|---|---|---|---|
| Translocation | TxT | HxT | OxT | CxT |
| Hatchery | TxH | HxH | OxH | CxH |
| Outplanting | TxO | HxO | OxO | CxO |
| Control | TxC | HxC | OxC | CxC |

Comment [JAE54]: Change "Hatchery" to "Propagation" in the matrix heading.

**Page B-4: [1] Comment [DBJ15] Jepsen, David 3/30/2014 8:53:00 PM**

These are interesting research questions but supplementation is not necessary to pursue these questions. For example, lifestage survival models using parentage-based genetic analysis could be developed anywhere spawning or migrating adults can be captured (like Smith River falls, Umpqua River Basin); and different types of irrigation diversion screens are tested in lab studies (e.g., Rose and Mesa 2012) using larval lampreys that can be readily collected from areas of larval abundance in the wild using relatively simple capture techniques.

-Another consideration is density dependent effects-i.e. survival might be higher if you have 2 lamprey per basin than 100 lamprey per basin-i.e. spread out the breeders to maximize juvenile survival

- The use of hatchery reared individuals may even bias results based on potential for selection (c.f.-salmonid literature)

**Page B-4: [2] Comment [H17] Hebdon,Lance 3/30/2014 8:53:00 PM**

I agree but restoration should focus on the major limiting factors. For example if upstream adult passage is the primary concern let's not divert attention from that issue with other minor habitat issues..

**Page B-4: [3] Comment [BM19] Brian McIlraith 3/30/2014 8:53:00 PM**

Perhaps in the early paragraphs we cite something that highlights all of the potential/important threats to lamprey survival—USFWS assessment, CRBLTWG critical uncertainties

**Page B-4: [4] Comment [SMN20] Shivonne M Nesbit 3/30/2014 8:53:00 PM**

I think it is premature to state the need for a conservation hatchery bc we really don't know if artificial propagation is do-able. Might be better stated that research is needed to determine if conservation hatcheries are a viable recovery tool for lamprey.

**Page B-4: [5] Comment [DBJ21] Jepsen, David 3/30/2014 8:53:00 PM**

Conserving the remaining genetic diversity and overall viability of the species assumes that the Pacific lamprey is facing an imminent loss of genetic diversity and the viability of the species is actually threatened. If the interior CRB is really part of a panmictic population that include Oregon and Washington, as the genetic research suggests and the research framework reports, then genetic diversity and species viability should be discussed at this scale. Unfortunately, almost all population trend estimates for Pacific lamprey come from locations where barriers hinder upstream passage of lampreys. Many have misguidedly extrapolated these dramatically declining populations to the entire region and treated these point counts or estimates as representative of a trend for the species. Instead, these point estimates should be considered case studies of a particular location with specific conditions that affect local lamprey abundance. More population status information is needed from watersheds without barriers from throughout the range to understand the actual status of the species. In short, threats to genetic diversity and species viability are not valid arguments for developing a captive breeding program when status and trend information only comes from severely biased samples sites.

**Page B-4: [6] Comment [SMN23] Shivonne M Nesbit 3/30/2014 8:53:00 PM**

I struggle with discussion of supplementation risks when we haven't discussed specific threats - perhaps that level of detail will be address in the subbasin plans? I.e. If we haven't addressed specific threats to lamprey how will supplementation help? Or will supplemented fish face the same fate i.e. downstream migrants being impinged on

**Wasco final DRAFT completion report Lamprey Framework CRITFC 05122014 test**

## Main document changes and comments

**Page B-2: Comment [JAE1]** **Easterbrooks, John A (DFW)** **3/30/2014 8:53:00 PM**

Is this true? I was not aware that targeted chemical eradication of PL had occurred in the CRB. What documentation do we have? I thought chemical eradication only occurred in the Great Lakes region to control invasive Sea Lamprey that bypassed Niagra Falls through the Welland Lock/Canal.

**Page B-2: Comment [DBJ2]** **Jepsen, David** **3/30/2014 8:53:00 PM**

An important goal of the supplementation program would be to boost adult returns to the interior CRB to allow for more tribal harvest for food and cultural use of lampreys, which has been severely reduced in recent years. If supplementation is successful and millions of captive-bred larvae are planted in the interior CRB, it essentially increases the rearing capacity of the species and will likely increase the number of adults returning to spawn in the Pacific Northwest. However, current data suggest that Pacific lamprey do not home to their natal spawning grounds as do salmon, rather they will mix with the largely panmictic population of the Pacific Northwest. Only a fraction of the increase of adults will even attempt to access the interior CRB; and because of dams hindering upstream passage, only a tiny fraction of those will make it to the interior CRB. This suggests that supplementation in interior CRB may provide little bang for the buck in adult returns in this region. This research framework draft should be clearer about the connection between supplementation and expectations of adult returns in the interior CRB.

**Page B-2: Comment [DBJ3]** **Jepsen, David** **3/30/2014 8:53:00 PM**

So is the conservation objective of this research to implement supplementation actions? Or is it to inform future/current conservation actions in an adaptive and structured decision-making process? Maybe insert a paragraph here that really outlines this body of RME relative to risk reduction strategies such as dam passage and habitat restoration. Define here why lamprey supplementation is different than salmonid supplementation, where the later is seen as a short –term experiment to be implemented once the factors of decline are addressed.

**Page B-2: Comment [DBJ4]** **Jepsen, David** **3/30/2014 8:53:00 PM**

Alternative to what?

**Page B-3: Comment [DBJ5]** **Jepsen, David** **3/30/2014 8:53:00 PM**

As we discussed in the meeting, perhaps this is a place where you communicate co-manager buy-in and decisions process (i.e. jurisdictions, regional goals, existing plans/agreements, allowances under scientific take permits, other potential permitting issues, etc.).

**Page B-3: Comment [DBJ6]** **Jepsen, David** **3/30/2014 8:53:00 PM**

As a general rationale for the use of artificial production:

- it could beneficially help with reintroductions in upriver tributaries where lamprey <u>are extinct</u>.

-it could supply a source of lampreys for research so the researchers throughout the basin could stop or cut back on use of wild lampreys.

- there are low risks to planting artificially-produced lampreys in a basin where they are extinct. The lampreys might be wasted, but they won't cause a risk.

**Page B-3: Comment [DBJ7]** **Jepsen, David** **3/30/2014 8:53:00 PM**

Need a paragraph here on the risks/considerations involved in taking adult fish from a productive watershed and putting them into one that by definition has some lamprey issues. That is a risk and regional co-managers may have concern about best investment of wild adults.

| **Page B-3: Comment [DBJ8]** | **Jepsen, David** | **3/30/2014 8:53:00 PM** |
|---|---|---|

Good; but what are the criteria to stop doing it?

| **Page B-4: Comment [DBJ9]** | **Jepsen, David** | **3/30/2014 8:53:00 PM** |
|---|---|---|

So the goal/objective is to improve the status within a subbasin; and I assume this is without doing any harm to the status in other basins?

| **Page B-4: Comment [SMN10]** | **Shivonne M Nesbit** | **3/30/2014 8:53:00 PM** |
|---|---|---|

Time-line? And what is the long-term strategy?

DW: Reference the USFWS Conservation Template and the Tribal Restoration Plan. Tribal plan says "sustainable harvestable levels" by 2050

| **Page B-4: Comment [BM11]** | **Brian McIlraith** | **3/30/2014 8:53:00 PM** |
|---|---|---|

Again need to check point of view within this document—who is the WE

| **Page B-4: Comment [H12]** | **Hebdon,Lance** | **3/30/2014 8:53:00 PM** |
|---|---|---|

Hatchery propagation

| **Page B-4: Comment [SMN13]** | **Shivonne M Nesbit** | **3/30/2014 8:53:00 PM** |
|---|---|---|

Long-term is repeated throughout this document but I am unclear on what sort of timeline we are talking about or how we will use this framework to inform long-term thinking/strategies.

| **Page B-4: Comment [H14]** | **Hebdon,Lance** | **3/30/2014 8:53:00 PM** |
|---|---|---|

Assumes that hatchery larvae will successfully migrate and return

| **Page B-4: Comment [DBJ15]** | **Jepsen, David** | **3/30/2014 8:53:00 PM** |
|---|---|---|

These are interesting research questions but supplementation is not necessary to pursue these questions. For example, lifestage survival models using parentage-based genetic analysis could be developed anywhere spawning or migrating adults can be captured (like Smith River falls, Umpqua River Basin); and different types of irrigation diversion screens are tested in lab studies (e.g., Rose and Mesa 2012) using larval lampreys that can be readily collected from areas of larval abundance in the wild using relatively simple capture techniques.

-Another consideration is density dependent effects-i.e. survival might be higher if you have 2 lamprey per basin than 100 lamprey per basin-i.e. spread out the breeders to maximize juvenile survival

- The use of hatchery reared individuals may even bias results based on potential for selection (c.f.-salmonid literature)

| **Page B-4: Comment [H16]** | **Hebdon,Lance** | **3/30/2014 8:53:00 PM** |
|---|---|---|

I don't think the model should be the focus. The focus should be on identifying the bottleneck to increased adult returns. The model is a tool for evaluating conservation strategies.

**Page B-4: Comment [H17]** **Hebdon,Lance** **3/30/2014 8:53:00 PM**

I agree but restoration should focus on the major limiting factors. For example if upstream adult passage is the primary concern let's not divert attention from that issue with other minor habitat issues..

**Page B-5: Comment [SMN18]** **Shivonne M Nesbit** **3/30/2014 8:53:00 PM**

What are we doing to address the threats? I.e. passage at mainstem dams?

**Page B-5: Comment [BM19]** **Brian McIlraith** **3/30/2014 8:53:00 PM**

Perhaps in the early paragraphs we cite something that highlights all of the potential/important threats to lamprey survival—USFWS assessment, CRBLTWG critical uncertainties

**Page B-5: Comment [SMN20]** **Shivonne M Nesbit** **3/30/2014 8:53:00 PM**

I think it is premature to state the need for a conservation hatchery bc we really don't know if artificial propagation is do-able. Might be better stated that research is needed to determine if conservation hatcheries are a viable recovery tool for lamprey.

**Page B-5: Comment [DBJ21]** **Jepsen, David** **3/30/2014 8:53:00 PM**

Conserving the remaining genetic diversity and overall viability of the species assumes that the Pacific lamprey is facing an imminent loss of genetic diversity and the viability of the species is actually threatened. If the interior CRB is really part of a panmictic population that include Oregon and Washington, as the genetic research suggests and the research framework reports, then genetic diversity and species viability should be discussed at this scale. Unfortunately, almost all population trend estimates for Pacific lamprey come from locations where barriers hinder upstream passage of lampreys. Many have misguidedly extrapolated these dramatically declining populations to the entire region and treated these point counts or estimates as representative of a trend for the species. Instead, these point estimates should be considered case studies of a particular location with specific conditions that affect local lamprey abundance. More population status information is needed from watersheds without barriers from throughout the range to understand the actual status of the species. In short, threats to genetic diversity and species viability are not valid arguments for developing a captive breeding program when status and trend information only comes from severely biased samples sites.

**Page B-5: Comment [H22]** **Hebdon,Lance** **3/30/2014 8:53:00 PM**

This is absolutely critical to develop culture techniques prior to dangerously low abundance.

**Page B-5: Comment [SMN23]** **Shivonne M Nesbit** **3/30/2014 8:53:00 PM**

I struggle with discussion of supplementation risks when we haven't discussed specific threats - perhaps that level of detail will be address in the subbasin plans? I.e. If we haven't addressed specific threats to lamprey how will supplementation help? Or will supplemented fish face the same fate i.e. downstream migrants being impinged on screens? The attached subbasin plan (Yakama Nation) does address threats and limiting factors so would suggest including a sentence explaining that threats will be addressed in the subbasin plans.

**Page B-5: Comment [DBJ24]** **Jepsen, David** **3/30/2014 8:53:00 PM**

This research framework summarizes some of the valid risks of supplementation thorough artificial propagation but leaves out the most glaring risk. This draft does not mention any of the research that illuminates the risks associated with captive-bred salmonids. These risks include captive-bred adults producing offspring with reduced fitness (Araki et al 2007, Araki et al. 2008), genetic adaptation occurring in a single generation in captivity (Christie et al. 2011), and the reduction of reproductive fitness of wild-spawning fish when they spawn with a captive-bred adult (Araki et al. 2009). If these risks apply to captive-bred lampreys, their adverse effects might be magnified by the fact that adult lampreys do not home to natal spawning grounds so their likelihood of straying and mixing with wild populations is greater than it is with salmonids. Furthermore, for the small fraction of captive-bred adults attempting to return to the interior CRB, the vast majority of them would be turned back at one of the mainstem dams and even these fish would likely spawn with natural-spawning populations. In short, supplementation through artificial propagation runs the risk of doing almost nothing for Pacific lamprey adult abundance in the interior CRB while reducing the fitness of natural-spawning lampreys throughout the Pacific Northwest.

DW: some of this is worth bringing forth in the "context" text.

**Page B-5: Comment [H25]** **Hebdon,Lance** **3/30/2014 8:53:00 PM**

Hatchery

**Page B-5: Comment [H26]** **Hebdon,Lance** **3/30/2014 8:53:00 PM**

This section is about artificially propagated lamprey so the translocation is out of place.

**Page B-5: Comment [H27]** **Hebdon,Lance** **3/30/2014 8:53:00 PM**

Are these captive reared to maturation or captive broodstock?

**Page B-5: Comment [SMN28]** **Shivonne M Nesbit** **3/30/2014 8:53:00 PM**

One focus of this framework is to research & develop long-term supplementation strategies. I know we at ground zero with lamprey in regards to supplementation but I would still ask the question- in addition to figuring out supplementation strategies- we also need to discuss when to stop supplementation i.e. it isn't working, or certain strategies are not cost-effective or it is working so well we hit target abundance, distribution. Not sure if that needs to be defined in this document bc this is more of a 'set the stage for how to proceed' but will likely need to define stopping points somewhere.

**Page B-5: Comment [SMN29]** **Shivonne M Nesbit** **3/30/2014 8:53:00 PM**

Is the intent of all products to be adopted by all fisheries managers? I.e. tribal and non-tribal? Need to define process for coordinated efforts between fisheries managers for the different products.

**Page B-7: Comment [SMN30]** **Shivonne M Nesbit** **3/30/2014 8:58:00 PM**

I have not had a chance to review this document.

**Page B-8: Comment [H31]** **Hebdon,Lance** **3/30/2014 8:58:00 PM**

Parental Based Tagging.

**Page B-8: Comment [H32]** **Hebdon,Lance** **3/30/2014 8:58:00 PM**

If all spawning adults in a population are known.

**Page B-9: Comment [SMN33] Shivonne M Nesbit 3/30/2014 8:58:00 PM**

Likely missed it but what is the reporting plan?

**Page B-9: Comment [SMN34] Shivonne M Nesbit 3/30/2014 8:58:00 PM**

On page 16 Section 3.3 the Scope of the framework is described as narrow in time (5years) and space (a few select basins) so how does that fit with long-term RME?

**Page B-9: Comment [H35] Hebdon,Lance 3/30/2014 8:58:00 PM**

Separate R, M &E

**Page B-9: Comment [SMN36] Shivonne M Nesbit 3/30/2014 8:58:00 PM**

Might be worth spelling out a process i.e. 5-year review of framework.

**Page B-10: Comment [JAE37] Easterbrooks, John A (DFW) 3/30/2014 8:58:00 PM**

Rotenone treatments intentionally targeting lamprey? Clarify what the rotenone treatments were for….directly or indirectly killed lamprey.

**Page B-13: Comment [JAE38] Easterbrooks, John A (DFW) 3/30/2014 8:58:00 PM**

Use a footnote to explain that the higher count at Priest Rapids, relative to McNary, is because lamprey that use the navigation lock at McNary are not counted. There is no nav lock at PRD, so all lamprey must pass the fish ladder counting window. That is why there has not been a noticeable decline in counts at PRD since 2002. The lower CR and Snake R. dams all have navigation locks that bypass lamprey around the counting stations.

**Page B-14: Comment [DBJ39] Jepsen, David 3/30/2014 8:58:00 PM**

The goal of attracting adults to specific watersheds by supplementing them with larvae will likely have some effect since adults are indeed attracted to larval pheromones. If other factors, such as discharge or temperature, don't obscure the effect of greater numbers of larvae in a watershed, supplementation is likely to only improve the particular watershed where the treatment has occurred. Since there are relatively small numbers of adults reaching the interior CRB and they don't home to natal watersheds, a gain in a supplemented watershed may not represent an increase of adults since it is likely to detract from another watershed that didn't receive a larval supplement.

(However, more lamprey might be tempted to attempt upstream passage both pre and post passage improvements thereby increasing actual numbers in the UCB)

**Page B-14: Comment [SMN40] Shivonne M Nesbit 3/30/2014 8:58:00 PM**

Assuming these areas have been identified? How were they defined? How will we define additional areas? i.e. is there a process?

**Page B-15: Comment [SMN41] Shivonne M Nesbit 3/30/2014 8:58:00 PM**

'Long-term' is repeated throughout this document. How does the 5-year scope fit with long-term planning & research?

**Page B-15: Comment [SMN42] Shivonne M Nesbit 3/30/2014 8:58:00 PM**

How were these basins selected?

**Page B-15: Comment [SMN43] Shivonne M Nesbit 3/30/2014 8:58:00 PM**

Okay- so how will adaptive management work? Annual review of supplementation techniques? 5-year review of framework? Answer some research questions, ask more?

| **Page B-15: Comment [SMN44]** | **Shivonne M Nesbit** | **3/30/2014 8:58:00 PM** |
|---|---|---|

Expand how? To more basins? Longer time frame? Different supplementation techniques?

| **Page B-15: Comment [SMN45]** | **Shivonne M Nesbit** | **3/30/2014 8:58:00 PM** |
|---|---|---|

So why the 5-year scope?

| **Page B-16: Comment [SMN46]** | **Shivonne M Nesbit** | **3/30/2014 8:58:00 PM** |
|---|---|---|

A simple flow chart showing all the relevant documents and how they are linked as far as Supplementation might be a handy visual esp for those that aren't familiar with all the different plans.

| **Page B-17: Comment [JAE47]** | **Easterbrooks, John A (DFW)** | **3/30/2014 8:58:00 PM** |
|---|---|---|

To match "Action Effectiveness Monitoring" described on the previous page.

| **Page B-18: Comment [JAE48]** | **Easterbrooks, John A (DFW)** | **3/30/2014 8:58:00 PM** |
|---|---|---|

True, but don't over sell this ecological benefit, particularly in the near-term. Overall abundance of adult lamprey is low and total biomass is miniscule compared to salmon and steelhead because each adult only weighs about 1 pound. It takes 30 lamprey carcasses to be equivalent to a single 30 lbs. fall chinook carcass. I suggest you be "up front" about the biomass disparity.

| **Page B-19: Comment [JAE49]** | **Easterbrooks, John A (DFW)** | **3/30/2014 8:58:00 PM** |
|---|---|---|

Provide the translocation guidelines as an appendix to the Supplementation Research Framework.

| **Page B-19: Comment [JAE50]** | **Easterbrooks, John A (DFW)** | **3/30/2014 8:58:00 PM** |
|---|---|---|

These are all good strategies for implementing regional-level translocation in a consistent manner.

| **Page B-20: Comment [JAE51]** | **Easterbrooks, John A (DFW)** | **3/30/2014 8:58:00 PM** |
|---|---|---|

What do you mean by this? Maturity of the fish? the month of the year that fish matured?

| **Page B-20: Comment [JAE52]** | **Easterbrooks, John A (DFW)** | **3/30/2014 8:58:00 PM** |
|---|---|---|

Due to the difficulty in propagating large numbers of larvae or larger juveniles, artificial synthesis of lamprey pheromone in a biochemistry lab deserves serious consideration.

| **Page B-36: Comment [H53]** | **Hebdon,Lance** | **3/30/2014 8:58:00 PM** |
|---|---|---|

Why is this limited to Ceded Area Subbasins? If this is a Tribal/State/Private document then the Outline should be generic to a Subbasin, Watershed etc.

| **Page B-39: Comment [JAE54]** | **Easterbrooks, John A (DFW)** | **3/30/2014 8:58:00 PM** |
|---|---|---|

Change "Hatchery" to "Propagation" in the matrix heading.

**Header and footer changes**

**Text Box changes**

**Header and footer text box changes**

**Footnote changes**

**Endnote changes**

August 28, 2014

Memorandum

To: Brian McIlraith, Lamprey Coordinator
Columbia River Inter-Tribal Fish Commission

From: Howard Schaller, Project Leader
Columbia River Fisheries Program Office (CRFPO), Vancouver, WA

Subject: Pacific Lamprey Supplementation Framework

Thank you for the opportunity to preview the draft "Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin". The Pacific Lamprey framework is much improved from previous draft versions. The following are the collective comments of the CRFPO staff.

The framework clearly identified that supplementation is a short-term action. However, the definition of "short-term" was not clear? This could be expressed in estimated generations of lamprey and subsequent monitoring could be established to evaluate the success of supplementation. The length of the supplementation programs should be guided by specific goals that are monitored through an adaptive management framework. The entire group of partners in the Columbia Basin (and outside of the basin) should be in collaboration on any broad supplementation framework so that efficiencies can be gained and resources pooled to maximize effectiveness.

**RESPONSE**

**Within the document, we define short-term actions as 0-10 years and long-term actions as > 10 years. This was not clear within the reviewed draft and as a result there were multiple changes made to the new draft to present this information more clearly. This designation was somewhat arbitrary and is generally based on the life history of the lamprey (~0-13 years), the potential for monitoring and evaluating ongoing supplementation projects (e.g. translocation projects beginning in 2000), and projected budgets and outyear spending capabilities. We felt like 10 years encompassed these broad topics relatively well but fully admit that this designation could be (should be) fine-tuned.**

**The length of supplementation programs should be guided by specific goals that are monitored through an adaptive management framework. The Pacific Lamprey Restoration and Supplementation Research Subbasin Plans (Subbasin Supplementation Research Plans; Appendices C and D) are initial attempts to begin planning out some of these actions at the subbasin scale. Ultimately, these are intended to be reviewed by the region so that potential collaborations and subbasin-subbasin comparisons can be identified. Also, further specificity for a broad supplementation framework will likely be included in a Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research scheduled to be completed in 2015.**

**See below, specific locations with the Supplementation Research Framework where comments are addressed.**

**Page 5 — Added time information (0-10 years) to short-term throughout.**

Supplementation is defined in terms of translocation of adults or propagation of larvae and juveniles. It is not clearly identified what will be supplemented and for what reason. Is the target natural populations, vacant habitat, or new populations previously established (e.g., translocation efforts). Also it is not clearly defined what may be the trigger or purpose for the supplementation. Examples may be to offset demographic concerns, to bolster populations above migration barriers, or to establish new populations (not really supplementation). It is also not clear whether areas are being supplemented with naturally-produced or donor populations.

**RESPONSE**

**We added language to the document to broaden the potential reasons for specific strategies. However, each subbasin has a unique set of problems so the supplementation strategy implemented and the reasons for this will be specific to the subbasin. Within the body of the document, we tried to list all of the potential reasons for different strategies but left the specifics to the subbasin managers. Much of this information is contained in The Pacific Lamprey Restoration and Supplementation Research Subbasin Plans (Subbasin Supplementation Research Plans; Appendices C and D). Also, further specificity will likely be included in a Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research scheduled to be completed in 2015 (e.g. what will be supplemented and for what reason).**

**See below, specific locations with the Supplementation Research Framework where comments are addressed.**

**Pages 4, 5, 18, and 20 — added "to offset demographic concerns, to bolster populations above migration barriers, or to reestablish a presence of Pacific lamprey"**

The metrics to monitor success (or failure) are not clearly established. More attention could be given to monitoring schemes that have some probability or power to detect changes in populations due to supplementation actions.

**RESPONSE**

**We certainly agree with this comment. However, the initial focus of this draft was to propose possible monitoring approaches for each of the strategies identified, organized around the life history of lamprey. Basically, provide an organizational framework. Further work should occur to fine-tune these methods for specific supplementation actions in a way that provides quantitative comparisons and has "some probability or power to detect changes in populations." Unfortunately, the implementation of the best monitoring schemes may be limited by projected budgets and outyear spending capabilities. Further discussion should consider the feasibility of certain schemes so that information can be generated within existing or projected project capabilities.**

**Further specificity will likely be included in a Master Plan for Pacific Lamprey Supplementation, Aquaculture, Restoration, and Research scheduled to be completed in 2015.**

In addition, it appears that monitoring through spawning surveys will only occur in targeted (e.g. translocation) areas. Since it is not clear that adults would only be attracted to targeted areas, the monitoring design would benefit from surveys in other areas. Explicit goals such as a target number of larvae in a given area, survival rate for larvae (i.e., to transformation) or number of returning adults. Monitoring and evaluation is a key component to adaptive management that gives the information that may lead to altering the supplementation scheme to maximize success.

**RESPONSE**

**Contained within this Supplementation Research Framework is an "experimental control" stream section but it is not fully developed and is admittedly lacking in specifics (See page 40—Experimental Controls). The basic idea is that any M&E that is conducted in a supplementation location would occur in similar control location. Though not fully developed within this document, we understand the need to monitor in experimental as well as control locations, preferably at multiple scales.**

**Your comments are noted and we hope to expand this section within new versions of this document, within the master planning process, or both.**

There is a heavy influence placed on the ability of larval pheromones to attract spawning adults and that this may be the primary justification for supplementation. Although some literature documenting the types and concentrations of pheromones that (primarily sea lamprey) adults can detect and respond to, there is still much uncertainty on this topic and much more experimentation may be necessary. The use of tightly controlled experiments, as well as field experiments with control reaches need to be carefully designed to make legitimate conclusions about the utility of larvae producing adequate concentrations of pheromone attractants. In addition, recent work has suggested that pheromones from spawning adults may also be involved in the attraction of other adults. If both sources of pheromones are important, will supplementation efforts always include both larvae and adults? It needs to be identified whether directed, behavioral responses can be induced from adult lamprey due to the presence of larvae and spawning adults and presumed pheromone attractants. Furthermore, if pheromone attractants are effective, further work to synthesize the pheromone itself could alleviate the need for larval or adult supplementation.

**RESPONSE**

**Throughout the document we note that there may be several potential mechanisms guiding adult lamprey to spawning locations, including pheromones from larval Pacific lamprey. "The use of tightly controlled experiments, as well as field experiments with control reaches" would help the region make some legitimate conclusions about the role of larval pheromones in restoration activities. The CTUIR and NOAA are currently doing some of this work and the discussion should continue within the region. We certainly agree that pheromone related research should be included in ongoing planning as there are likely restoration benefits to this information.**

**See below, specific locations with the Supplementation Research Framework where comments are addressed.**

**Page 6, 2nd full paragraph down — Added "For example, by releasing hatchery-reared lamprey in a tightly controlled field experiment, an evaluation of whether these fish can attract upstream migrating adult lamprey though the release of larval pheromones and ultimately contribute to increased recruitment, can occur."**
**Pages 11 and 13 — Alternative adult guidance mechanism mentioned here.**
**Page 12-13 — Added, "By releasing hatchery-reared larval and juvenile lamprey in tightly controlled field experiments, an evaluation of whether these fish can attract upstream migrating adult lamprey through the release of larval pheromones and ultimately contribute to increased recruitment can occur."**

Finally, the framework may benefit from additional, theoretical modeling. The use of life history modeling may be extremely valuable in determining the magnitude of supplementation that is needed to

produce a concomitant response. Such a response may be an increase in the number of subsequent life history stages.

**RESPONSE**

**See below, specific locations with the Supplementation Research Framework where comments are addressed.**

**Page 6 — Life history modeling mentioned as an important management and restoration tool. The information provided by the next stages of any supplementation research will help set the stage for these efforts.**

We at CRFPO are more than willing to help with advancing study designs to collaboratively develop the adaptive framework for assessing supplementation in conjunction with other restoration actions for Pacific Lamprey.

**RESPONSE**

**We appreciate the review of this document by the USFWS and we look forward further discussions.**

# Appendix C. Pacific Lamprey Restoration and Supplementation Research Plan – Umatilla River Subbasin

# Pacific Lamprey Restoration and Supplementation Research Plan – Umatilla River Subbasin

**Confederated Tribes of the Umatilla Indian Reservation**

**November 2013**

Prepared by
HDR Engineering, Inc.
1001 SW 5th Avenue
Portland, OR 97204-1134

# Contents



# Tables

## Figures

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# 1 Introduction

## 1.1 Subbasin Overview

The Umatilla River originates in the Blue Mountains of northeastern Oregon and flows north and west to enter the Columbia River in Umatilla, Oregon at river mile (RM) 289 (Figure 1-1and Figure 1-2). The mainstem Umatilla River is 89 miles long and drains an area of nearly 2,290 square miles (Phelps et al. 2004). Elevations in the Umatilla River subbasin range from about 5,800 feet near Pole Springs on Thimbleberry Mountain to 260 feet at the confluence with the Columbia River.

The subbasin experiences strong seasonal fluctuations in both temperature and precipitation. In summer the days are warm and nights are cool (summer highs and lows in Umatilla are 88 $^{o}$F and 61 $^{o}$F, respectively), whereas winters are much colder, with average temperatures often only slightly above freezing. Most precipitation in the subbasin falls during fall, winter and spring. Precipitation falls mainly as rain in the northwestern, low elevation portion of the subbasin and averages approximately nine inches annually. Up to 55 inches of precipitation falls in high-elevation areas of the Blue Mountains with much of this occurring as snowfall.

Water development for irrigation has had a large impact on both the hydrology and ecology of the Umatilla River Subbasin. Irrigated agriculture is served by six diversion dams found in the lower Umatilla River (from RM 4.1 to RM 32.4) and two reservoirs, Cold Springs and McKay Creek. During the summer months, discharge in the lower Umatilla River decreases with water withdrawals and increases slightly with irrigation return water. Water is released from McKay Reservoir at RM 50.5 during peak irrigation periods. The impact of water storage in McKay Reservoir and releases during summer is to lower mean monthly instream flows during winter when water is stored and increase flows during the summer when stored water is released for irrigation.

The Umatilla Basin Project Act passed by Congress in 1988 allows irrigators to exchange Umatilla River water for Columbia River water. This allows water historically appropriated for irrigation to remain in the Umatilla River during times when flows are critical for juvenile and adult steelhead and salmon in spring and fall. Despite this progress, irrigation still removed approximately half of the instream flows from June through September. Beginning in 2006, an extension of the pumping period during July and the first half of August has provided minimum passage flows for adult Pacific lamprey during their peak migration period when flows have normally been near zero. One important effect of water use by agriculture is an increase in summer water temperatures, which decreases the availability of the lower river as habitat to lamprey and salmonids, although releases from McKay Reservoir from June to September have a beneficial impact on temperature and flow from June through September.

## 1.2 Importance of Pacific Lamprey

Historically, Pacific lamprey were used both as food and for medicinal purposes by Native Americans throughout the Columbia basin (Close 1999). Lamprey numbers have declined dramatically in the subbasin over the past century and there is no longer a tribal harvest of these animals. From a tribal perspective, the decline of lamprey continues to have at least three negative effects: (1) loss of cultural heritage, (2) loss of fishing opportunities in traditional fishing areas, and (3) necessity to travel great distances to lower Columbia River tributaries for ever-decreasing lamprey harvest opportunities. As a

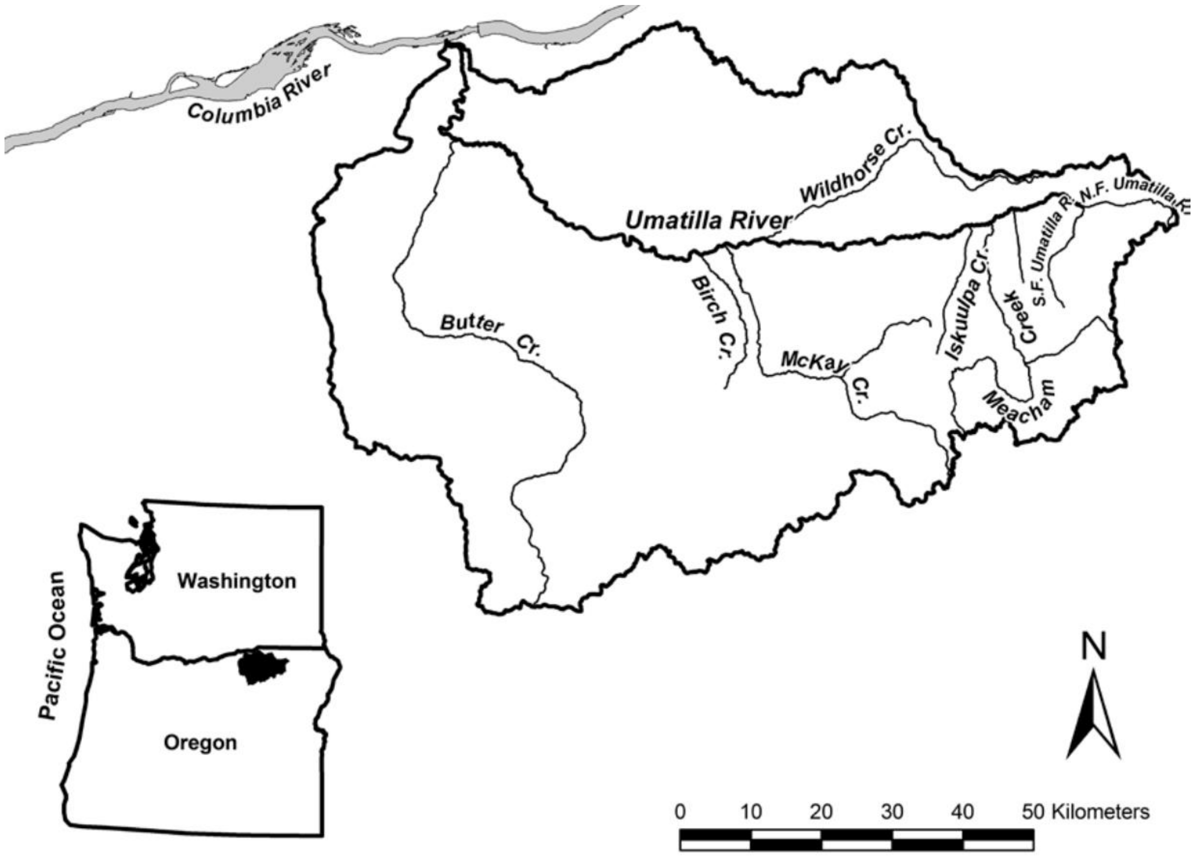


**Figure 1-1. Map of the Umatilla River Subbasin in northeastern Oregon (from Jackson and Moser 2013).**

consequence of restriction or elimination of harvest in interior Columbia River tributaries, young tribal members are losing historically important legends associated with lamprey because they have not learned how to harvest and prepare them.

For countless generations people of the CTUIR have depended on lamprey for food and medicine. Tribal members historically harvested lamprey in a sustainable manner, taking only what their families needed for subsistence. Through the years, many stories and legends surrounding the eel were passed down from generation to generation and this important species has become an integral part of tribal culture. And, the tribes clearly recognize that restoration of lamprey populations is necessary for the restoration of the ecological health of Pacific Northwest watersheds, along with salmonids and other native fish populations.

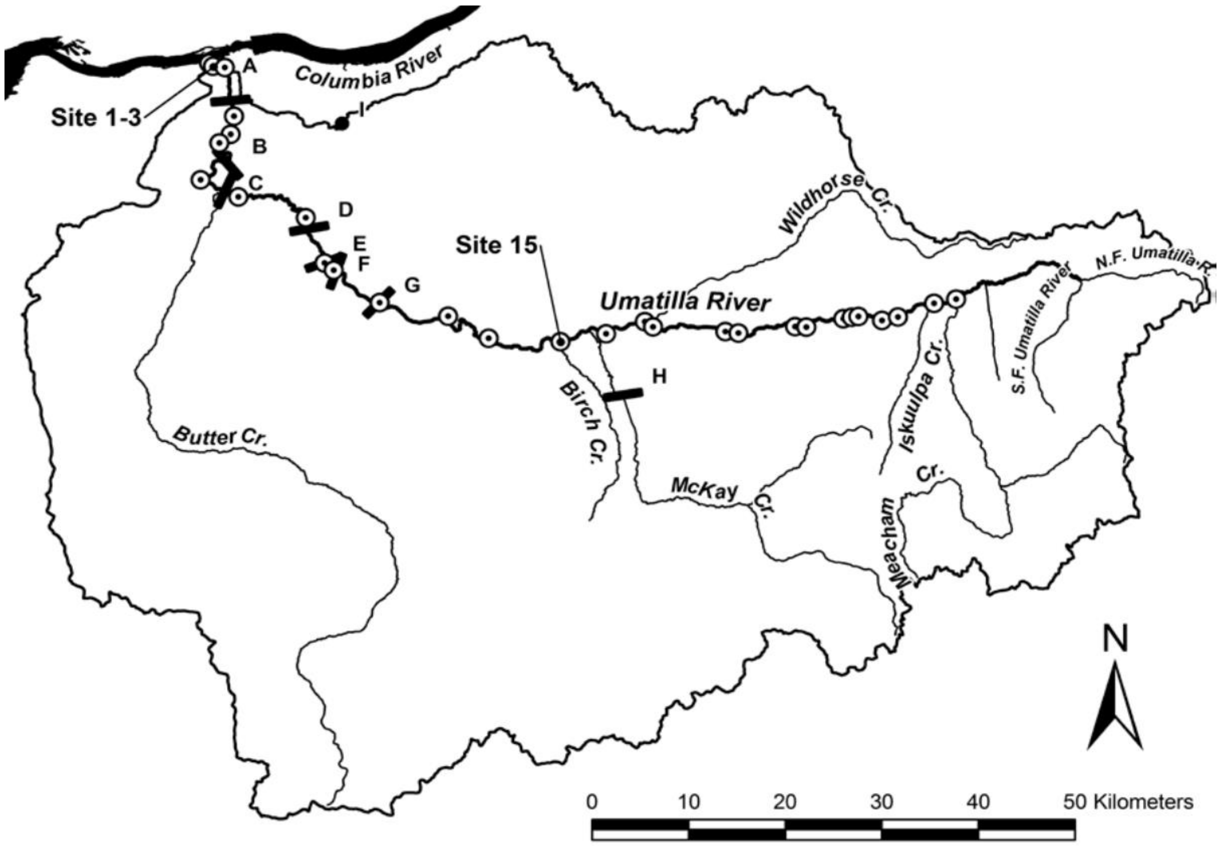


**Figure 1-2. Location of irrigation diversion dams (black rectangles) and larval lamprey sampling sites (circles) in the Umatilla River Subbasin. Three Mile Falls Dam = A, Boyd Hydro Dam = B, Maxwell Diversion Dam = C, Dillion Dam = D, Westland Diversion Dam = E, Feed Canal Dam = F, Stanfield Dam = G, McKay Dam = H, Cold Springs Dam = I.**

## 1.3 USFWS Conservation Assessment Findings

The 2011 USFWS Pacific Lamprey Assessment and Template for Conservation Measures (Luzier at al. 2011) characterized the status of Pacific lamprey as "imperiled to critically imperiled" for the Umatilla River subbasin. The ratio of current to historic distribution within the subbasin was assigned a value of 0.5. Primary factors limiting Pacific lamprey and habitat in the subbasin include passage, dewatering and flow management, stream and floodplain degradation, water quality, predation, and small population size (Table 1-1).

**Table 1-1. Limiting factors for Pacific lamprey and habitat in the Umatilla River subbasin, as identified and ranked by participants in regional meetings. Scores range from high (4) to insignificant (1). From Luzier et al. (2011).**

| Threat | Scope | Severity |
|---|---|---|
| Passage | 4 | 3.5 |
| Dewatering and flow management | 3 | 3.5 |
| Stream and floodplain degradation | 4 | 4 |
| Water quality | 3.5 | 3 |
| Small population size | 3 | 3 |

## 1.4 Vision and Goal

The Vision for this Restoration and Supplementation Research Plan is consistent with the Vision outlined in the 2004 Umatilla Subbasin Plan (Phelps et al. 2004):

"*The vision for the Umatilla/Willow subbasin is a healthy ecosystem with abundant, productive, viable, and diverse populations of aquatic and terrestrial species, which will support sustainable resource-based activities that contribute to the social, cultural, and economic well-being of the communities within the subbasin and the Pacific Northwest*."

This strategy is also consistent with the goal of Restoration Plan for Pacific Lampreys in the Umatilla River, developed by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) (Close 1999). That goal was to restore natural production of Pacific lampreys in the Umatilla River to self-sustaining and harvestable levels. The Umatilla River basin was chosen by the CTUIR as an initial pilot project because: 1) the Umatilla River historically produced a fishable population of lampreys, 2) restoration efforts for salmonids in the basin may accelerate Pacific lamprey restoration, and 3) the current population of Pacific lampreys in the Umatilla River is extremely low.

# 2 Summary of Pacific Lamprey Status in the Umatilla Subbasin

Through oral interviews with tribal members and former state and federal agency fisheries personnel, Jackson and Kissner (1997) determined that Pacific lamprey were historically abundant, and that fishing occurred throughout the Umatilla Subbasin. No records were kept of lamprey counts, but former agency personnel noted that "there were so many adult Pacific lamprey in the Umatilla River that they were a nuisance." Tribal members and agency personnel stated that abundance decreased dramatically after rotenone treatments in 1967 and 1974. Throughout the 1990's very few Pacific lamprey were observed, although 12 adult Pacific lamprey were found in the ladder at Three Mile Falls Dam during dewatering in 1996. No Pacific lamprey were collected during numerous electroshocking surveys upstream from the dam in the 1990s. Kostow (2002) noted that lamprey production in the Umatilla appeared to be restricted to the lower few miles of the subbasin, and that Pacific lamprey may be gone from the upper subbasin.

## 2.1 Adult Abundance, Run Timing, and Spawning Locations

### 2.1.1 Abundance

In 1999, the CTUIR developed and began implementing a peer-reviewed restoration plan for Pacific lamprey (Close 1999). The restoration plan called for 1) locating an appropriate donor stock for translocation of adult Pacific lamprey, 2) identifying suitable and sustainable habitat within the subbasin for spawning and rearing, 3) translocating up to 500 adult lampreys annually, and 4) long-term monitoring of spawning success, changes in larval density and distribution, juvenile growth and outmigration, and adult returns. Translocations of adults began in 2000 (Table 2-1). The number of adults observed in the Umatilla River increased beginning four years after the first translocations, with a clear increase beginning after six years (Figure 2-1), although the total number of individuals entering the Umatilla River remained relatively low through 2010.

**Table 2-1. Releases of adult Pacific lamprey into the Umatilla River Subbasin, 2000-13, as part of a translocation program. Rkm = river kilometer.**

| Year | Number released | Umatilla River | | | Iskúulktpe Creek | Meacham Creek | South Fork Umatilla River |
|---|---|---|---|---|---|---|---|
| | | Rkm 98.8 | Rkm 118.4 | Rkm 139.9 | | | |
| 2000 | 600 | -- | 150 | 300 | -- | 150 | -- |
| 2001 | 244 | -- | 82 | 81 | -- | 81 | -- |
| 2002 | 491 | 150 | 100 | 141 | -- | 100 | -- |
| 2003 | 484 | -- | 90 | 110 | 54 | 230 | -- |
| 2004 | 133 | -- | -- | 63 | -- | 70 | -- |
| 2005 | 120 | -- | -- | 50 | 15 | 55 | -- |
| 2006 | 198 | -- | -- | 90 | 21 | 87 | -- |
| 2007 | 394 | -- | -- | 200 | 25 | 169 | -- |
| 2008 | 68 | -- | -- | 26 | -- | 42 | -- |
| 2009 | 337 | -- | -- | 100 | 25 | 150 | 62 |
| 2010 | 291 | -- | -- | 128 | 13 | 150 | -- |
| 2011 | 89 | -- | -- | 40 | 10 | 39 | -- |
| 2012 | 232 | -- | -- | 130 | 12 | 90 | -- |
| 2013 | 259 | -- | -- | 126 | 10 | 123 | -- |

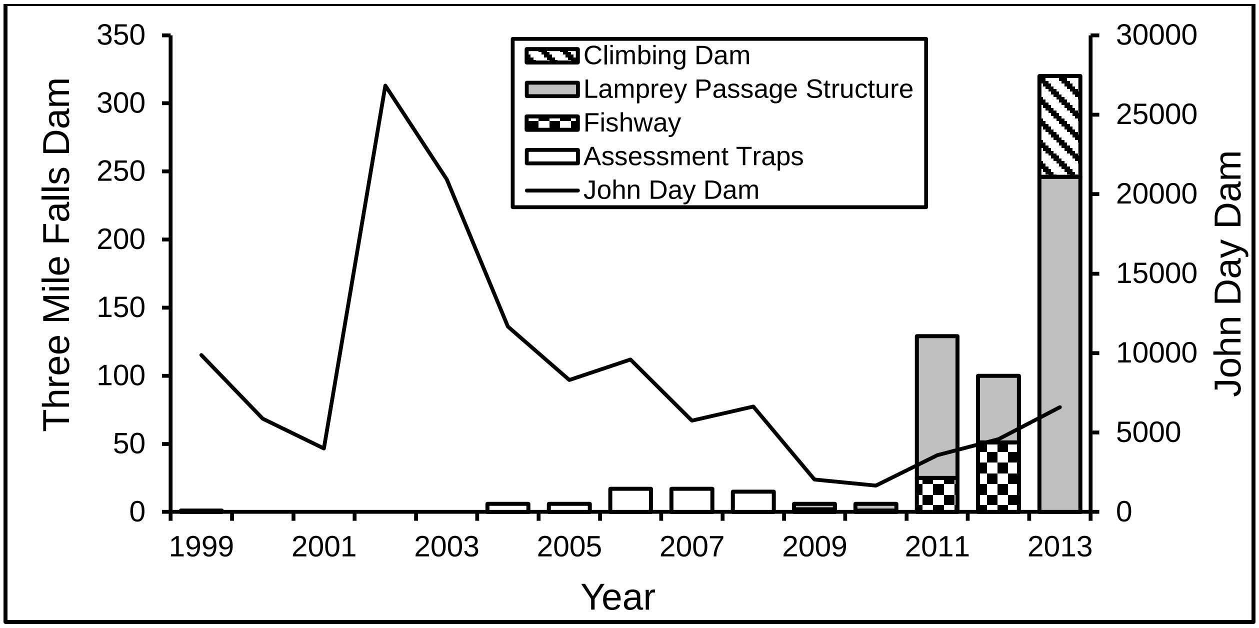


**Figure 2-1. Number of adult Pacific lamprey counted at Three Mile Falls Dam on the Umatilla River (bars) and at John Day Dam on the Columbia River (line).**

To be proactive and with expected increased returns of adult lamprey forthcoming, an adult radio telemetry study was initiated in 2005 to identify adult passage bottlenecks at low-elevation diversion dams within the subbasin. Results from the radio telemetry study identified where adults were having difficulties passing these structures and helped prioritize which diversion dams needed improvement first. After installation of a lamprey passage structure at Three Mile Falls Dam, the number of adults counted increased substantially in 2011 (Figure 2-2).

### 2.1.2 Run Timing

Information on adult run timing into the Umatilla River Subbasin is limited to what can be concluded from counts at Three Mile Falls Dam since adults began entering the Umatilla River again in 2004. Information collected since adults began returning in greater numbers in 2011 indicates that numbers of returning adults appears to peak in May and then again in August/September (Figure 2-2). During these same years, adults were generally observed at John Day Dam from May through October, with counts peaking in early August. It is likely that the adult lamprey observed at Three Mile Falls Dam in May had passed John Day Dam the previous year and held in the Columbia River prior to ascending the Umatilla River to spawn. Fish observed at three Mile Falls Dam in August/September likely passed John Day Dam the same year, and some may over-winter in the Umatilla River before spawning.

### 2.1.3 Spawning Locations

Little is known about the current extent of Pacific lamprey spawning in the Umatilla River Subbasin; however, in 2001, 2002, 2009, and 2010 surveys were conducted by foot on the Umatilla River and Meacham Creek to locate lamprey redds. Surveys were conducted in 1) the mainstem Umatilla River

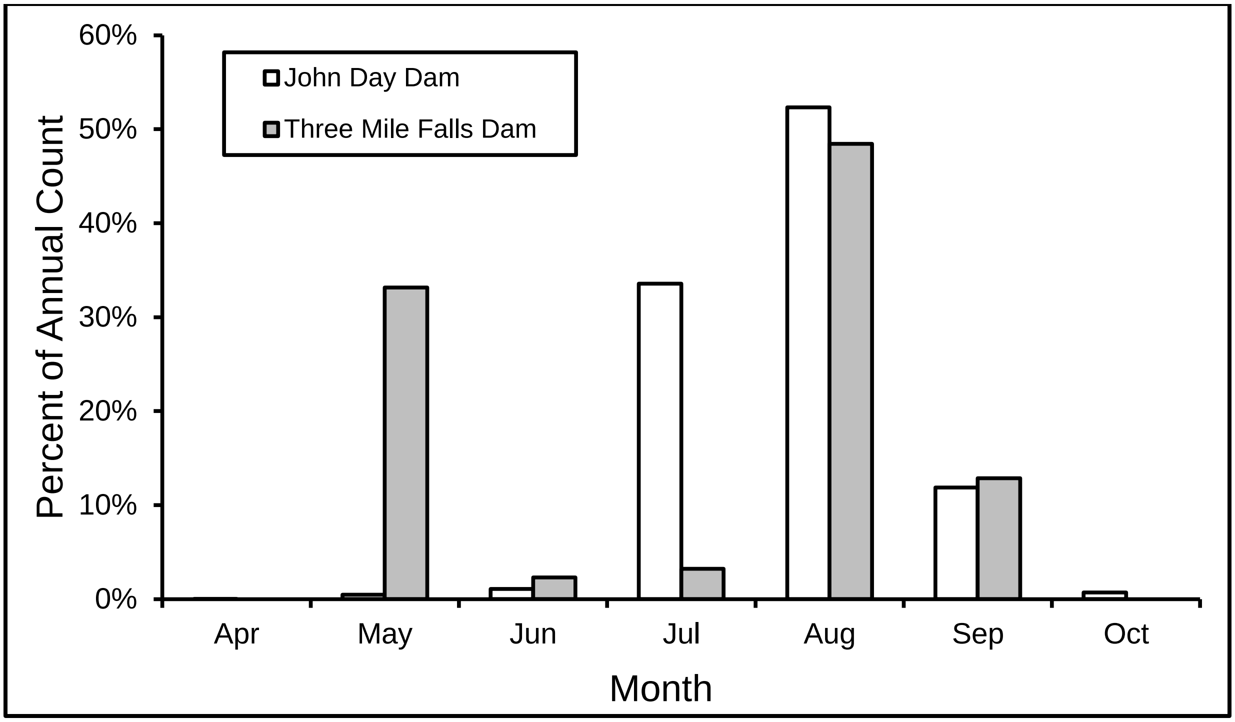


**Figure 2-2. Average 2011-2013 run timing of adult Pacific Lamprey at John Day and Three Mile Falls dams expressed as mean percent of annual counts.**

above river kilometer 90 to the confluence of the north and south forks, 2) the lower 4 km of North Fork Umatilla River, 3) the lower 4 km of the South Fork Umatilla River and 4) the lower 24 km of Meacham Creek.

Translocated lamprey spawned and produced viable eggs. In 2001, 19 viable redds were found in the Umatilla River and 30 were found in Meacham Creek. In 2002, 21 viable redds were found in the Umatilla River and 46 were found in Meacham Creek. Mean egg viability per redd was 93.4% in the Umatilla River and 81.4% in Meacham Creek. No redds were found in the North Fork or the South Fork of the Umatilla River.

Eighty one and 85 redds were identified during surveys in 2009 and 2010, respectively. In 2009, redds were located above release locations in Iskúulktpe Creek, and above and below release locations in the Umatilla River and in Meacham Creek (Figure 2-3).

## 2.2 Juvenile Abundance and Run Timing

The out-migration of larval and metamorphosed lampreys has been monitored from approximately October through May using rotary-screw trap located about 1.2 miles upriver from the mouth. Abundance of outmigrating lamprey in the Umatilla River has increased in most years since restoration efforts began (Figure 2-4).

Captured juvenile lamprey are counted and identified to life stage and species. Periodic past examinations of the captured lamprey between 2010 and 2013 indicate that the majority of these outmigrating juvenile lamprey during the winter high flow conditions are Pacific lamprey macrophthalmia; hence, these counts


**Figure 2-3. Locations of Pacific lamprey redds observed during surveys in 2009 and 2010 relative to locations where translocated adult Pacific lamprey were released.**

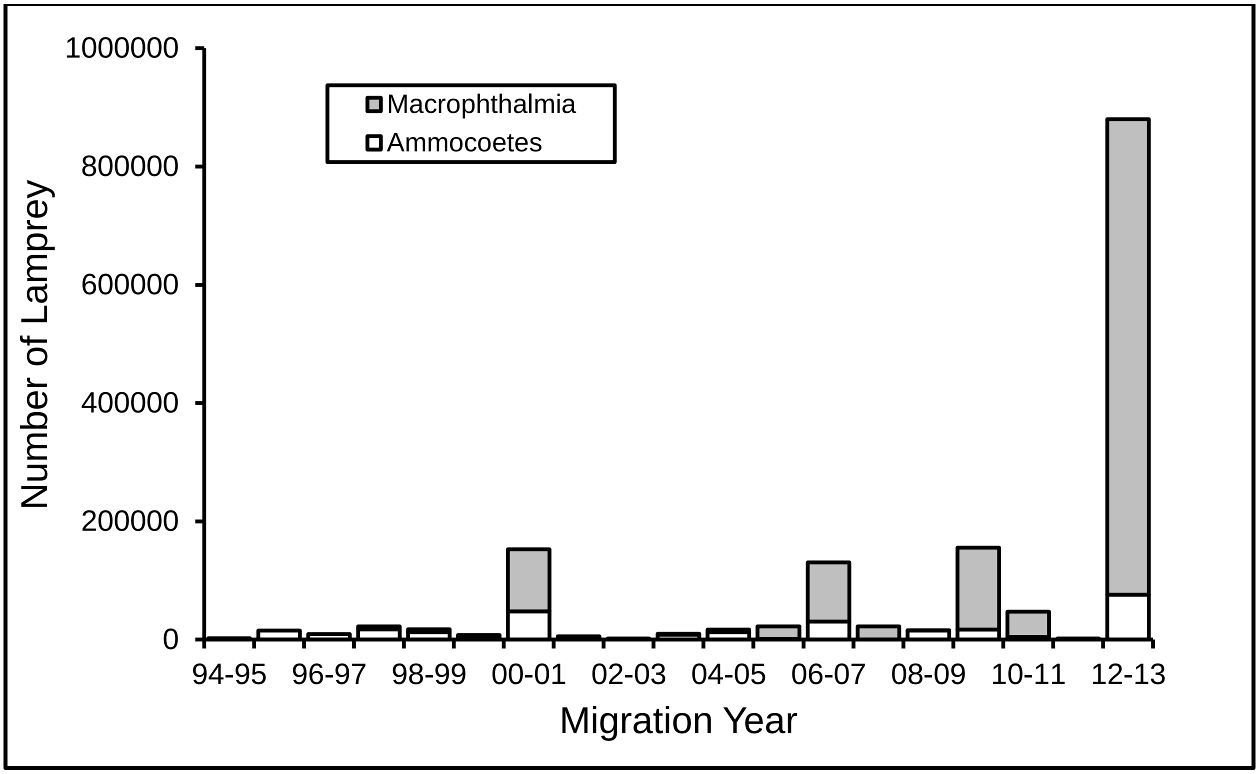


**Figure 2-4. Yearly estimates of the number of migrating Pacific lamprey ammocoetes and macrophthalmia in the lower Umatilla River.**

could potentially be used as an index for juvenile lamprey abundance. Additionally, a large proportion of ammocoetes are captured in the trap. It is likely that these lamprey are completing the juvenile rearing stage in the mainstem Columbia River. Catches of larval and juvenile lamprey are highest from December through March, with catch (both life history forms combined) in 2013 peaking in March (Figure 2-5).

## 2.3 Ammocoete Abundance and Distribution

Thirty sites have been sampled in the Umatilla River in August and September annually since 1999 to document ammocoete densities and distribution. All sites were 7.5 $m^2$ in area with silt substrates where ammocoetes are typically most abundant. Ammocoete density in these index plots sharply increased one year after translocation of adult lamprey (Figure 2-6). Mean densities remained elevated through 2012.

Larval distribution also increased through time (Figure 2-7). In the years prior to translocation of adults, no larvae were found in the upper Umatilla River. One year after translocation of adults, larval densities increased and the distribution of larvae moved downstream. By 2007, larval distribution extended downstream to the middle reaches of the Umatilla River, with little change in larval densities in the lower river. Distribution in 2011 was similar to that in 2007.

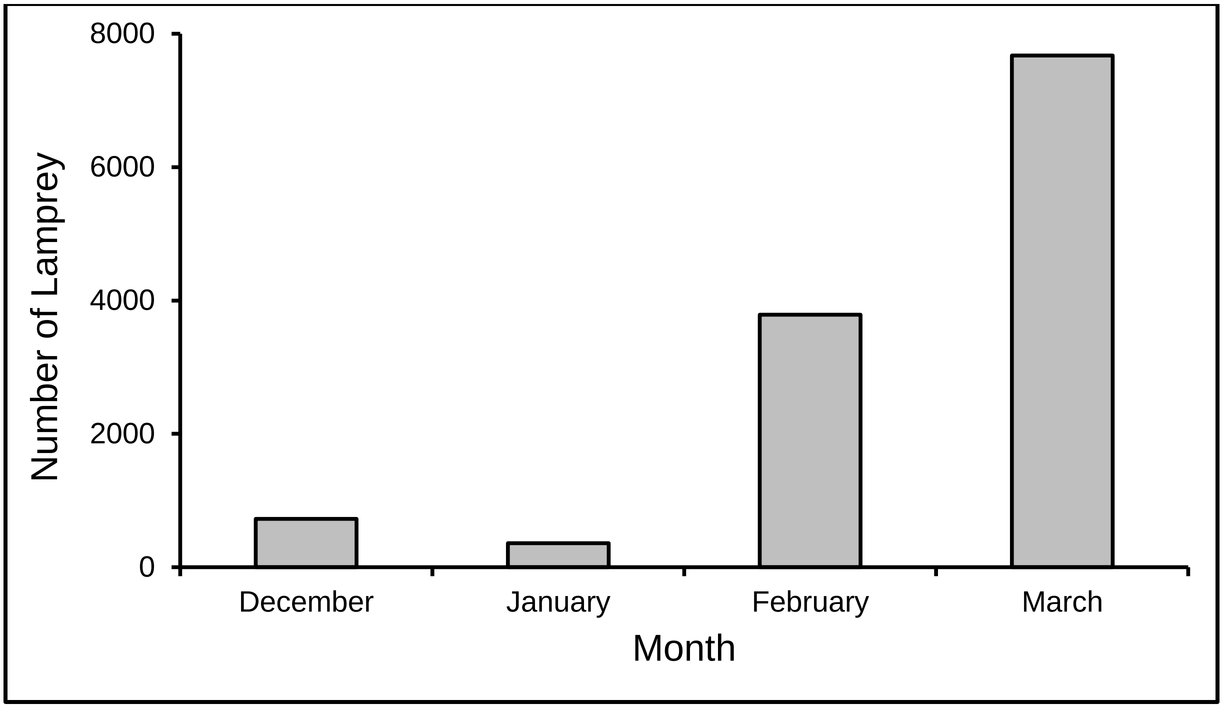


**Figure 2-5. Number of lamprey ammocoetes and macrophthalmia captured in the lower Umatilla River from December 2012 through March 2013.**

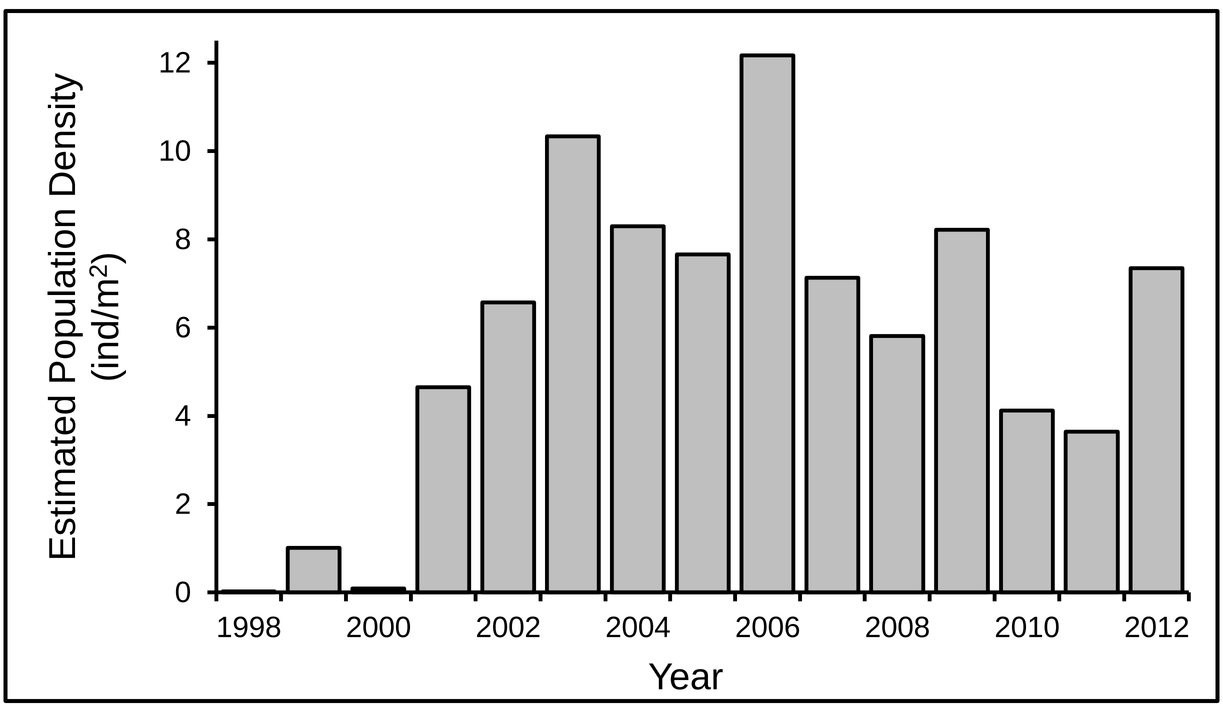


**Figure 2-6. Changes in ammocoete densities (mean of 30 index sites), 1999-2012.**

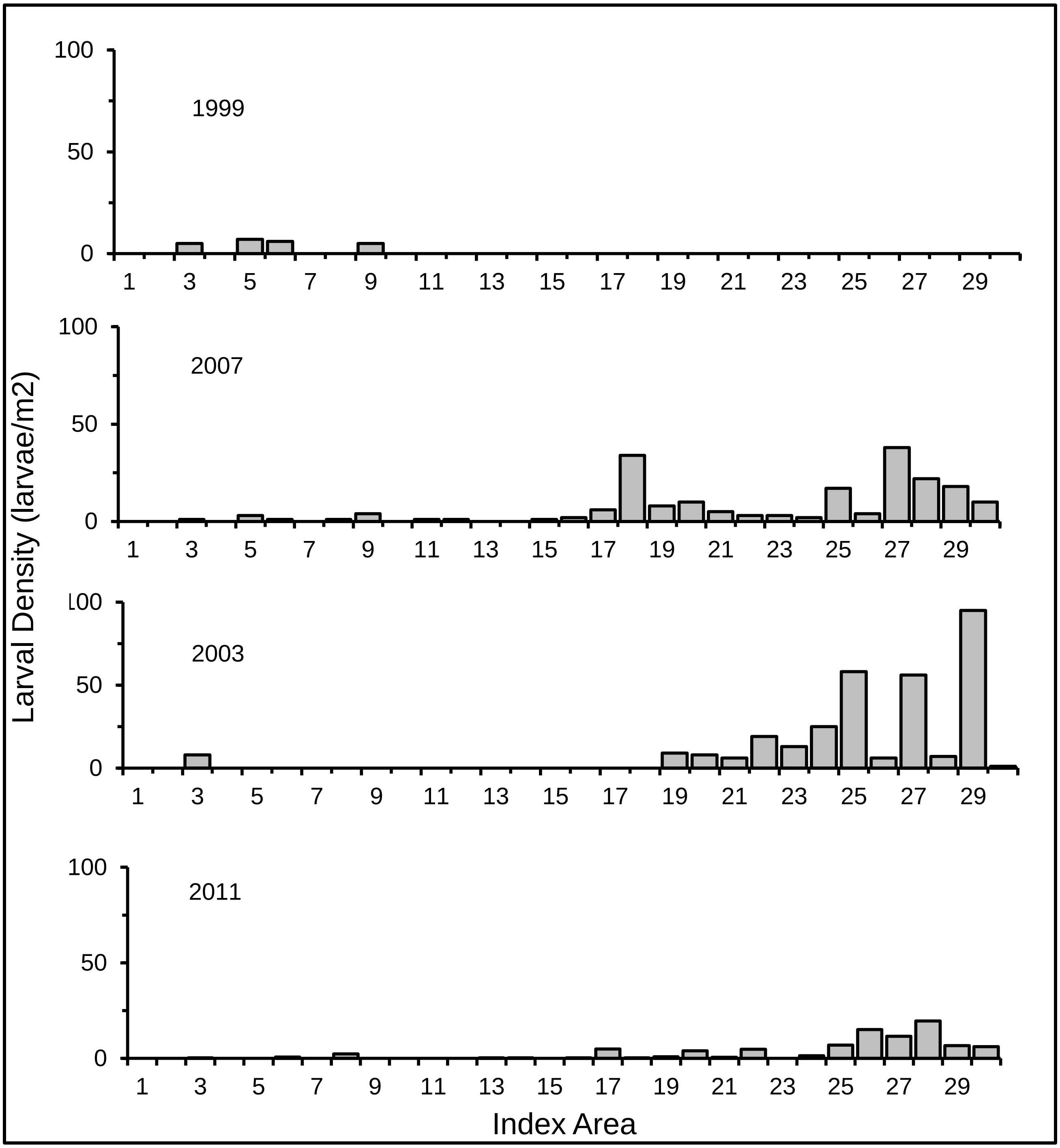


**Figure 2-7. Density of Pacific lamprey ammocoetes in the Umatilla River, 1999-2011. Index plot 1 is near the mouth and index plot 30 is in the upper Umatilla River.**

# 3 Summary of Pacific Lamprey Limiting Factors

## 3.1 Upstream Passage: Adults

Dams are known to be a challenge to Pacific lamprey passage, whether large head hydroelectric dams of the Columbia River or irrigation dams along smaller tributaries, such as the Umatilla River. In 2005, a radio telemetry study was initiated to determine if seven low elevation dams on the Umatilla River impede upstream passage of adult Pacific lamprey (Jackson and Moser 2012). Results indicated that fewer than 50% of the lamprey that approach Three Mile Falls Dam were able to pass successfully. The removal of Boyd's Diversion dam in fall of 2006 resulted in a substantial improvement in lamprey passage through this area, particularly for spawning-phase fish. Some lower elevation dams (< 2m) such as Dillon and Westland diversions were found to impede passage, whereas others such as Maxwell and Stanfield diversions allowed higher rates of passage. Recommendations based on results from the telemetry studies included fitting Three Mile Falls, Maxwell, Dillon, Westland, Feed, and Stanfield diversion dams with lamprey passage structures. Considerations for Boyd's diversion would be made if FERC relicenses this facility.

## 3.2 Downstream Passage: Juvenile Entrainment

Juvenile lamprey are likely entering many irrigation diversion ditches within the Umatilla River Subbasin and getting behind various screens designed for salmonid criteria. To date, only preliminary work has commenced to understand how juvenile lamprey are actually getting behind these screens. Investigations are currently underway to understand this issue and to develop and implement new screening criteria. The CTUIR will continue to survey irrigation ditches throughout much of the subbasin over the next five years, and expand juvenile outmigrant PIT tagging as a measure to evaluate current screen effectiveness. However, resources for this work are extremely limited.

## 3.3 Dewatering and Flow Management

Water management has substantially changed flow conditions throughout much of the Umatilla River Subbasin (Phelps et al. 2004). Multiple diversions still remove approximately half of the instream flows from June through September. Much of the flow in the Umatilla River was diverted at Three Mile Falls Dam, preventing continuous flow from reaching the Columbia River. The lack of flow during peak migration periods may explain why few adults were detected at Three Mile Falls Dam.

Beginning in 2006, an extension of the Umatilla Basin Project Act implemented pumping from the Columbia River during July and the first half of August to provide recommended passage flows for adult Pacific lamprey during their peak migration period when flows have normally been near zero. The "year round" exchange period is now necessary because increased numbers of adult lamprey are expected as a result of the ongoing restoration program.

## 3.4 Stream and Floodplain Degradation

Land use practices have improved significantly over the past few decades. Land managers, local land owners, and others have improved habitat management to enhance watershed conditions to support anadromous salmonids. Actions to improve watershed conditions from the uplands to the floodplain are allowing, in some cases, natural ecosystem functions to recover. Although many steps have been taken, many more are needed. Habitat degradation from past and/or present land use remains a key concern.

Pacific lamprey have been adversely affected by degraded channel structure and complexity (including riffles, pools and large woody debris), loss of riparian vegetation, and reduced floodplain connectivity. Threats contributing to these factors include agricultural, forestry and grazing practices, roads, railroads and channel manipulations.

## 3.5 Water Quality: Temperature

Water temperature is a concern throughout most of the Umatilla River subbasin during periods of low flow from May through early November (Phelps et al. 2004). The highest water temperatures have been recorded in late July and early August when ambient air temperatures are high. During this period, the Umatilla River warms rapidly from the headwaters to the mouth, reaching sub-lethal (64-74 $^{o}$F) and incipient lethal temperatures (70-77 $^{o}$F) for its entire length (Phelps et al. 2004). Summer water temperatures in Meacham Creek are frequently in the high 60s ºF. However, maximum summer temperatures drop further downstream as a result of cold water releases from McKay Reservoir for the benefit of irrigation and fish. Excessive stream temperatures in the Umatilla River Subbasin are influenced primarily by non-point sources including riparian vegetation disturbance (reduced stream surface shade), summertime diminution of flow (reduced assimilative capacities), and channel widening (increased surface area exposed to solar radiation).

## 3.6 Small Population Size

Pacific lamprey abundance in the Umatilla River subbasin is critically low, and in some watersheds, presumed extirpated. Although ongoing translocation has helped alleviate the problem, low adult counts excluding those translocated raises the questions "can adults successfully find a mate?" and "what are the genetic risks associated with such a low brood population?".

## 3.7 Critical Uncertainties

In addition to these known primary limiting factors, many other critical uncertainties exist that may play a significant role in the abundance of Pacific lamprey in the Umatilla River Subbasin. The effects of water quality including contaminants and toxicants are largely unknown at this point. Because of the early life history of lamprey (burrowing in fine sediment in low gradient channels for several years), the likelihood that ammocoetes are exposed to a high level of toxicants is high. Predation is also a potential threat to Pacific lamprey. The number of native and non-native piscivorous predators (fish, avian, mammal) has increased greatly in the Columbia River Basin. Because of the lamprey's lack of bone structure, most studies examining the stomach content of predators miss clues about juvenile lamprey predation, especially for ammocoetes because they also lack teeth. Global climate change appears to be eminent and will likely affect the flow dynamics and temperatures of watersheds in the Umatilla River Subbasin. Some prediction models indicate that the timing of snow melt floods will arrive earlier than it has been in the past, further reducing flow in late summer. This may further hinder the upstream migration of adult Pacific lamprey.

# 4 Ongoing / Planned Lamprey Restoration Actions over the Next 5-10 Years

Restoration actions are intended to address priority limiting factors across the Umatilla River Subbasin. Recognizing that lamprey need to use habitats that extend widely, our strategy views the Umatilla River

subbasin holistically, and recommends priority actions across the subbasins as part of the overall recovery strategy. See Section 5 for more specific information.

- **Passage.** Complete fitting priority diversion dams with passage structures specific to adult Pacific lamprey. Passage structures have been installed at Three Mile Falls, Maxwell, Dillon, and Feed dams. Current priority actions include installing a passage structure at Westland Dam, and modifying passage features at Feed, Brownell, and Stanfield diversions. Continue to evaluate passage at all diversions to obtain information needed to maximize efficiency of passage structures.

- **Entrainment.** Continue to evaluate the degree that entrainment is occurring within irrigation diversion ditches, identify priority locations to focus near-term work and implement corrective actions.

- **Supplementation.** Continue to implement the adult translocation program initiated by the CTUIR in 2000). Monitoring has demonstrated that released individuals survive, breed, and produce offspring. Translocated lamprey were able find suitable spawning habitat, construct nests and deposit viable eggs; their larvae were able to feed, grow, and migrate downstream; and the geographical distribution and abundance of larvae expanded in the Umatilla River. Adults subsequently returned to the river, although more monitoring is needed to determine whether these were the results of the introductions. Long-term monitoring will be required to track trends in abundance, distribution, and diversity, and to be able to assess persistence and the need to intervene further.

- **Biological Surveys**. Continue to document current status of adult and juvenile lamprey presence, distribution, and relative abundance. Continue to identify, describe and monitor key Index Sites for long-term status and trends at the reach, watershed and at the subbasin context.

- **Habitat Surveys**. Identify habitat characteristics that are preferred at various life stages (habitat quality) and determine the extent (habitat quantity) these areas are available and are being utilized.

- **Habitat Restoration**. Consider certain types of in-stream restoration efforts to benefit salmonids and to monitor potential benefits towards lamprey productivity. Habitat quality and quantity may not be limiting population growth at this time because of relatively low lamprey abundance. However, some restoration activities in key stream reaches (Meacham Creek, Birch Creek, and the mid to upper Umatilla River) will benefit both salmonid and lamprey recovery.

- **Coordination and Collaboration**. Continue to work directly and collaboratively with local and regional land and resource management agencies and entities to develop and implement a well-founded public involvement and information strategy and to gain efficiencies in both time and resources in implementing lamprey restoration actions.

# 5 Ongoing / Planned Lamprey Supplementation Research Actions over the Next 5-10 Years

As described in the restoration plan for Pacific lamprey (Close 1999), supplementation in the Umatilla River Subbasin is focused on translocation of adults and long term monitoring of success. Over 3,900 adult Pacific lamprey were translocated into the subbasin from 2000 through 2013. Lamprey are held until they are considered sexually mature and then released into spawning habitat that has been determined to be suitable for adult spawning. This is typically the same type of spawning habitat that is utilized by summer steelhead and spring Chinook.

Monitoring the success of translocation efforts has been underway since 2000. Pacific lamprey require extensive post-reintroduction management and a well-designed monitoring program. This is in part due

to the long life cycle of Pacific lamprey and the likelihood that they do not home to natal streams. Current research and monitoring efforts therefore follow guidelines described in the Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin (Table 5- through Table 5-).

**Table 5-1. Numerical codes for monitoring and evaluating supplementation research strategies. Strategies are described in Section 4.3 of the Framework for Pacific Lamprey Supplementation Research in the Columbia River Basin; codes reflect the section number in the Framework document.**

| Translocation | | Hatchery | | Outplanting | |
|---|---|---|---|---|---|
| **4.3.1** | Adult Translocation | **4.3.2** | Larval and Juvenile Rearing | **4.3.3** | Larval and Juvenile Outplanting |
| **4.3.1.1** | Adult Survival | **4.3.2.1** | Broodstock survival | **4.3.3.1** | Larval Survival and Growth |
| **4.3.1.2** | Adult Spawning | **4.3.2.2** | Fertilization to hatch survival | **4.3.3.2** | Larval Abundance and Distribution |
| **4.3.1.3** | Larval Survival and Growth | **4.3.2.3** | Hatch to outplant survival | **4.3.3.3** | Larval and Juvenile Outmigration |
| **4.3.1.4** | Larval Abundance and Distribution | | | **4.3.3.4** | Adult Returns |
| **4.3.1.5** | Larval and Juvenile Outmigration | | | | |
| **4.3.1.6** | Adult Returns | | | | |

**Table 5-2. Comparison chart displaying all potential comparison pairs of the different supplementation and research strategies. T = Translocation; larval/juvenile lamprey from translocated adults. H = Hatchery; larval/juvenile lamprey born and reared in a hatchery environment. O = Outplanting; larval/juvenile lamprey artificially propagated and released into the natural environment. C = Control; larval/juvenile lamprey born and rearing in the natural environment.**

| Comparison | Translocation | Hatchery | Outplanting | Control |
|---|---|---|---|---|
| Translocation | TxT | HxT | OxT | CxT |
| Hatchery | TxH | HxH | OxH | CxH |
| Outplanting | TxO | HxO | OxO | CxO |
| Control | TxC | HxC | OxC | CxC |

**Table 5-3. Lamprey supplementation research actions over the next 5-10 years within the Umatilla River Subbasin. See Tables 5-1 and 5-2 for the monitoring and evaluation (M&E) and comparison codes.**

| Location | Supplementation Research Strategy | | | | | | | | Start Timeline | End Timeline |
|---|---|---|---|---|---|---|---|---|---|---|
| | Adult Translocation (T) | | Hatchery Rearing (H) | | Larval and Juvenile Outplanting (O) | | Control (C) | | | |
| | M&E Approach | Comparison | M&E Approach | Comparison | M&E Approach | Comparison | M&E Approach | Comparison | | |
| Mainstem Umatilla River | 4.3.1.1 – 4.3.1.5 | TxC<br>TxH<br>TxT | -- | -- | -- | -- | -- | -- | Ongoing | 1-3 years<br>5+ years<br>1-3 years |
| Upper Maxwell Diversion | -- | -- | -- | -- | 4.3.3.1 - 4.3.3.2 | OxH<br>OxO | -- | -- | Ongoing | 1-3 years<br>1-3 years |

# 6 References

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# INVENTORY OF ADULT TRANSLOCATION SITES IN THE UMATILLA RIVER SUBBASIN

## ADULT TRANSLOCATION SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| **EXAMPLE** | | **Owner name** | **Habitat type/configuration, known flow levels, access limitations** | **Currently extirpated, unknown, population verified (relative size of population, if known)** | **Include existing/ongoing/previous monitoring efforts and potential for future monitoring. (E.g., existing survey data, plans for future surveys, locating antenna arrays, dam counting, screw traps)** | **This column is for any pertinent goals that would be specifically addressed by supplementation at this particular location.** |
| Reith | Umatilla River, Rkm 67.92, accessed via dirt road off Umatilla River Rd (Reith Rd)<br>Lat: 45.659783°<br>Long: -118.971669° | Private | Large deep pool at release site. | Larvae (electrofishing) and adults (radio telemetry) documented in the area. | Has not been used as translocation site in last decade. | |
| Reith (2) | Umatilla River, Rkm 74.7, accessed via dirt road off Umatilla River Rd (Reith Rd)<br>Lat: 45.648743<br>Long: -118.904941 | Private | Large deep pool at release site. | | Has not been used before. | |

## ADULT TRANSLOCATION SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| Thornhollow | Umatilla River, Rkm 117.65, access off Thornhollow Rd<br>Lat: 45.685041°<br>Long: -118.454287° | Private<br>CTUIR | Glide habitat in perennial stream. Transition area from bedrock controlled channel to deeper alluvial deposit. | | Used for translocation in 2001-2003, but not since. | |
| Iskuulktpe | Iskuulktpe Creek, Rkm ~11.45, no vehicle access – access from Iskuulktpe Creek road via 4-wheeler<br>Lat: 45.612712°<br>Long: -118.424938° | CTUIR | Large pool in perennial stream, good spawning habitat both upstream and downstream, good steelhead spawning reach. Creek is the subject of a watershed model for the Umatilla Basin and therefore use of the area is highly regulated. | Larvae (electrofishing) and adults (translocated) documented in the area. | Site currently used for translocation. Current monitoring includes electrofishing surveys, redd surveys, and a screw trap in the lower portion of Iskuulktpe Creek. Ongoing temperature monitoring data available. | |
| Meacham Creek at Camp Creek | Meacham Creek, Rkm ~17.35, access off Meacham Creek Rd<br>Lat: 45.574666°<br>Long: -118.324654° | Private | Large pool in perennial stream, good spawning habitat both upstream and downstream, good steelhead spawning reach. Use of the area is highly regulated. | Larvae (electrofishing) and adults (translocated) documented in the area. | Site currently used for translocation. Current monitoring includes electrofishing surveys, redd surveys, and a screw trap in the lower portion of Meacham Creek. Ongoing temperature monitoring data available. | |

## ADULT TRANSLOCATION SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| Umatilla River at Bear Creek | Umatilla River, Rkm 139.68, access off Umatilla River Rd<br>Lat: 45.742899°<br>Long: -118.224675° | ODF/Bar-M Ranch | Large pool in perennial stream, good Chinook & steelhead spawning habitat throughout reach. High public use area. | Larvae (electrofishing) and adults (translocated) documented in the area; lamprey spawning documented in area (translocated fish). | Site currently used for translocation. Current monitoring includes electrofishing surveys, redd surveys, and a screw trap downstream at Fred Grays site (aka Imaques). | |
| South Fork Umatilla River Translocation Site | SF Umatilla River, Rkm 1.20, access off FS-32<br>Lat: 45.716521°<br>Long: -118.190158° | USFS | Manmade habitat pool (USFS installed grade control) next to road, cobble substrate. High public use area. | Larvae (electrofishing) and adults (translocated) documented in the area; lamprey spawning has been documented in tailouts of pools in the area. | Site occasionally used for translocation depending on availability of adults for translocation program. Current monitoring includes electrofishing surveys, redd surveys, and a screw trap downstream at Fred Grays site (aka Imaques). | |
| Wildhorse Creek Potential Translocation Site | Wildhorse Creek, Rkm 42.43, access from CR 652<br>Lat: 45.745955°<br>Long: -118.385578° | Private (within boundary of reservation) | Pool habitat prevalent at and adjacent to site; predominantly redband trout/steelhead habitat. | Currently extirpated (adults & juvenile). | Has not been previously used for lamprey translocation; good candidate site for monitoring limiting factors of newly introduced population, but may require increased survey/monitoring efforts. | Habitat characteristics and use by steelhead indicate a viable self-sustaining population could become established if passage conditions in lower river (including Umatilla River) are improved. |

## ADULT TRANSLOCATION SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| East Birch Creek Potential Translocation Site | East Birch Creek, Rkm 20.10, access from East Birch Creek Rd<br>Lat: 45.395392°<br>Long: -118.717456° | Private w/ ODFW habitat conservation easements | Steelhead habitat – wild fish basin without supplementation; extensive in-stream habitat restoration work completed by ODFW; good water temperature and quantity parameters in this reach. | Currently extirpated. | Has not been previously used for lamprey translocation; good candidate site for monitoring limiting factors of newly introduced population. Current monitoring includes effectiveness monitoring of habitat features, redd surveys for steelhead, electrofishing for steelhead and salmon, and a screw trap in lower mainstem Birch Creek operated by ODFW. | Habitat characteristics and use by steelhead indicate a viable self-sustaining population could become established if passage conditions in lower river (including Umatilla River) are improved. |

# INVENTORY OF JUVENILE RELEASE/REARING SITES IN THE UMATILLA RIVER SUBBASIN

## JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| **EXAMPLE** | **Stream name, nearest road access, Rkm**<br>**Lat: XX.XXXXX°**<br>**Long: -XXX.XXXXX°** | **Owner name** | **Habitat type/configuration, known flow levels, access limitations** | **Currently extirpated, unknown, population verified (relative size of population, if known)** | **Include existing/ongoing/previous monitoring efforts and potential for future monitoring. (E.g., existing survey data, plans for future surveys, locating antenna arrays, dam counting, screw traps)** | **This column is for any pertinent goals that would be specifically addressed by supplementation at this particular location.** |
| Stanfield Diversion | Umatilla River, Rkm 51.6 Access from Reith Rd<br>Lat: 45.691322°<br>Long: -119.119877° | Bureau of Reclamation | Uppermost irrigation project in basin; headrack, fish bypass & screens; sections of concrete and earthen bottom canal. | Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts. | No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies. | Focus on entrainment research studies. |

## JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| Feed Diversion | Umatilla River, Rkm 45.13 Access from Ramos Lane<br>Lat: 45.721003°<br>Long: -119.176364° | Bureau of Reclamation | Headrack, fish bypass & screens; earthen bottom section behind headracks; feeds Cold Springs Reservoir. | Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts. | No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies. | Focus on entrainment research studies. |
| Westland Diversion | Umatilla River, Rkm 43.54 Access on private road off Snow Rd<br>Lat: 45.727954°<br>Long: -119.193768° | Westland Irrigation District | Largest water user in basin; headrack, fish bypass & screens; concrete canal. | Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts. | No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies. | Focus on entrainment research studies. |

## JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| Dillon Diversion | Umatilla River, Rkm 39.11 Access on private road off Correa Ln<br>Lat: 45.758327 °<br>Long: -119.216328° | Dillon Irrigation Company | Point diversion for flood irrigation; smallest diversion in basin; headrack, fish bypass & screens; may be removed over next 5 years (or less). | Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts. | No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies. | Focus on entrainment research studies. |
| Maxwell Irrigation Canal | Umatilla River, Rkm 24.41 Access from unnamed road off Hermiston Hwy<br>Lat: 45.795818°<br>Long: -19.328074° | Bureau of Reclamation | Earthen bottom irrigation canal; continuous flow year round. | Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts. | No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies, as well as habitat use and survival studies in the riverine environment. | Riverine environment rearing experiments, as well as entrainment studies |

## JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| Boyd's Hydro Diversion | Umatilla River, Rkm 16.00 Access across private land off Quick Rd<br>Lat: 45.821371°<br>Long: -119.326138° | Private – Go With the Flow | Currently offline. New owner is working on renewing FERC license and making upgrades to screens and fish bypass; short earthen bottom canal. | Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts. | No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies. | Focus on entrainment research studies. |
| West Extension Irrigation Diversion (aka 3-mile Dam) | Umatilla River, Rkm 5.70 Access from Canal Rd<br>Lat: 45.882097°<br>Long: -119.325868° | Bureau of Reclamation & West Extension Irrigation District | Huge concrete canal with multiple braids (secondary canal extensions); return flow at Boardman Rest Area (may be concern for lamprey pheromone attraction). | Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts. | No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies and pheromone attraction hypothesis. | Focus on entrainment research studies. |

## JUVENILE RELEASE/REARING SITES – UMATILLA RIVER SUBBASIN

| Site | Location | Property Owner | Site Features | Population Status | Monitoring Opportunities | Supplementation/Research Goals |
|---|---|---|---|---|---|---|
| Brownell Diversion | Umatilla River, Rkm 3.14 Access from Old Hwy<br>Lat: 45.904808°<br>Long: -119.326961° | Brownell Irrigation Ditch Company | Primarily basalt composition; old inoperable facility needs upgrades; may be removed over next 5 years. | Natural and translocated adults & juveniles documented in area through electrofishing and radio telemetry studies, as well as adult return counts. | No current monitoring; potential to implement monitoring specifically targeted toward entrainment studies. | Focus on entrainment research studies. |

# INVENTORY OF PROPAGATION FACILITIES IN THE UMATILLA RIVER SUBBASIN

## PROPAGATION FACILITIES – UMATILLA RIVER SUBBASIN

| Site | Location | Owner | Current Use | Available Resources | Facility Features | Monitoring Opportunities | Other Benefits | Potential Concerns |
|---|---|---|---|---|---|---|---|---|
| **EXAMPLE** | **River**<br>**Rkm**<br>**Lat: XX.XXXXX°**<br>**Long: -XXX.XXXXXX°** | **Owner name** | **Existing propagation, rearing, acclimation uses?** | **Underutilized facilities, facilities already allocated toward lamprey, future upgrades?** | **Key features and water source parameters beneficial to lamprey activities** | **Include existing/ongoing/previous monitoring efforts and potential for future monitoring. (E.g., existing survey data, plans for future surveys, locating antenna arrays, dam counting, screw traps)** | **Watershed location, water quality/quantity, accessibility to natural habitats adjacent?** | **Use conflicts, watershed position, lacking in natural habitat adjacent and/or unwanted riverine features adjacent? (e.g., diversions, entrainment potential), infrastructure deficiencies, owner problems** |
| Minthorn Springs | Umatilla River<br>Rkm 101.73<br>Lat: 45.669290°<br>Long: -118.620123 ° | CTUIR | Steelhead spawning & acclimation; adult lamprey holding | Existing holding tanks being used for lamprey; potential to expand facility for lamprey holding & rearing | Unlimited water right | | | Water quality concerns (DO) during late summer |

## PROPAGATION FACILITIES – UMATILLA RIVER SUBBASIN

| Site | Location | Owner | Current Use | Available Resources | Facility Features | Monitoring Opportunities | Other Benefits | Potential Concerns |
|---|---|---|---|---|---|---|---|---|
| Fred Grays (aka Imaques C-min-icum) Acclimation Pond | Umatilla River Rkm 127.15 Lat: 45.707085° Long: -118.349891° | CTUIR/BPA | Acclimation of spring Chinook | Four existing ponds; currently in use for Chinook from November through May; lots of space available on adjacent land to build additional ponds | May be able to utilize existing ponds during season not in use for other programs; may be able to construct new troughs (there is available unused space on-site); unlimited water right; good water quality/quantity | Existing screw trap nearby; ongoing electrofishing and redd surveys in vicinity. | | |
| Pendleton Acclimation Pond | Umatilla River Rkm 90.44 Lat: 45.670796° Long: -118.743584° | CTUIR/BPA | Acclimation of steelhead, spring/fall Chinook, and coho | Four ponds, currently in use for steelhead/salmon from May to November; potential to expand facility for lamprey holding and rearing | May be able to utilize existing ponds during season not in use for other programs; may be able to construct new troughs (there is available unused space on-site); unlimited water right | | | |

## PROPAGATION FACILITIES – UMATILLA RIVER SUBBASIN

| Site | Location | Owner | Current Use | Available Resources | Facility Features | Monitoring Opportunities | Other Benefits | Potential Concerns |
|---|---|---|---|---|---|---|---|---|
| Thornhollow Acclimation Pond | Umatilla River Rkm 117.57 Lat: 45.685041° Long: -118.454287° | CTUIR/BPA | Acclimation of spring Chinook (Carson stock – Bonneville Dam) | Two ponds, currently in use for Chinook from November through May; potential to expand facility for lamprey holding and rearing | May be able to utilize existing ponds during season not in use for other programs; may be able to construct new troughs (there is available unused space on-site); unlimited water right | | | |
| Bonifer Acclimation Pond | Meacham Creek Rkm 3.56 Lat: 45.684070° Long: -118.363384° | CTUIR/BPA | Currently unused | Natural pond with regulated outlet, no longer used as acclimation pond for steelhead program for past decade | Natural/earthen pond (wetland system) available for lamprey program; spring fed | Current monitoring includes electrofishing surveys, redd surveys, and a screw trap in the lower portion of Meacham Creek. Ongoing temperature monitoring data available. | Water quality/quantity fairly consistent – need to verify | Review water quality/quantity data to verify appropriate parameters for lamprey rearing |

## PROPAGATION FACILITIES – UMATILLA RIVER SUBBASIN

| Site | Location | Owner | Current Use | Available Resources | Facility Features | Monitoring Opportunities | Other Benefits | Potential Concerns |
|---|---|---|---|---|---|---|---|---|
| Three-mile Falls Dam | Umatilla River Rkm 5.83<br>Lat: 45.881731 °<br>Long: -119.322791 ° | CTUIR/BPA | Adult holding and spawning of Fall Chinook and coho; eggs incubated and reared at Umatilla Hatchery | Holding ponds used September to November for salmon programs; space available to build additional ponds; lamprey passage facility | May be able to utilize existing ponds/raceways for holding adult lamprey for translocation and rearing juveniles; potential to construct new ponds in unused gravel area; | Good opportunity to collect broodstock; opportunity for outside experiments (larval rearing experiments) | | Limited space – no incubation or rearing facilities; low in basin; water quality/quantity issues during some times of year |

# Appendix D. Confederated Tribes and Bands of the Yakama Nation – Draft Supplementation Research Plan for Ceded Area Subbasins

# 1 Introduction

## 1.1 Subbasin Overview

The Yakima River subbasin is located in south central Washington and contains a diverse landscape of rivers, ridges, and mountains totaling just over 6,100 square miles. Along the western portion of the basin, the glaciated peaks and deep valleys of the Cascade Mountains exceed 8,000 feet. East and south from the Cascade crest, the elevation decreases to the broad valleys and the lowlands of the Columbia Plateau. The lowest elevation in the basin is 340 feet at the confluence of the Yakima and Columbia Rivers at Richland. Precipitation is highly variable across the basin, ranging from approximately 7 inches per year in the eastern portion to over 140 inches per year near the crest of the Cascades. Total runoff from the basin averages approximately 3.4 million acre-feet per year, ranging from a low of 1.5 to a high of 5.6 million acre-feet.

Six major reservoirs are located in the subbasin and form the storage component of the federal Yakima Project, managed by the Bureau of Reclamation. Total storage capacity of all reservoirs is approximately 1.07 million acre feet, total diversions average over 2.5 million acre feet. The construction and operation of the irrigation reservoirs have significantly altered the natural seasonal hydrograph of all downstream reaches of the mainstem and some tributaries. Associated with these reservoirs are numerous irrigation dams and diversions throughout the subbasin.

Historically, the hydrologic cycle in this basin was characterized by extensive and complex exchange of water between the surface, hyporheic (area of surface / groundwater exchange) and groundwater zones. Under pre-1850s conditions, vast alluvial flood plains were connected to complex webs of braids and distributary channels. These large hydrological buffers spread and diminished peak flows, promoting infiltration of cold water into the underlying gravels. Side channels and sloughs provided a large area of edge habitat and a variety of thermal and velocity regimes. For Pacific lamprey, these side channel complexes increased productivity, carrying capacity, and life history diversity by providing suitable habitat for all freshwater life stages in close physical proximity.

## 1.2 Importance of Pacific Lamprey

Lamprey (eels) are of great importance to Native American tribes for cultural, spiritual, ceremonial, medicinal, subsistence and ecological reasons. From a tribal perspective, the decline of Pacific lamprey continues to have at least three negative effects: 1) loss of an important nutritional source and cultural heritage, 2) loss of fishing opportunities in traditional fishing areas, and 3) necessity to travel large distances to lower Columbia River tributaries, such as the Willamette River, for ever-decreasing lamprey harvest opportunities. As a consequence of declining or elimination of harvest in interior Columbia River basin tributaries, many young tribal members have not learned how to harvest and prepare lamprey for drying. In addition, young tribal members are losing opportunities to learn historically important legends associated with lamprey and lamprey fishing.

For over 10,000 years the Yakama people have depended on lamprey for food and medicine. Tribal members historically harvested lamprey in a sustainable manner, taking only what their families needed for subsistence. During historic times, lamprey were plentiful in the Yakama Nation Ceded Lands, and specifically in the Yakima River. Through the years, many stories and legends surrounding the eel were passed down from generation to generation and this important species has become an integral part of tribal culture. And, the tribes clearly recognize that restoration of lamprey populations is necessary for the restoration of the ecological health of Pacific Northwest watersheds, along with salmonids and other native fish populations.

## 1.3 USFWS Conservation Assessment Findings

The 2011 USFWS Pacific Lamprey Assessment and Template for Conservation Measures (Conservation Assessment) characterized the status of Pacific lamprey as critically impaired for the Naches subbasin (the Naches and Tieton rivers above the confluence with the Yakima River) and possibly extirpated for the Upper Yakima (mainstem and all streams above the confluence with the Naches River) and Lower Yakima (mainstem and all streams below the confluence with the Naches River) subbasins. The assessment document used “population groupings” to evaluate the species status based on geographic locality, but it does not imply that there are Yakima subbasin populations that are formally recognized as being distinct from other subbasin populations. The term “population grouping,” in this case, is being used loosely as a convenient term to be defined as a local assemblage of Pacific lamprey at the subbasin scale. Table 7-1 provides information contained in the USFWS Conservation Assessment outlining "Expert Opinion" of the current and historic status and trend. As is clearly indicated, Pacific lamprey populations are considered well below average historic levels. Reductions in the Yakima subbasin "population" are believed to be a cumulative result of many limiting factors - both within and outside of the subbasin. Table 7-2, also from the Conservation Assessment, identifies and ranks "Threats" to Pacific lamprey and their habitats in the Yakima subbasin.

**Table 1. Categorical rank inputs and resulting NatureServe ranks for Pacific lamprey population groupings within the Yakima River Subbasin (USFWS Conservation Assessment, 2011).**

| Watershed (population grouping) | Calculated Risk Rank[1] | Distribution | | Population Size | Threat | |
|---|---|---|---|---|---|---|
| | | Historic ($km^2$) | Current ($km^2$) | (number) | Scope | Severity |
| **Upper Yakima** | SH | 250 - 5,000 | 0 | Unknown - 0 | High | High |
| **Lower Yakima** | SH | 100 - 1,000 | 0 - 0.4 | 0 - 50 | High | High |
| **Naches** | S1 | 100 - 1,000 | > 0 - 4 | 1 - 250 | High | High |

**Table 2. Threats to Pacific lamprey and their habitat in the Yakima River subbasin, as identified and ranked by participants in regional meetings. High = 4; Medium = 3; Low = 2; Insignificant = 1. (USFWS Conservation Assessment, 2011).**

| Threat | | Population Grouping | | |
|---|---|---|---|---|
| | | Upper Yakima | Lower Yakima | Naches |
| **Passage** | Scope | 4 | 3 | 3 |
| | Severity | 4 | 4 | 3 |
| **Dewatering and Flow Mgt.** | Scope | 4 | 4 | 3 |
| | Severity | 4 | 4 | 3 |
| **Stream / Floodplain Degradation** | Scope | 2 | 2 | 2 |
| | Severity | 2 | 2 | 2 |
| **Water Quality** | Scope | 1 | 4 | 2 |
| | Severity | 1 | 4 | 2 |
| **Harvest** | Scope | 1 | 1 | 1 |
| | Severity | 1 | 1 | 1 |
| **Predation** | Scope | 1 | 2 | 1 |
| | Severity | 1 | 4 | 1 |

## 1.4 Vision and Goal

The Vision for this Supplementation Research Strategy is consistent with the Vision outlined in the 2004 NPCC Yakima Basin Subbasin Plan (Subbasin Plan), specifically:

"*Yakima River Basin communities have restored the Yakima river basin sufficiently to support self-sustaining and harvestable populations of indigenous fish and wildlife while enhancing the existing customs, cultures, and economies within the basin. Decisions that continuously improve the river basin ecosystem are made in an open and cooperative process that respects different points of view and varied statutory responsibilities, and benefits current and future generations.*"

Additionally, one of the guiding principles for this Subbasin Plan states "*That the natural environment including its fish and wildlife resources is the cultural heritage that is common to the diversity of human*

[1]*Definitions: SH = possibly extirpated; S1 = critically impaired; Scope – High = 71-100% of total population, occurrences or area affected; Threat – High = Near total destruction of suitable habitat and/or functional loss of Pacific lamprey from this watershed (>100 years of recovery).*

*existence. The underlying premise of the Yakima Subbasin Planning Board's Mission and Vision is to prepare and implement a balanced plan of action that plays a key role in the long-term sustainability of our common cultural heritage within the Yakima Basin*".

The primary Goal of the Yakama Nation, a member of this Planning Board is "*to restore natural production of Pacific Lamprey to a level that will provide robust species abundance, significant ecological contributions and meaningful harvest within the Yakama Nations Ceded Lands and in the Usual and Accustomed areas for harvest*". In both the Yakima Basin Vision and the Yakama Nation Goal for Pacific lamprey there is a strong consensus and desire to restore and support *self-sustaining and harvestable populations* of Pacific lamprey, important to the subbasin ecology and customs of the people. The Yakima subbasin has witnessed and endured decades of decline in lamprey populations and the resulting effects upon the culture. Research into the appropriate use of supplementation, along with needed habitat restoration, is an important action for the re-establishment of this local population in a timely manner.

# 2 Summary of Pacific Lamprey Status in the Yakima Subbasin

The U.S. Fish and Wildlife Service (USFWS) conducted a study on the "Distribution and Abundance of Fish in the Yakima River" (Patten et al. 1970)[2] between April 1957 and May 1958. The study covered the mainstem of the Yakima River from Richland, Washington upstream to Easton Dam, a total of approximately 281 kilometers (km) (174 miles). Although the report did not provide a distinction between Western Brook Lamprey (*Lampetra richardsonii*) and Pacific Lamprey (*Entosphenus tridentatus*) species (due to difficulty of juvenile identification), lamprey were noted in various sample reaches throughout the study area. The 1970 USFWS report documents catching 146 lamprey throughout 10 of the 18 sample reaches. This included the collection of lamprey from the uppermost upstream sample reach (Easton Dam 281 km) and second to lowest downstream sample reaches (16km to 24km). This information supports information from current WDFW[3] and YNPLP[4] surveys and oral histories indicating that lamprey utilized the entire mainstem Yakima River for adult migration and for juvenile rearing.

The historical extent of salmonid species and Pacific lamprey distribution are very similar in many basins within the northwestern USA (Hamilton et al. 2005; Moyle 2002; Scott and Crossman 1973) and may be the best surrogate we have available to estimate historical abundance of Pacific lamprey. The Yakima Subbasin historically supported large runs of six anadromous salmonid species (Table 7-3). Based on the estimated historic run sizes of anadromous salmonids within the Columbia Basin (NPPC 1986) and that within the Yakima Subbasin (BPA 1996), the historic run of Pacific lamprey is estimated to be between 20,656 and 31,297 adults (because summer Chinook largely went to Snake Basin historically, we exclude the estimated run based on summer Chinook). Spatial distribution of spawning habitat for Pacific lamprey is similar to many salmonid species as well. Though there is plenty of overlap in the spatial range, generally speaking, coho and steelhead tend to spawn in slightly higher gradient reaches and fall Chinook tend to spawn in slightly lower gradient reaches compared to Pacific lamprey. Based on the similar migration timing and spatial range of spawning, we hypothesize that spring Chinook salmon (where they exist) may be the best surrogate/index for historic Pacific lamprey abundance and distribution. Historic run of Pacific lamprey is estimated to be 31,297 adults based on estimated spring Chinook pre-historic runs.

[2] *Patten, B. G., R. B. Thompson, and W. D. Gronlund. 1970. Distribution and abundance of fish in the Yakima River, Wash., April 1957 to May 1958. Special Scientific Report – Fisheries No. 603. U.S. Fish and Wildlife Service, Washington, D.C.*

[3] Washington Department Fish and Wildlife

[4] Yakama Nation Pacific Lamprey Project

**Table 3. Assessed runs of historic salmonid species in Columbia Basin vs. Yakima subbasin to estimate historic runs of Pacific lamprey within the Yakima Subbasin.**

| Species | Estimated Columbia Prehistoric Run | Estimated Yakima Prehistoric Run | % (Yakima/ Columbia) | Target Species | *Columbia Historic High Run (1939-1969) | Estimated Yakima Historic High Run | Current Yakima Run (11 year ave.) | % (Current / Historic Yakima) |
|---|---|---|---|---|---|---|---|---|
| Spring CH | 1716000 | 200000 | 11.7 | Pacific Lamprey | 268524 | 31297 | 23 | 0.07 |
| Summer CH | 3433000 | 68000 | 2.0 | Pacific Lamprey | 268524 | 5319 | 23 | 0.43 |
| Fall CH | 1716000 | 132000 | 7.7 | Pacific Lamprey | 268524 | 20656 | 23 | 0.11 |
| Sockeye | 1940000 | 200000 | 10.3 | Pacific Lamprey | 268524 | 27683 | 23 | 0.08 |
| Coho | 1328000 | 110000 | 8.3 | Pacific Lamprey | 268524 | 22242 | 23 | 0.10 |
| Steelhead | 1006000 | 80000 | 8.0 | Pacific Lamprey | 268524 | 21354 | 23 | 0.11 |
| Overall | 11139000 | 790000 | 7.1 | Pacific Lamprey | 268524 | 19044 | 23 | 0.12 |

*Columbia Historic High Run for Pacific lamprey is based on the average of the five high counts between 1939 and 1969.

## 2.1 Adult abundance, run timing, and spawning locations

### 2.1.1 Abundance

Adult abundance is considered very low within the Subbasin. Adult counts at the Prosser Dam Fish Counting Facilities (FCF) (river km 75.7), from Year 2000 – 2013 (Figure 7-1) indicate that, on average approximately 20 adult lamprey have entered the subbasin per year and potentially moved into upper reaches suitable for spawning. In three years zero fish were counted, and in three other years between 65 - 87 fish were counted. In five other years, the average was less than three lamprey passing Prosser Dam per year. Even if we account for the low detection rates of lamprey passing through the dam (roughly 55% based on radio telemetry results), it is reasonable to conclude that adult abundance in the Yakima subbasin is critically low and that genetic diversity has been critically impaired. Given these low counts observed in the lower Yakima River, abundance of Pacific lamprey in the upper reaches is most likely insignificant or non-existent. No adult lamprey have been observed at the counting station at Roza Dam (river km 210.5) since the new counting system was implemented in 1997 (and no positive records prior to that). However, some of the radio tagged lamprey that were transferred to upper Yakima subbasin passed the dam in 2012 and 2013.

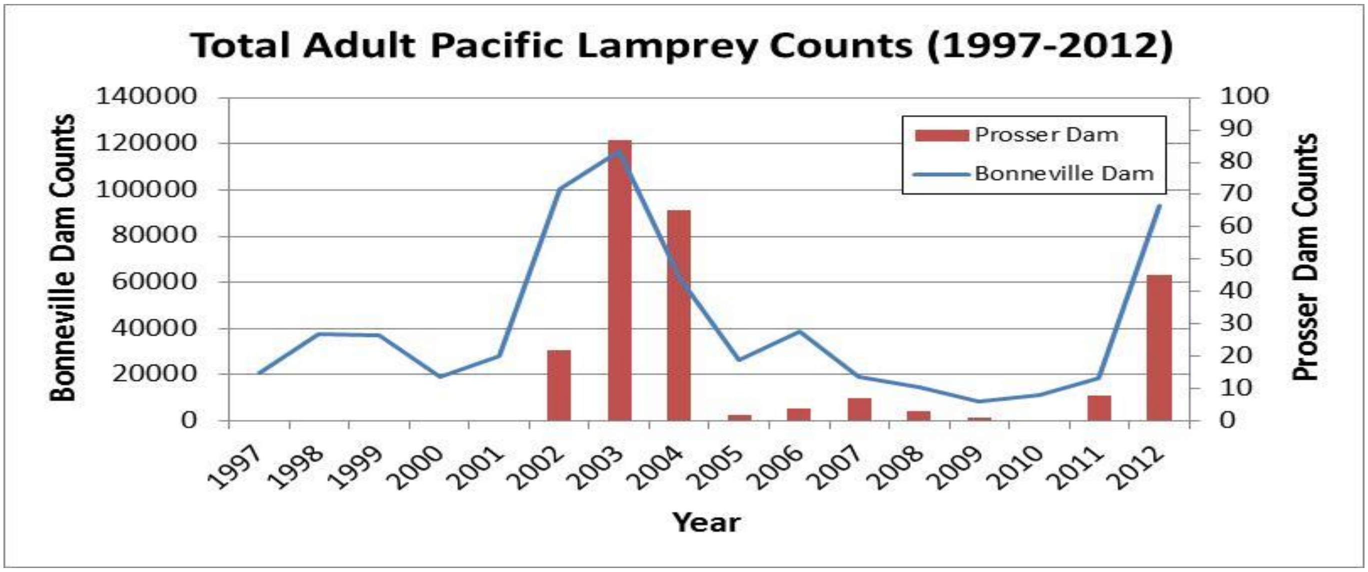



**Figure 1**. **Total adult Pacific lamprey counts at Prosser and Bonneville dams between 1997 and 2012.**

## 2.1.2 Run Timing

Little is known about adult run timing into the Yakima River subbasin other than what can be concluded from daily counts at the Prosser Dam FCF. Figure 7-2, below, illustrates that between years 2000 - 20012 there is two distinct runs of Pacific lamprey at the FCF: a larger run that span between late March and late May, and a smaller run that span between early June and early October (see the yellow line that hypothesizes the transition point between the overwintered fish vs. fresh migrants). Interestingly, during these same years, the average annual run timing of adults reaching McNary Dam began no earlier than late May and very few adults entered the Yakima River during this early summer period (particularly between late June and mid-August, which corresponds to the time period for peak water temperature). It is apparent that a large portion of adult lamprey overwinter somewhere in the Columbia River prior to their ascent up the Yakima River. It is reasonable to speculate that due to current flow management, the combined impacts of less flow reaching the lower river and higher river temperatures compared to historic conditions may deter many of the fresh migrant Pacific lamprey from entering into the subbasin during the peak run period for fresh migrants.

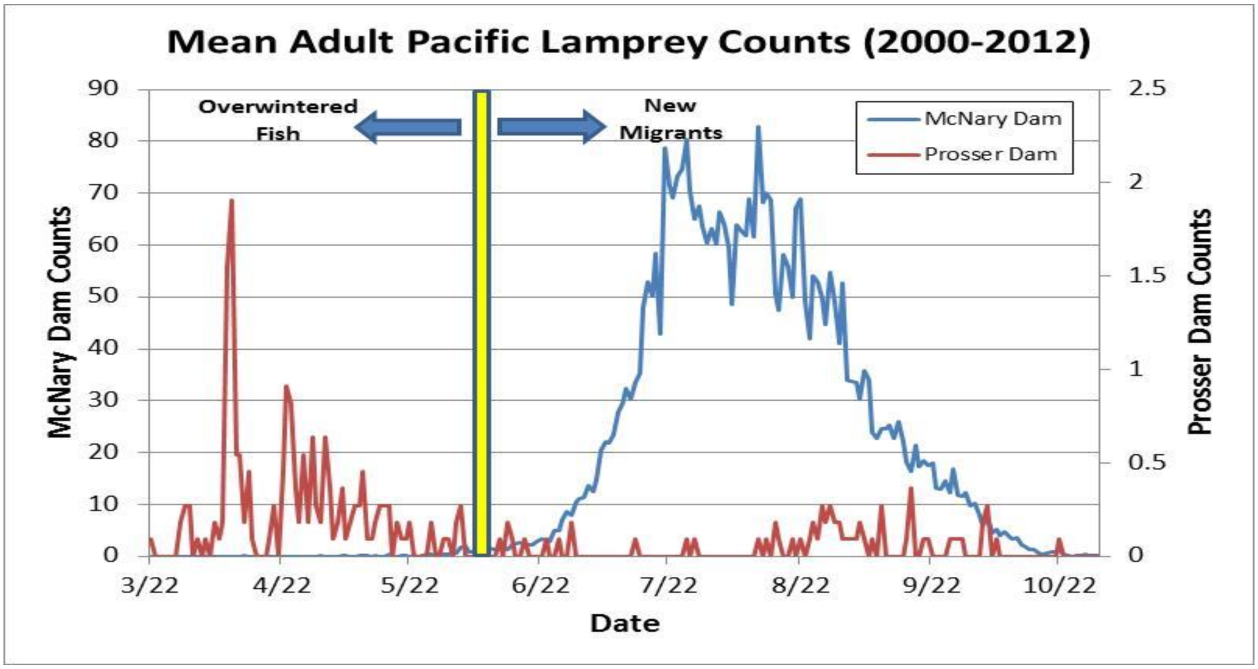



**Figure 2**. **Mean adult Pacific Lamprey Counts between 2000 and 2012 at Prosser Dam and McNary dams.**

### 2.1.3 Spawning Locations

Very little is known about lamprey spawning locations within the Yakima River. It is likely that many known spawning locations for salmonid species, such as spring Chinook, coho and steelhead, are also suitable for Pacific lamprey. These areas exist in many stream reaches throughout the entire subbasin. But due to the very low adult Pacific lamprey returns over the recent past, very little information exists that describes eye-witness accounts of significant spawning activity in any of these, or other locations. Tribal elders have shared some locations where adults were historically encountered during the spawning period, including Toppenish, Status, and middle reaches of the Yakima River. Given the combination of geomorphic characteristics (flow, gradient, and valley width), water temperature regime, and expert opinions, we suspect that Satus, Toppenish, Ahtanum, Naches, Wenas and mainstem Yakima (middle reach, such as Wapato area) will be productive streams/rivers for spawning Pacific lamprey. Tributaries in the upper Yakima, such as Taneum, Teanaway, Cle Elum, also appear to have good potential habitat and favorable conditions for Pacific lamprey.

### 2.1.4 Juvenile Abundance and Run Timing

Juvenile abundance is considered to be very low throughout the entire Yakima Subbasin, and essentially non-existent above Roza Dam and the upper Naches. The primary sources of information available to resource managers are site specific counts made by WDFW, juvenile lamprey surveys undertaken by the YNPLP (2010 through present) and juvenile counts at the Prosser FCF (2000 through present). Counts made by WDFW indicate that juvenile Pacific lamprey (macrophthalmia) are found primarily in the lower Yakima River during the winter season. This also matches with the data from the Prosser FCF. Juvenile lamprey counts at the Prosser FCF have ranged between 18 and 1450 individuals between 2000 and 2012 (between 55 and 4273 for the extrapolated counts) (Figure 7-3). The facility is located within the bypass system of the Chandler Canal,

which diverts roughly 30-50% of the Yakima River water during the juvenile lamprey migration season in the winter. Water is screened within this canal (5/32" mesh large drum screens, which is small enough to prevent macrophthalmia from passing through), and fish are diverted into the Facility through the bypass channel. Captured juvenile lamprey are counted, but species and life stage identification have not been recorded consistently to date. Periodic past examinations of the captured lamprey between 2010 and 2013 indicate that the majority of these outmigrating juvenile lamprey during the winter high flow conditions are Pacific lamprey macrophthalmia; hence, these counts could potentially be used as an index for juvenile lamprey abundance.

Analysis of the run timing for outmigrating juvenile lamprey is limited in scope by the Prosser FCF sampling period, which typically runs between early January and mid-July (Figure 7-4). There appears to be two peak runs; one between January and February (peak in mid-January) and one between March and June (peak in mid-May). The second peak corresponds closely in timing with the adult counts at Prosser Dam. Based on these data, it appears that juvenile lamprey are keying into high flow events for outmigration and it is unlikely that juvenile lamprey are moving out during the summer / fall season when the flow is typically much lower.

**Figure 3. Outmigrating juvenile lamprey counts at Prosser Dam FCF (lamprey species not identified). Extrapolated counts use the daily subsampling rates to provide estimated overall migrants.**

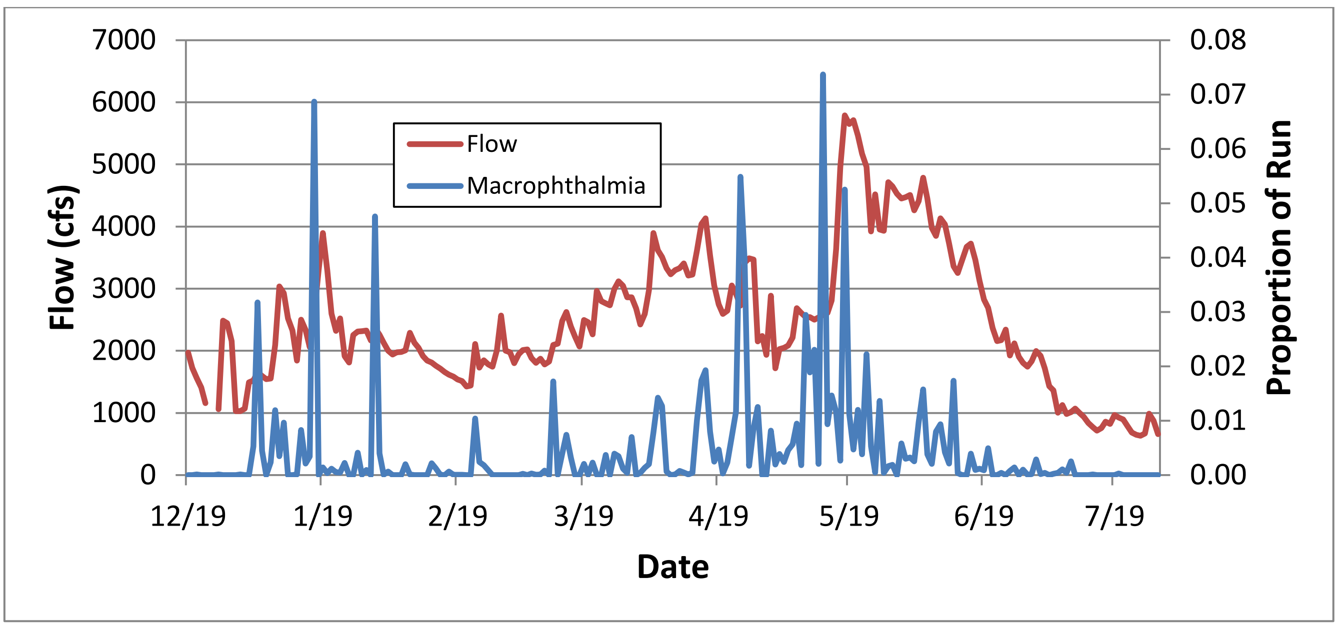



**Figure 4. Mean proportion of outmigrating juvenile lamprey counts and corresponding river flow rates at Prosser Dam FCF between 2000 and 2012 (lamprey species not identified). The mean proportion is based on the extrapolated overall counts based on daily subsampling rates.**

## 2.1.5 Ammocoete Abundance and Distribution

Since 2009, the Yakama Nation Pacific Lamprey Project (YN PLP) has begun conducting juvenile lamprey surveys to document their distribution and relative abundance within the Ceded Area of the Yakama Nation. In 2012, we surveyed a total of 98 sites using a backback electrofisher designed for larval lamprey. In addition, there were over 70 other sites that were surveyed quickly (quick assessments) using an electrofisher or a fine-mesh hand net to simply evaluate prescence/absence of juvenile lamprey. Juvenile Pacific lamprey

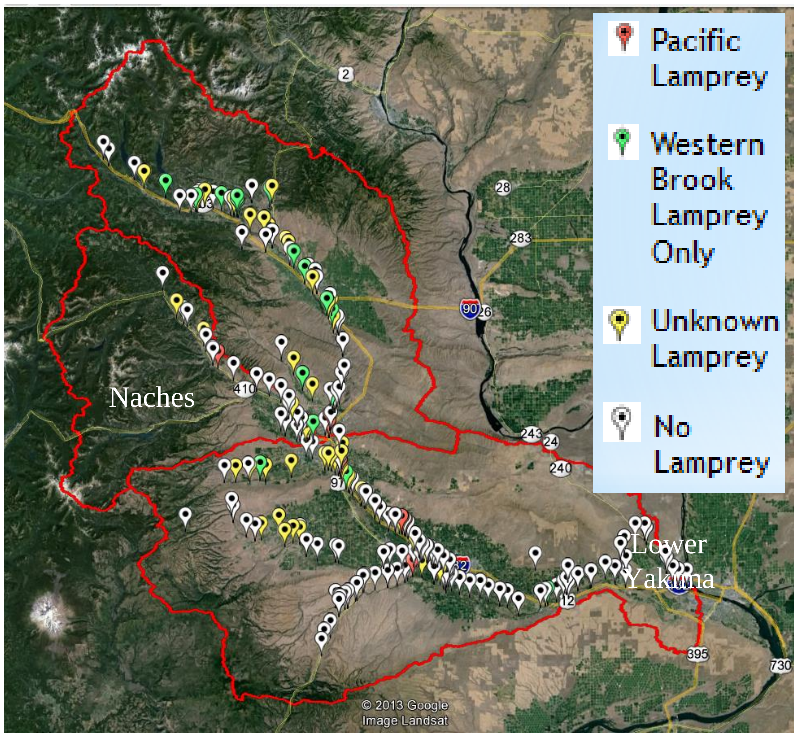
were only found in the Lower Yakima and Naches subbasins and the mean ratio of Pacific lamprey (vs. Western brook lamprey) were 13.3%, 5.3%, respectfully. Within the Yakima Subbasin, we only found Pacific lamprey ammocoetes in the Yakima River, Satus Creek, Ahtanum Creek, and Naches River. The ratio of Pacific lamprey vs. Western brook lamprey in these rivers/streams were 22.0%, 8.3%, 28.6%, 7.7%, respectfully. We did not detect any juvenile lampreys in the lower reaches of the Yakima River until river km 137. 6. No juvenile Pacific lamprey have been detected upstream of river km 195.2 in the Yakima River since these surveys began in 2009. On the other hand, Western brook lamprey were detected most frequently in the Upper Yakima Subbasin (73.7% of all sites surveyed) compared to all other subbasins surveyed in 2012.

We also detected an inverse relationship between habitat availability and fish density at the subbasin scale. For instance, Naches Subbasin had the lowest amount of habitat available per site, but the mean fish density was the highest of all the subbasins. This potentially indicates that lack of habitat within the stream/river may force the lamprey to use the habitat at a higher fish density level compared to sites with more larval habitat available, and suggests that ammocoete density may not be the best indicator for fish abundance and status (i.e. it could be an indication that habitat is limiting).

All previous surveys starting in 2009 paint the general same picture for the Yakima Subbasin. That is, Pacific lamprey are rare and primarily limited to the Lower Yakima Subbasin (below Roza Dam) and the majority that we have detected were found in side channels of the Yakima River (primarily in the Wapato reach area) and the lower reaches of major tributaries, including Satus and Ahtanum Creek. Ammocoete habitat and Western brook lamprey, on the other hand, is fairly abundant in the Lower Yakima as well as in the Upper Yakima subbasins. It is important to note that Western Brook and Pacific lamprey juveniles less than 60 mm size are nearly impossible to distinguish in the field. As a result, many of the juveniles captured are categorized as “unknown” leaving a lot of uncertainties in the exact distribution of the lamprey species. Also, the survey crew has varying levels of species identification skills, and some of the identification may not have been 100% accurate.

Additionally, the Yakama Nation has surveyed various irrigation canals, shortly after annual dewatering, for juvenile lamprey presence. Although Western brook lamprey ammocoetes and transformers (equivalent to the macrophthalmia life stage of Pacific lamprey, except eyes of Western brook lamprey transformers are much smaller) have been found in large numbers in various diversions throughout the subbasin, none of the larger ammocoetes and transformers have been identified positively as Pacific lamprey. No Pacific lamprey macrophthalmia have been found to date in the streams and rivers of the Yakima subbasin during regular sampling surveys as well.

**Figure 5. Juvenile lamprey survey sites within the Yakima Subbasin in 2010-2012. As shown in the legend, red balloons indicate sites that had Pacific lamprey, green balloons indicate sites that had only Western brook lamprey, yellow balloons indicate sites that had no Pacific lamprey but included some lamprey that were unidentifiable (due to small size), and white balloons indicate sites that had no lamprey.**

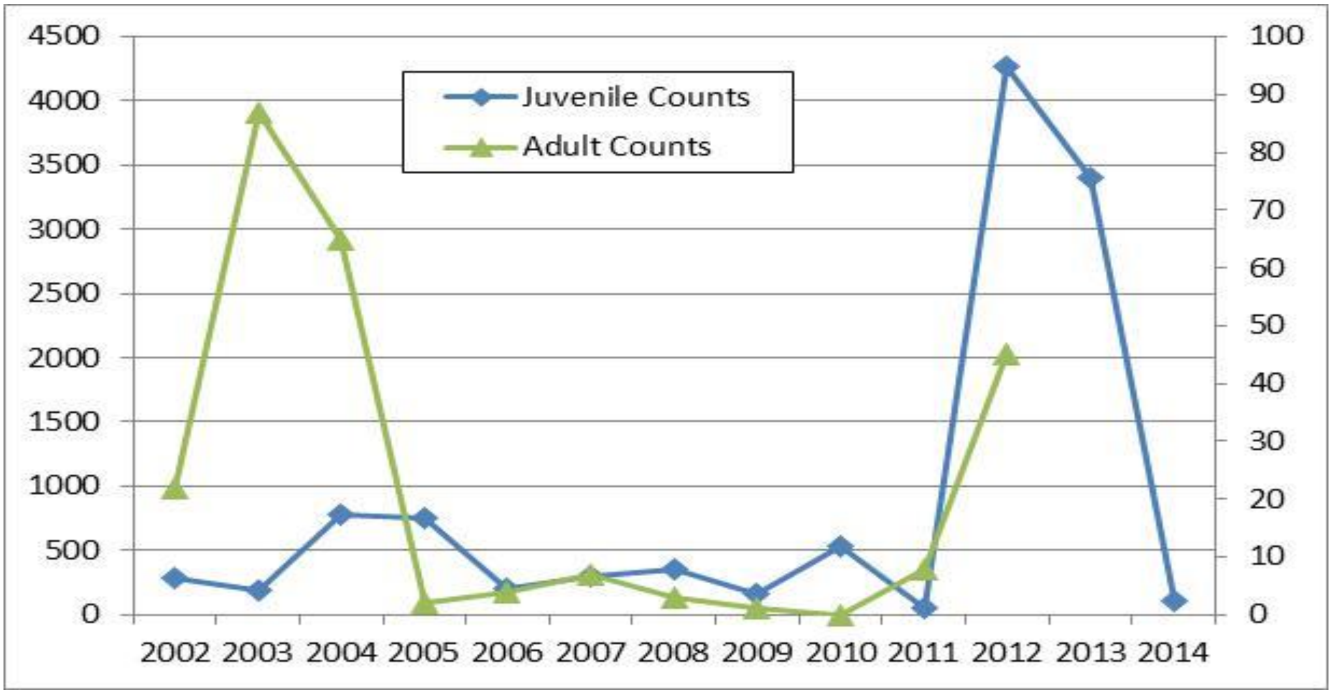



## 2.1.6 Life Stage Overview

There are still many uncertainties in the linkage between juvenile and adult lamprey abundance and more specifically the life stage survival model of Pacific lamprey. One primary limiting factor is that fisheries managers still do not fully understand the life span of the fish (both life stage specific and overall), which makes any modeling problematic and challenging. However, some interesting relationship surfaces based on the Prosser Dam data. Outmigrating juvenile lamprey counts from Prosser FCF (with a 7-year lag), correlate strongly with the adult counts from Prosser Dam with a 7-year lag, indicating that the adult counts can be an excellent predictor for juvenile production (Figure 7-6). Because the majority of adult lamprey passing through Prosser Dam are overwintered adults, this indicates that the outmigrating juvenile lamprey may be primarily 6-year-old lamprey. If this prediction is true, we will continue to see low depressed abundance of outmigrating juveniles all the way until 2018. Conversely, adult counts appear to have some correlation with the outmigrating juvenile counts with a 2-year lag, indicating that the juvenile counts may also be an effective predictor for adult production (Figure 7-7). For instance, the relatively high juvenile production in 2010 resulted in a relatively high adult count in 2012. According to this predication model, the adult counts in 2013 will stay relatively high, but it will drop down again in 2014.

**Figure 6. Extrapolated outmigrating juvenile lamprey counts at Prosser FCF between 2000 and 2012 and corresponding adult counts with a 7-year lag to predict outmigrating juvenile lamprey production between 2003 and 2019.**

**Figure 7. Adult lamprey counts at Prosser Dam between 2002 and 2012 and corresponding extrapolated outmigrating juvenile counts with a 2-years prior to predict adult lamprey recruitment between 2002 and 2014.**



# 3 Summary of Pacific Lamprey Priority Limiting Factors

## 3.1 Adult Migration: Passage

Dams are known to be a challenge to Pacific lamprey passage, whether large head hydroelectric dams of the Columbia River or irrigation dams along smaller tributaries, such as the Yakima River. Since 2010, the USFWS, in cooperation with the Yakama Nation, BOR and USACE (Seattle District) has been evaluating passage of lamprey at irrigation facilities in the lower and mid - Yakima River. As noted in the USFWS 2012 Annual Report (Johnsen et. al. 2013)[5] "*To date, our results indicate the diversion dams on the Yakima River are impeding the upstream migration of Pacific lampreys. We suggest several different modifications that may increase lamprey passage including a lamprey passage system (LPS), reduced fishway velocities, and modifications to fishway entrances*". This telemetry research is anticipated to continue for several years to come, moving upstream to evaluate all major diversion dams throughout the Yakima subbasin.

## 3.2 Downstream Passage: Juvenile Entrainment

Recent surveys by the YNPLP clearly indicate that juvenile lamprey are entering many irrigation diversion ditches within the Yakima subbasin and getting behind various screens designed for salmonid criteria. The YNPLP, in coordination with the BOR, has documented these findings and annual reports are available upon request. To date, only preliminary work has commenced to understand how juvenile lampreyare actually getting behind these screens. Considerable investigations are currently underway by Dr. Matt Mesa and others at the USGS Western Fisheries Research Center in Cook, WA to understand this issue and to develop new screening criteria. Additionally, the Yakama Nation is now working closely with the WDFW, USFWS, BOR and USGS developing and implementing studies using screw traps and passive traps to determine the means for escapement below these screens and future measures to prevent these entrapments. The YNPLP, along with the WDFW and BOR will continue to survey irrigation ditches throughout much of the subbasin over the next five years, but due to the lack of resources it is anticipated that the primary focus for addressing entrainment issues in the near-term will be at the Reclamation facilities in the Mid - and Lower Yakima AU's.

## 3.3 Water Quantity - Flow Management

As is well established in numerous local planning documents, including the 2004 Subbasin Plan, water management has substantially changed flow conditions throughout much of the Yakima subbasin. As noted above in the Subbasin Overview, most of the entire subbasin flows are controlled by large reservoirs in the headwaters. And many smaller tributaries, once habitable for lamprey, are significantly dewatered from multiple diversions.

One of the more important issues directly affecting the upper mainstem of the Yakima River is the lowering of the river flow (stage elevation) in early September to accommodate safe spawning of spring Chinook salmon and later, the hatching of these eggs. It is well established that the relatively quick ramping rates associated with this process causes widespread mortality to a number of invertebrate populations (caddis fly larvae, for example) substantially impacting the productivity of the upper reaches. Additionally, it is believed by some fishery managers that larvae lamprey residing at the stream margins are left to desiccate as the stream

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

stage elevation is reduced in such a rapid manner. This hypothesis will be tested over the next 2-3 years in various locations throughout the upper Yakima River.

## 3.4 Water Quality - Temperature: Lower Yakima River

Water temperatures in the lower Yakima River typically exceed or approach 80 degrees Fahrenheit during the warmest periods in the summer months. These temperatures are known to be lethal for juvenile lamprey. Besides one Western brook larva that was found just downstream of Prosser Dam (river km 73.5) in 2011, there has been no juvenile lamprey detected below river km 136.7 (1.5 miles northwest of Granger, WA) on mainstem Yakima River between 2010 and 2012 during the summer sampling surveys. There is no clear consensus on how current water management and environmental conditions have increased river water temperature compared to historic conditions. It is widely believed by resource managers that (1) river temperatures in the lower Yakima subbasin during summer months were, in fact, relatively high in historic times but (2) river management (withdrawals) likely exacerbate these conditions, albeit to an un-quantified amount. It is likely that due to current water management, when flows are reduced from diversions during the early summer months, water temperatures are elevated. This occurs when adults migrate past the Yakima River and may be a factor that discourages entrance and assenting up to headwater tributaries.

## 3.5 Small Effective Population Size

As noted above, Pacific lamprey populations in the Yakima subbasin are critically low, and in some watersheds, presumed extirpated. Specifically, the last "high" adult counts at Prosser Dam were noted in 2003 and 2004 (87 and 65 adults counted, respectively). Assuming a 7-year juvenile life stage, the last of these juvenile year classes would have left the Yakima subbasin in 2011. Subsequent low adult counts between 2005 and 2011 (ranging from zero to a high of 14 in 2011) begs the questions "can adults successfully find a mate?" and "what are the genetic risks associated with such a low brood population?". Given simply the adult counts, and the very low numbers of juveniles found in the 2010 - 2012 YNPLP distribution surveys, current information establishes that Pacific lamprey populations in the Yakima subbasin are fundamentally extirpated.

## 3.6 Critical Uncertainties

In addition to these known primary limiting factors, there are many other critical uncertainties that exist, which may play a significant role in the population abundance of Pacific lamprey in the Yakima subbasin. The effects of water quality including contaminants and toxicants are largely unknown at this point. Due to the early life history of lamprey (burrowing in fine sediment in low gradient channels for several years), the likelihood that ammocoetes are exposed to a high level of toxicants is high. Predation is also a potential threat to Pacific lamprey. The number of native and non-native piscivorous predators (fish, avian, mammal) have increased greatly due to dams within the Yakima subbasin as well as Columbia basin at large. However, due to the lamprey's unique physiology (lack of bone structure), most studies examining the stomach content of predators miss any clue for juvenile lamprey predation, especially for ammocoetes which lack teeth at this stage. Global climate change appears to be eminent and will likely affect the flow dynamics and temperature of the local rivers in the Yakima subbasin. Some prediction models indicate that the timing of snow melt floods will arrive earlier than it has been in the past, further reducing flow in late summer. For adult Pacific lamprey that migrate extensively during this time period, this may hinder their upstream migration.

# 4 Ongoing / Planned Lamprey Restoration Actions over the Next 5-10 Years

This restoration strategy intends to address priority limiting factors across the subbasin. Recognizing that lamprey need to use habitats that extend widely, our strategy views the Yakima River subbasin holistically, and recommends priority actions across the subbasins as part of the overall recovery strategy. See Appendix 7-A (Action Table) for more information.

- **Passage**. Continue to evaluate passage issues and appropriate passage structures on irrigation diversion facilities, starting with Projects lower in the subbasin and working upstream. Implement passage structures as needed and feasible.

- **Entrainment**. Continue to evaluate the degree that entrainment is occurring within irrigation diversion ditches, identify priority locations to focus near-term work and implement corrective actions. In general, actions will focus on Reclamation facilities initially but will expand to all relevant sources for entrainment over time.

- **Contaminants**. Continue taking water quality and juvenile lamprey tissue samples to determine the presence, the types and the amount of contaminants (potential threat of industrial, urban or agricultural contaminants) being ingested or otherwise absorbed into local lamprey populations. Initiate a planning strategy to identify the sources and potential remedies for toxicants determined to be detrimental to lamprey health or survival.

- **Supplementation**. Given that the Yakima subbasin population is essentially extirpated, fishery managers will be actively pursuing the use of adult and juvenile supplementation within key watersheds in a manner that will also benefit key research needs throughout the Columbia River Basin. Research in supplementation is intended to identify appropriate supplementation strategies for watersheds within the Yakima subbasin. Methodologies and biological benefits and risks of expanding this program to other subbasins will be evaluated. Over the next three-to-five years, the focus will be to explore and evaluate translocation and artificial propagation techniques of Pacific Lampreys, test juvenile growth, survival and movements in the natural environments and refine future research plans for propagation activities and propagated lamprey.

- **Biological Surveys**. Continue to document current status of adult and juvenile lamprey with regards to presence, distribution, and relative abundance. Continue to identify, describe and monitor key Index Sites for long-term status and trends at the reach, watershed and at the subbasin context.

- **Habitat Surveys**. Identify habitat characteristics that are preferred at various life stages (habitat quality) and determine the extent (habitat quantity) these areas are available and are being utilized.

- **Habitat Restoration**. Consider certain types of in-stream restoration efforts to benefit salmonids and to monitor potential benefits towards lamprey productivity. Habitat quality and quantity are not likely limiting population growth at this time - especially given the very low populations currently existing. However, we expect that certain types of restoration activities in key stream reaches (Wapato Reach, Satus and Toppenish creeks) will benefit both salmonid and lamprey recovery, together.

**Coordination and Collaboration**. Continue to work directly and collaboratively with local and regional land and resource management agencies and entities to develop and implement a well-founded public involvement and information strategy and to gain efficiencies in both time and resources in implementing lamprey restoration actions.

# 5 Ongoing / Planned Lamprey Supplementation Research Actions over the Next 5-10 Years

Need a general overview of the supplementation effort (translocation in lower Yakima where they still exist in small numbers; supplementation in upper Yakima where they appear to be extinct as well as diversions and other settings for research purposes here

**Table 4. Numerical codes for monitoring and evaluating the three supplementation research strategies described in section 4.3 of the *Framework for Pacific Lamprey Supplementation Research in the Columbia River* Basin. The codes also reflect the section number in the Framework document.**

| 4.3.**1** | Adult Translocation | 4.3.**2** | Larval and Juvenile Rearing | 4.3.**3** | Larval and Juvenile Outplanting |
|---|---|---|---|---|---|
| 4.3.**1.1** | Adult Survival | 4.3.**2.1** | Broodstock survival | 4.3.**3.1** | Larval Growth and Survival |
| 4.3.**1.2** | Adult Spawning | 4.3.**2.2** | Fertilization to hatch survival | 4.3.**3.2** | Larval Abundance and Distribution |
| 4.3.**1.3** | Larval Survival and Growth | 4.3.**2.3** | Hatch to outplant survival | 4.3.**3.3** | Larval and Juvenile Outmigration |
| 4.3.**1.4** | Larval Abundance and Distribution | | | 4.3.**3.4** | Adult Returns |
| 4.3.**1.5** | Larval and Juvenile Outmigration | | | | |
| 4.3.**1.6** | Adult Returns | | | | |

**Table 5. Comparison chart displaying all potential comparison pairs of the different supplementation and research strategies. T = Translocation; larval/juvenile lamprey from translocated adults. H = Hatchery; larval/juvenile lamprey born and reared in a hatchery environment. P = Propagation; larval/juvenile lamprey artificially propagated and released into the natural environment. C = Control; larval/juvenile lamprey born and rearing in the natural environment.**

| Comparison | **T**ranslocation | **H**atchery | **O**utplanting | **C**ontrol |
|---|---|---|---|---|
| **T**ranslocation | TxT | HxT | OxT | CxT |
| **H**atchery | TxH | HxH | OxH | CxH |
| **O**utplanting | TxO | HxO | OxO | CxO |
| **C**ontrol | TxC | HxC | OxC | CxC |

**Table 6. Lamprey supplementation research actions over the next 5-10 years within the Yakima Subbasin (see Table 6-3 and 6-4 for the M&E and Comparison codes).**

| Subbasin | Stream | Location | Supplementation Research Strategy | | | | | | | | Start Timeline | End Timeline |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Adult Translocation (T) | | Hatchery Rearing (H) | | Larval and Juvenile Outplanting (O) | | Control (C) | | | |
| | | | M&E Approach | Comparison | M&E Approach | Comparison | M&E Approach | Comparison | M&E Approach | Comparison | | |
| Lower Yakima | Satus | Mainstem | 4.3.1. **2, 4-6** | *xO, xC, xT* | | | | | | | Ongoing | 5+ years |
| | Toppenish | Mainstem / Simcoe | 4.3.1. **1-6** | *All* | | | | | | | Ongoing | 5+ years |
| | Ahtanum | Mainstem / SF Ahtanum | 4.3.1. **2, 4-6** | *xO, xC, xT* | | | 4.3.3 **1-6** | *All* | | | Ongoing | 5+ years |
| | Lower Yakima | Mainstem (Dam Passage) | 4.3.1. **1-2** | *xT* | | | | | | | Ongoing | 1-3 years |
| | Lower Yakima | *Prosser Fish Hatchery | | | 4.3.2. **1-3** | *All* | | | | | Ongoing | 10+ years |
| | Lower Yakima | *Marion Drain Fish Hatchery | | | 4.3.2. **3** | *xO, xH* | | | | | 1-3 years | 5+ years |
| | Lower Yakima | *City of Yakima side channel restoration | | | | | 4.3.3 **4-5** | *xT, xC, xO* | | | 1-3 years | 5+ years |
| | Lower Yakima | *Diversions (Passage Tests on Sunnyside, Wapato, etc.) | | | | | 4.3.3 **3-5** | *xH, xO* | | | 1-3 years | 5+ years |
| Upper Yakima | Upper Yakima | Mainstem (Dam Passage) | 4.3.1. **1-2** | *xT* | | | | | | | Ongoing | 1-3 years |
| | Taneum | Mainstem | 4.3.1. **2-6** | *xO, xC, xT* | | | 4.3.3 **4-6** | *xT, xC, xO* | | | 5+ years | 10+ years |
| | Wenas | Mainstem | | | | | 4.3.3 **4-6** | *xT, xC, xO* | | | 1-3 years | 5+ years |
| | Cle Elum | Side Channel Restoration Sites | | | | | 4.3.3 **4-6** | *xT, xC, xO* | | | 1-3 years | 5+ years |
| | Swauk | Mainstem | | | | | | | 4.3.1. **1, 4** | *xT, xO, xC* | Ongoing | 5+ years |
| | Teanaway | Mainstem | | | | | | | 4.3.1. **1, 4** | *xT, xO, xC* | 1-3 years | 5+ years |
| | Upper Yakima | *Cle Elum Fish Hatchery / Side Channel | | | 4.3.2. **1-3** | *xO, xH* | 4.3.3 **3-6** | *All* | | | 5+ years | 10+ years |
| | Upper Yakima | *Holmes Acclimation Pond | | | | | 4.3.3 **3-6** | *All* | | | 1-3 years | 5+ years |
| | Upper Yakima | *Diversions (Passage Tests on Roza, Snipes Allen, etc.) | | | | | 4.3.3 **3-5** | *xH, xO* | | | 1-3 years | 5+ years |
| Naches | Naches | Mainstem (Dam Passage) | 4.3.1. **1-2** | *xT* | | | | | | | Ongoing | 1-3 years |
| | Cowiche | Mainstem / SF Cowiche | | | | | | | 4.3.1. **4** | *xT, xO, xC* | Ongoing | 5+ years |
| | Tieton | Mainstem | | | | | | | 4.3.1. **4** | *xT, xO, xC* | 1-3 years | 5+ years |
| | Rattlesnake | Mainstem | | | | | | | 4.3.1. **4** | *xT, xO, xC* | 1-3 years | 5+ years |
| | Bumping | Mainstem / American | | | | | | | 4.3.1. **4** | *xT, xO, xC* | 1-3 years | 5+ years |
| | Little Naches | Mainstem / Crow | | | | | | | 4.3.1. **4** | *xT, xO, xC* | Ongoing | 5+ years |
| | Naches | Eschbach Park Side Channel | | | | | 4.3.3 **3-6** | *All* | | | 1-3 years | 5+ years |

| Subbasin | Stream | Location | Supplementation Research Strategy | | | | | | | | Start Timeline | End Timeline |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Adult Translocation (T) | | Hatchery Rearing (H) | | Larval and Juvenile Outplanting (O) | | Control (C) | | | |
| | | | M&E Approach | Comparison | M&E Approach | Comparison | M&E Approach | Comparison | M&E Approach | Comparison | | |
| | Naches | *Diversions (Passage Tests on Wapatox, Scott Ditch, etc.) | | | | | 4.3.3 **3-5** | *xH, xO* | | | 1-3 years | 5+ years |
| Wenatchee | Wenatchee | Mainstem (Dam Passage) | 4.3.1. **1-2** | *xT* | | | | | | | 1-3 years | 5+ years |
| | Icicle | Mainstem | 4.3.1. **4-6** | *xO, xC, xT* | | | | | | | 1-3 years | 5+ years |
| | Nason | Mainstem | | | | | 4.3.3 **4-6** | *xT, xC, xO* | | | 5+ years | 10+ years |
| | Chewawa | Mainstem | | | | | | | 4.3.1. **1, 4-5** | *xT, xO, xC* | Ongoing | 5+ years |
| | White | Mainstem | | | | | | | 4.3.1. **1, 4-5** | *xT, xO, xC* | 1-3 years | 5+ years |
| | Little Wenatchee | Mainstem | | | | | | | 4.3.1. **1, 4-5** | *xT, xO, xC* | 1-3 years | 5+ years |
| | Icicle | *Leavenworth National Fish Hatchery | | | 4.3.1. **1-3** | *xO, xH* | | | | | 1-3 years | 5+ years |
| | Wenatchee | *Wenatchee Fish Hatchery (Future Plan) | | | 4.3.1. **1-3** | *xO, xH* | | | | | 5+ years | 10+ years |
| Upper Columbia / Entiat | Entiat | Mainstem / Mad | | | | | | | 4.3.1. **1-6** | *All* | Ongoing | 5+ years |
| Methow | Methow | Mainstem / Lost | 4.3.1. **1-6** | *xO, xC, xT* | | | | | | | 1-3 years | 5+ years |
| | Twisp | Mainstem | | | | | 4.3.3 **4-6** | *xT, xC, xO* | | | 5+ years | 10+ years |
| | Chewuch | Mainstem | | | | | | | 4.3.1. **1, 2-4** | *xT, xO, xC* | Ongoing | 5+ years |
| | Methow | *Winthrop National Fish Hatchery | | | 4.3.1. **1-3** | *xO, xH* | | | | | 5+ years | 10+ years |
| Middle Columbia - Hood | Rock | Mainstem | | | | | | | 4.3.1. **4** | *xT, xO, xC* | 1-3 years | 5+ years |
| | Wind | Mainstem | | | | | | | 4.3.1. **4-6** | *xT, xO, xC* | 1-3 years | 5+ years |
| | White Salmon | Mainstem / Trout Lake | | | | | | | 4.3.1. **1, 4-6** | *xT, xO, xC* | Ongoing | 10+ years |
| Klickitat | Klickitat | Mainstem / Little Klickitat | | | | | | | 4.3.1. **1-6** | *All* | Ongoing | 10+ years |

*Indicates rearing in artificial settings

**Table 7. Pacific Lamprey Restoration Actions Table for the Yakima Subbasin.**

| ID # | Threats / Actions | Description of Actions | Subbasin / Watershed | Geographic Scale | Timing | Feasibility | Potential Funding Source | Implementing Entity |
|---|---|---|---|---|---|---|---|---|
| **Threat #1** | **Adult Migration** | | | | | | | |
| **Action 1.1** | **Passage Improvement** | initial focus (2013-2015) is on four lower dams (fix) and start assessments of upstream projects in near future. Also continue focus on radio telemetry to evaluate passage. | Lower Yakima (lower 4 dams), Upper Yakima (Roza Dam, Town Canal Dam) | **Point** | 2 release groups [summer (September) and spring (March)] to monitor movement year round | High | BOR / BPA / USACE | Yakama Nation / USFWS |
| **Action 1.2** | **Prevention of Canal Access** | Prevent adults from entering canal (both inlets & outlets), which could be a significant issue considering the high level of pheromone attraction steming from canal waters. | Lower Yakima, Upper Yakima, Naches?, Others? | **Point** | *future project - during spawning migration (March - October) | High | BOR | Yakama Nation / BOR |
| **Action 1.3** | **Lack of Information on Status and Trend** | Limited info exist on where the historical and existing Pacific lamprey population migrate to and spawn within the Yakima Basin. Take advantage of existing radio telemetry to study their current distribution. Historical info could be supplied from elder interviews. If adult usage is hard to confirm, larval presence could be used as an indicator for assessment as well. | Region-wide | **Region** | year round | High | BOR / BPA | Yakama Nation / USFWS |
| **Threat #2** | **Downstream Passage - Entrainment** | | | | | | | |

| ID # | Threats / Actions | Description of Actions | Subbasin / Watershed | Geographic Scale | Timing | Feasibility | Potential Funding Source | Implementing Entity |
|---|---|---|---|---|---|---|---|---|
| **Action 2.1** | **Determining New Screening Criteria for Larval/Juvenile Lamprey** | Support USGS in defining new lamprey screening criteria from laboratory research. | Region-wide | **Region** | year round (lab study) | High | BOR | Yakama Nation / USGS |
| **Action 2.2** | **Monitoring of Entrainment Impacts** | Continue canal surveys to document entrainment and implement new monitoring that showcase precisely how lamprey are being entrained ("when", "how", "where", etc.). Focus is on four lower dams at this time, but expand as needed. | Lower Yakima (lower 4 dams), Upper Yakima (Roza Dam, etc.), and diversions in supplementation sites (Ahtanum, Naches, Toppenish) | **Point** | winter (October - March) | High | BPA / BOR | Yakama Nation / BOR |
| **Action 2.3** | **Reduction of Dewatering Mortality Associated with Canals** | Identify ways to reduce mortality of lamprey during dewatering periods (desiccation & predation) | Lower Yakima (lower 4 dams), Upper Yakima (Roza Dam, etc.), and diversions in supplementation sites (Ahtanum, Naches, Toppenish) | **Point** | early winter (October - November) | High | BOR | Yakama Nation / BOR |
| **Action 2.4** | **Characterize Juvenile Out-Migration** | Use Chandler (Prosser) juvenile facility to help characterize juvenile migration. Thousands of macrophthalmia (juvenile) lamprey have been documented passing through this facility during winter months (January~February) and we could effectively estimate outmigration numbers using pit tagging and other methods. | Lower Yakima (Prosser Dam) | **Point** | late winter (January - March) | High | BPA / USACE | Yakama Nation |
| **Threat #3** | **Stream and Floodplain Degradation** | | | | | | | |

| ID # | Threats / Actions | Description of Actions | Subbasin / Watershed | Geographic Scale | Timing | Feasibility | Potential Funding Source | Implementing Entity |
|---|---|---|---|---|---|---|---|---|
| **Action 3.1** | **Restoring Natural Deposition of Fine Sediment and Organic Matter** | Reduce fine sediment & organic matter (food source) collection in canals OR find ways to transport fine sediment & organic matter back into the flowing rivers at the end or beginning of the irrigation season. Also, need to refute the current paradigm which asserts that fine sediment is detrimental to stream health (in fact they are vital to stream health. | Basin wide, but focusing on: Lower Yakima (lower 4 dams), Upper Yakima (Roza Dam), and diversions in supplementation sites (Ahtanum, Naches, Toppenish) | **Point** | *future project - pilot project in 2013 | Medium | BOR / SRFB | Yakama Nation |
| **Action 3.2** | **In-Channel Restoration** | Implementation of pilot in-channel restoration projects that focuses on restoring lamprey habitat & associated effectivness monitoring. For mainstem Yakima, restoration focusing on side channels may be most effective. | Lower Yakima (Wapato Reach), potentially in Taneum, Toppenish, Satus, and/or Ahtanum | **Watershed** | *future project - pilot project in 2013 | High | SRFB | Yakama Nation |
| **Action 3.3** | **Riparian/Floodplain Restoration** | Restoration of natural, functioning riparian, floodplain, and side channels is a plus, but hard to find specific remedies that can fix this at a large scale (beyond what has already been done for salmon restoration). However, including lamprey as a "target species" for riparian/floodplain restoration activities is plausible. | Lower Yakima (focus on Wapato reach) | **Region** | *future project - pilot project in 2013 | Medium | SRFB | Yakama Nation |

| ID # | Threats / Actions | Description of Actions | Subbasin / Watershed | Geographic Scale | Timing | Feasibility | Potential Funding Source | Implementing Entity |
|---|---|---|---|---|---|---|---|---|
| **Action 3.4** | **Inclusion into "Target Species" for Other Restoration Activities** | Include lamprey as a "target species" for various restoration activities, including SRFB, so that exisiting salmon restoration activities could further enhance lamprey habitat needs. | Region-wide | **Region** | *future project - start in 2013 | High | SRFB | Yakama Nation / USFWS |
| **Action 3.5** | **Lack of Information on Status and Trend** | Survey for larval lamprey in high potential habitat and conduct index surveys in key locations to determine status and trend within the basin. These surveys will also aid evaluation of adult passage and effectiveness monitoring from supplementation activities. | Region-wide | **Region** | summer (June - Octoboer) | High | BPA | Yakama Nation / USFWS |
| **Threat #4** | **Water Quality - Temperature** | | | | | | | |
| **Action 4.1** | **Monitoring of Larval Survival in High Temperature Conditions** | Continue to document presence / absence in high water temperature reaches (to find temperature thresholds for survival). High temperature is a known problem, but remedy is difficult to find. | Lower Yakima (mainstem, lower Toppenish, lower Ahtanum, etc.), Upper Yakima (lower Wenas) | **Watershed** | summer (June - August) | High | BPA | Yakama Nation / USFWS |
| **Action 4.2** | **Monitoring of Flow Management on Thermal Dynamics during Spawning Season** | "Flip Flop" flow management can affect thermal dynamics of the river and considering that this happens during the spawning season (most critical period), it is important to understand the potential impact of this. | Upper Yakima & Naches | **Subbasin** | *future project - spring - summer (May - July) | Medium | BOR | Yakama Nation |
| **Threat #5** | **Water Quality - Contaminants & Chemistry (DO, BOD, pH etc)** | | | | | | BOR | Yakama Nation |

| ID # | Threats / Actions | Description of Actions | Subbasin / Watershed | Geographic Scale | Timing | Feasibility | Potential Funding Source | Implementing Entity |
|---|---|---|---|---|---|---|---|---|
| **Action 5.1** | **Monitoring of Water Chemistry Effects** | No known existing threat (limited monitoring currently), but beneficial to at least monitor conditions in art. prop. / translocation areas to document potential influence | Focusing on supplementation sites | **Watershed** | summer (June - July) | Medium | BOR | Yakama Nation |
| **Action 5.2** | **Monitoring of Contaminants Effects** | Monitor areas that are more heavily contaminated (usually lower in the River) and document the effects on Pacific lamprey (at all life stages) | Lower Yakima (Prosser), Toppenish, Ahtanum, Naches, Satus, Lower Wenas | **Watershed** | summer (June - july -> in 2012, it was collected in late October and early November to capture samples from canals) | High | BOR | Yakama Nation / USGS |
| **Threat #6** | **Water Quantity - Dewatering and Stream Flow Management** | | | | | | | |
| **Action 6.1** | **Minimize Flow Management Impacts** | Find solutions to ameliorate impacts from "Flip Flop" (flow management that balance water between Upper Yakima and Naches reservoirs). This happens during summer which coincides with the migration, spawning, and egg hatching period, which is a critical period for lamprey. | Upper Yakima & Naches | **Subbasin** | summer (May - September) | Medium | BOR | Yakama Nation |
| **Threat #7** | **Predation** | | | | | | | |
| **Action 7.1** | **Predation Reduction** | Support projects (such as salmon related ones) that reduce the abundance of predacious and/or invasive species that prey on juvenile, larval lamprey at a rate much higher than the historical background rates. | Lower Yakima (lower 4 dams), and expanding as needed | **Point** | *future project - year round (as opportunity arise) | Medium | BPA / BOR | Yakama Nation |

| ID # | Threats / Actions | Description of Actions | Subbasin / Watershed | Geographic Scale | Timing | Feasibility | Potential Funding Source | Implementing Entity |
|---|---|---|---|---|---|---|---|---|
| **Action 7.2** | **Providing Refuge in Areas of High Predation** | Provide overwintering / refuge habitat to reduce predation risks for adults | Lower Yakima (lower 4 dams), and expanding as needed | **Point** | *future project | Medium | BPA / BOR | Yakama Nation |
| **Threat #8** | **Disease** | | | | | | | |
| **Action 8.1** | **Disease Monitoring** | Work in conjunction with fish pathologists during the process of art prop. and translocation activities. | Lamprey holding facilities (Prosser Hatchery, etc.) | **Point** | year round (at the hatchery) | High | BPA | Yakama Nation / USFWS |
| **Threat #9** | **Harvest** | | | | | | | |
| **Action 9.1** | **Harvest Monitoring** | As far as we know, no harvest is taking place within the Yakima Basin currently, but ammocoete harvest (for use as a fish bait) may be taking place in some places | Region-wide | **Watershed** | *future project - year round | Medium | BPA / WDFW | Yakama Nation / WDFW |
| **Threat #10** | **Lack of Awareness** | | | | | | | |
| **Action 10.1** | **Outreach and Education** | Outreach activities through student / community events. | Region-wide | **Region** | year round | High | BPA / BOR | Yakama Nation / USFWS |
| **Action 10.2** | **Community Involvement in Restoration** | Student / community involvement during restoration activities. As a result of translocation and art. prop supplementation projects, there will be many opportunities to involve local students in these activities (fish release, monitoring, etc.) | Lower Yakima (Wapato k-12), Toppenish (White Swan / Harrah / Toppenish k- 12), Ahtanum (La Salles, West Valley, Ahtanum k-12), Naches (Naches k-12), Taneum (Thorp k-12), Cle Elum (Cle Elum k-12), Wenas (Selah k-12) | **Subbasin** | year round | Medium | BPA / BOR | Yakama Nation |

| ID # | Threats / Actions | Description of Actions | Subbasin / Watershed | Geographic Scale | Timing | Feasibility | Potential Funding Source | Implementing Entity |
|---|---|---|---|---|---|---|---|---|
| **Action 10.3** | **Larval Lamprey in Classrooms** | Lamprey (larval) in the classroom using aquarium tanks, etc. Providing more chances for students to have hands-on experiences with lamprey will greatly enhance awareness of lamprey (and potentially how they decide to interact with lamprey in the future in whatever careers they choose. | Lower Yakima (Wapato k-12), Toppenish (White Swan / Harrah / Toppenish k- 12), Ahtanum (La Salles, West Valley, Ahtanum k-12), Naches (Naches k-12), Taneum (Thorp k-12), Cle Elum (Cle Elum k-12), Wenas (Selah k-12) | **Subbasin** | *future project - year round except summer months (September - June) | High | USFWS / BPA / BOR | Yakama Nation |
| **Threat #11** | **Climate Change** | | | | | | | |
| **Action 11.1** | **Assessing Climate Change Impacts on Species Distribution** | Assess climate change impacts (in terms of temperature and flow dynamics, etc.) within the Yakima Basin to further our understanding on how that may affect future lamprey distribution within the basin. | Lower Yakima (mainstem, lower Toppenish, lower Ahtanum, etc.), Upper Yakima (lower Wenas) | **Region** | *future project | Low | BPA | Yakama Nation |

**Summary Analysis of Existing Lamprey Propagation/Rearing Facilities Within the Yakima Subbasin**

| Assessment Unit | Site | Location | Owner | Current Use | Available Resources | Facility Features | Monitoring Opportunities | Other Benefits | Potential Concerns |
|---|---|---|---|---|---|---|---|---|---|
| Upper Yakima | Cle Elum Hatchery | Yakima River Rkm 303.0 | Yakama Nation | Spring Chinook rearing | Existing raceways not being utilized, spawning channel, natural side channel for potential rearing | Water temperature modulation, high water quality | Propagation; rearing and feeding of larvae; Tests on adult and juvenile fish behavior | Located high in the watershed, good rearing habitat available in adjacent side channel, potential source of pheromone attraction into prime spawning reach | Potential interactions between spring Chinook and lamprey. |
| | Holmes Acclimation Ponds | Yakima River Rkm 260.7 | Yakama Nation | Floodplain mitigation – pasture, residence | Currently being developed for coho program and has both spawning channels and rearing ponds | 50 ac land area. Potential 12.6 ac available for facility development, approx. 4 ac wetland/floodplain meander scroll | Test rearing potential of salmon acclimation ponds; spawning recruitment relationship | Water rights on property acquired. Grant applications suggested water is to go to instream flow. Convert some to fish production? | Can coho and lamprey program goals both be achieved at this location? |
| Lower Yakima | Marion Drain | Yakima River Rkm 134.4 | Yakama Nation | None | Current design includes construction of buildings and ponds for lamprey propagation program | Existing well water on site, infiltration gallery proposed | Collection of macropthalmia and returning adults | Potential for rearing in adjacent riverine wetland areas; proximal to Yakama Nation office | Potential attraction of adults towards Marion Drain; requires investment and development of infrastructure. |
| | Prosser Hatchery | Yakima River Rkm 74.4 | Yakama Nation | Kelt re-conditioning, Spring/ Summer/Fall Chinook, Coho | Adequate space to implement proposed upgrades for lamprey propagation; existing spawning channel; sediment pond available for rearing; experienced staff on site | Surface and well water | Propagation; rearing and feeding of larvae; Tests on adult and juvenile fish behavior; effects of contaminants | High water quality; efficiency - potential to re-use sturgeon water; adjacent stream potentially available for modification as rearing habitat | Low in watershed; lack of good spawning and rearing habitat in immediate vicinity |
| | Yakima Groundwater Recharge Channel | Yakima River Rkm 182.4 | City of Yakima | None | City of Yakima is studying feasibility of running treated water from a treatment facility into a constructed channel for groundwater recharge | Surface water (through inlet) | Test rearing potential of restored side channels | Great pilot site to assess survival/movement over multiple years | Can lamprey survive year round in the restored side channel? |

# Appendix E. Workshop Information

| Date | Location | Participants | Meeting | Conference call |
|---|---|---|---|---|
| December 3-4, 2012 | Yakima, WA | BPA, CRITFC, WDFW, HDR Engineering, GeoEngineers | X | |
| December 10, 2012 | Walla Walla, WA | NPT, CTUIR, HDR Engineering, CRITFC, GeoEngineers | X | |
| January 22, 2013 | | CRITFC, BOA, USFWS, BioAnalysts, HDR Engineering, CTUIR, WDFW, WS, NOAA, YN, USACE, ODFW | | X |
| January 29, 2013 | Portland, OR | CRITFC, BOA, USFWS, BioAnalysts, HDR Engineering, CTUIR, WDFW, WS, NOAA, YN, USACE, ODFW | X | |
| March 14-15, 2013 | | CRITFC, YN, CTUIR, NPT, HDR Engineering, GeoEngineers | | X |
| June 18, 2013 | Portland, OR | CRITFC, CTUIR, NOAA | X | |
| August 16, 2013 | | CTUIR, NPT, YN, CRITFC, HDR Engineering | | X |
| September 5, 2013 | | CTUIR, NPT, YN, CRITFC, HDR Engineering, GeoEngineers | | X |
| October 8, 2013 | Portland, OR | CTUIR, NPT, YN, CRITFC, ODFW, IDFG, WDFW | X | |
| January 23, 2014 | Portland, OR | HDR Engineering, CRITFC | X | |
| February 4, 2014 | | GeoEngineers, CTUIR | | X |
| February, 11, 2014 | | CTUIR, NPT, YN, CRITFC, HDR | | X |