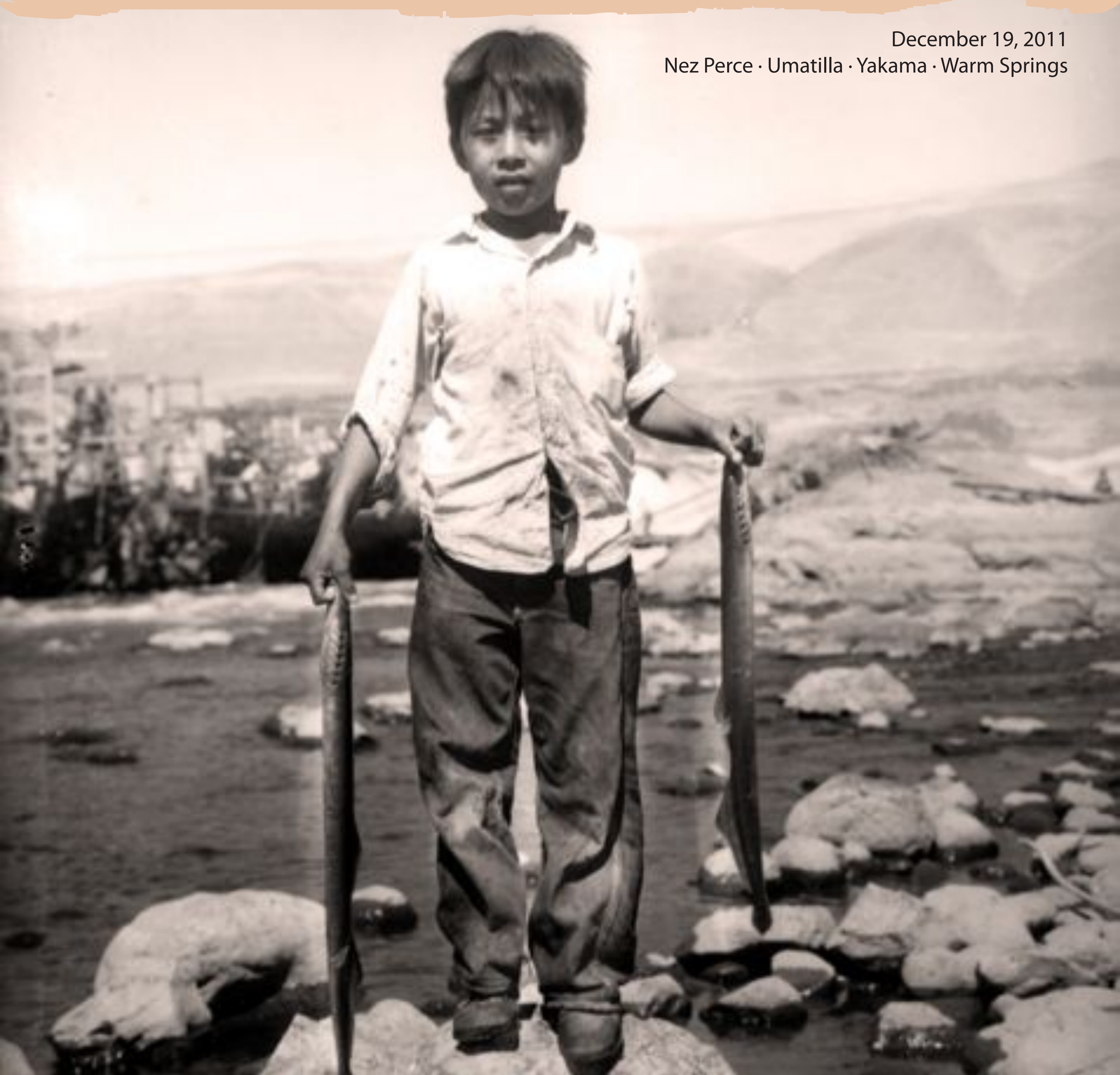
Tribal Pacific Lamprey Restoration Plan

for the Columbia River Basin

Columbia River
Inter-Tribal Fish
Commission

December 19, 2011
Nez Perce · Umatilla · Yakama · Warm Springs



Acknowledgements

This *Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin* (Plan) is a product of the efforts of many tribal and non-tribal biologists, policy representatives, and independent scientists throughout the Pacific Northwest. The tribes acknowledge the collective contributions of many that offered their time and expertise to improve this tribal plan. In particular, we thank Casey Justice and Starla Roels for their extensive review of the Plan.

The Plan addresses many regional comments on the draft tribal lamprey restoration plan from tribes, public utilities, federal, state and county agencies, independent scientists and the general public. These comments have greatly improved this Plan.

This Plan is a living document that will be periodically updated as new information becomes available through adaptive management practices.

Figure 1. Pacific lamprey spawning in an Idaho tributary.

Executive Summary

The Creator told the people that the eels would always return as long as the people took care of them, but if the people failed to take care of them, they would disappear.
—Ron Suppah, Vice Chair, Warm Springs Tribes

Pacific lamprey (*Lampetra tridentata*) abundance and distribution in the Columbia River basin and throughout the Pacific Northwest is declining precipitously, bringing the species dangerously close to regional extinction. The loss of lamprey, the basin's most ancient and foundational species, is jeopardizing the ecological balance in the basin. Populations continue to decline despite or, in some cases, due to measures taken to protect and restore salmonid species. Counts of adult Pacific lamprey at Bonneville dam have declined from an estimated 1,000,000 in the 1960's and 1970's to approximately 20,000 in current years. In the 1960's and 1970's total Bonneville Dam counts were estimated at 1,000,000 million adults, but in the last three years total Bonneville Dam counts number only about 20,000 adults. The plight of the Pacific lamprey has garnered some attention, but limited effective action.

Pacific lamprey are just as important to tribal peoples as salmon. For over 10,000 years the people of the Nez Perce, Umatilla, Yakama and Warm Springs tribes depended on lamprey (commonly referred to as "eels"), salmon, roots and berries. The tribal people used the eel for food and medicine, and many stories and legends surrounding the eel were passed down from generation to generation. Before the construction The Dalles Dam in 1957, the river at Celilo Falls was often black with eels. Tribal members took just what their families needed for a year. Eels were plentiful in many Columbia basin waters including the Walla Walla River, Asotin Creek, Clearwater River tributaries, the South Fork of the Salmon River, Swan Falls, the upper portions of the Yakima River and the tributaries of the upper Columbia.

Now many of these great rivers have no eels or at best remnant numbers. The eel has nearly vanished from tribal longhouse tables. As eels disappear, younger tribal members are losing their elders' collective memory for the species and the culture that surrounds the eel.

The tribes propose this Plan for the restoration of Pacific lamprey in the Columbia River basin to numbers adequate for the basin's ecological health and tribal cultural use. The tribes believe aggressive action must be taken now, despite gaps of information about the species' life history and population dynamics.

The goals of the plan are to immediately halt the decline of Pacific lamprey and ultimately restore them throughout their historic range in numbers that provide for ecological integrity and sustainable tribal harvest. The objectives of this Plan include addressing key uncertainties and identified threats with focused and expedited actions.

Mainstem Passage

Achieving substantive successful improvements in dam passage efficiencies and survival is of primary importance as only about 50% of adult lamprey successfully pass a single dam. Evidence also exists that thousands of juvenile lamprey are likely lost either directly or indirectly at various dam systems such as turbine cooling strainers, trashracks and dam screen-bypass systems designed for salmon but not lamprey. Other known impact areas include excessive bird, fish and marine mammal predation at dam outfalls, forebays and tailrace areas below powerhouses. Improving dam passage and survival in a timely manner requires a set of operational and structural modifications to all existing dams to accommodate adult lamprey passage. These modifications are possible, critical and should be undertaken immediately. They include the use of 24-hour adult counting, installation of lamprey passage systems, modifying existing fishway structures to prevent trapping, reducing velocity barriers, and reducing and/or eliminating juvenile impingement and mortality on screens and various bypass system components.

Tributary Passage

Another key factor limiting lamprey productivity in certain portions of the Columbia River basin is poor tributary passage. Screens at irrigation and municipal diversions are either lacking or cause juvenile lamprey impingement or entrainment and passage into blocked areas causing mortality. Dams in tributaries also inhibit both juvenile and adult access to spawning, rearing and migratory habitat. Lamprey passage structures (LPS) should continue to be developed, installed and evaluated to improve adult passage. The Plan recommends development and installation of devices to prevent entrainment of juveniles into irrigation canals and tributary water diversion. Effective juvenile and adult tagging technology should continue to be implemented to evaluate and resolve tributary passage problems.

Habitat

Improving tributary, mainstem and estuarine habitat for lamprey ammocoetes and macropthalmia is also important. Restoration of a more natural peaking hydrograph that will aid migration and enhance habitat quantity and quality is an essential action under this objective. Floodplain restoration actions taken to improve salmon habitat, such as establishing conservation easements, are likely beneficial for lamprey and should continue to be accelerated as a priority. This Plan contains and appendix with each tribe's ceded area plan for achieving habitat objectives within each tributary. Additionally, key uncertainties and limiting factors in the marine environment with respect to lamprey migration, habitat, distribution and predator/prey relationships require focused research.

Supplementation/Augmentation

Considering the rapidly declining adult lamprey numbers, especially in the interior basin watersheds, and the existing passage problems and other threats that may take decades to resolve, natural recolonization and restoration will not be enough to halt the lamprey's decline. The likely relationship of adult lamprey attraction to juvenile lamprey pheromones also supports the Plan's recommended use of multiple management strategies including translocation, propagation, reintroduction and supplementation/augmentation for short and long-term preservation of this species in the Columbia basin. The Plan emphasizes actively and carefully developing a regional supplementation/augmentation plan containing translocation and artificial propagation protocols, while concurrently developing pilot aquaculture facilities.

Contaminants and Water Quality

Until recently, the role of legacy and emerging contaminants as a threat to lamprey has been largely disregarded. Emerging data from tribal and other studies worldwide indicate that lamprey carry excessive concentrations of toxins and that these may pose a significant threat to their survival and productivity. Additional work is needed in this area to further define the effects of toxins to lamprey life histories and productivity. Actions are needed to improve water quality and reduce contaminant loading into lamprey habitats.

Outreach and Education

A chief challenge requires educating and mobilizing agencies, institutions and individual citizens in the restoration effort. Implementation of the Plan cannot succeed without consistent, coordinated public education and outreach programs to communicate: 1) the plight of lamprey and its vital role in the ecosystem, 2) the need for public infrastructure investments at all government levels for restoration actions and 3) the consequences of failing to act.

Research, Monitoring and Evaluation

There must be a basin-wide, coordinated effort to continue to fund and implement restoration actions while conducting priority research, monitoring and evaluation on all lamprey life history phases. This effort must include and integrate marine and climate change investigations. Prioritization and implementation of research projects is important and results need to be transparent and widely accessible.

Regional Coordination and Collaboration

The extreme challenge to restoring Pacific lamprey in the Columbia River basin is that little is known about many important variables affecting lamprey life history. The severe decline in lamprey abundance demands *urgent* actions to prevent further declines and the possible local extirpation of lamprey from much of their historic range. To address this challenge, this Plan's objectives address lamprey critical uncertainties through collaboration and cooperation with other regional entities, such as the U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Geological Survey, Environmental Protection Agency, the Bureau of Reclamation and several universities. Wherever possible, implementation of Plan actions will take advantage of collaborative cost sharing.

Plan objectives also contain specific actions to address known limiting factors and threats such as impaired adult passage at mainstem dams and juvenile impingement on irrigation screens. This dual strategy of addressing critical uncertainties through research, monitoring and evaluation while taking immediate action to address known threats is being successfully implemented in other countries for other similar species, such as the Arctic lamprey in Japan and the American eel in Canada. In this regard, the tribes will provide regional leadership. When policy makers, technical experts or implementers differ on restoration approaches and actions, dispute resolution must be timely so that progress is not stalled. The Pacific lamprey has been neglected and ignored for too long. There is no time to waste. *The time to act is now.*

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1 Introduction

The lamprey is our elder, without him the circle of life is broken.
—Elmer Crow Jr., Vice Chair, Nez Perce Fish and Wildlife Committee

The Pacific lamprey (*Lampetra tridentata)* or "eel" is an ancient, anadromous native species that is in steep and widespread decline throughout the Columbia River basin and the Pacific Coast from California to Alaska (USFWS 2011). One of three lamprey species in the Columbia River basin, Pacific lamprey are the most important to the tribes of the Pacific Northwest (Close et al. 2002) and an important ecological component of the region (Close 1995; Stansell 2006). (A photograph of a Pacific lamprey is shown in Figure 1.)

Once abundant with Pacific lamprey, most Columbia basin rivers now have few or none. Like other lamprey throughout the world, the Pacific lamprey's decline in abundance appears to be primarily due to anthropogenic change which includes the construction of hydroelectric and flood control dams, irrigation and municipal water diversions, habitat degradation and loss, poor water quality, excessive predation, and contaminants and targeted chemical eradication (Close et al. 2005; USFWS 2011). Of the 34 lamprey (Petromyzontidae) species, worldwide, approximately half are endangered (Renaud 1997). Renaud (1997) and Masters et al. (2006) reported the likely causes were pollution, regulation and diversion of streams, and over-harvest. In addition, access to much of the Columbia basin historic spawning and freshwater rearing habitat of Pacific lamprey has been blocked by a variety of obstacles including numerous mainstem and tributary dams.

The apparent decline of Pacific lamprey has not gone unnoticed. In 1993, Oregon listed Pacific lamprey as a state sensitive species and gave them further legal protection in 1997 (OAR 635-044-0130; Kostow 2002). In Idaho, lamprey were classified as an endangered species in 1993 (IAC 2011). In Washington state, lamprey have been placed in a monitoring status, the lowest threat level of the state's "species of concern" list. In 1994, after a precipitous decline in population numbers over 20 years, the United States Fish and Wildlife Service (USFWS) designated the species for listing as a Candidate 2 under the Endangered Species Act. In their 1994 Fish and Wildlife Program, the Northwest Power and Conservation Council (NPCC) noted the lamprey decline in the Columbia basin and called for a status report (Close et al. 1995). The Oregon Natural Resources Council petitioned the USFWS to list the species under the Endangered Species Act (ESA) in 2002 (Nawa 2003).

The USFWS denied consideration of the petition in 2004, citing that the petition did not present substantial scientific or commercial information to indicate the listing was warranted. Repeatedly the USFWS has noted the lack of information regarding the status and distribution of Pacific lamprey. Nonetheless, the USFWS has remained open to submission of new information concerning threats to lamprey and the status of the species, stating that this information would help them monitor and encourage conservation of the species. In 2008, the USFWS presented a "range wide conservation initiative" intended to bring focus on lamprey restoration, which resulted in the completion of the Pacific Lamprey (*Entosphenus tridentatus)* Assessment and Template for Conservation Measures (Assessment; USFWS 2011). This recent USFWS assessment incorporated many elements from the 2008 draft Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. In turn, this Plan has considered and incorporated, where appropriate, elements of the USFWS Assessment (2011).

Native American tribes revere Pacific lamprey for cultural, spiritual, ceremonial, medicinal, subsistence and ecological values. In part, due to their unfortunate association with the invasive Great Lakes sea lamprey (*Petromyzon marinus*) in addition to a limited understanding of the ecological and cultural importance of Pacific lamprey in the Columbia basin, these fish have long suffered a negative image among non-tribal peoples. The Columbia River Inter-Tribal Fish Commission's (CRITFC) member tribes—Nez Perce, Umatilla, Warm Springs and Yakama—recognize and stress that Pacific lamprey are an important part of the ecosystem contributing to food web dynamics, acting as a predator buffer for salmon and contributing important marine nutrients to inherently nutrient-poor watersheds. The tribes believe that eels are fundamentally important and linked to the ecological health of the Columbia basin in a similar manner as salmon and steelhead.

From a tribal perspective, the decline of lamprey has at least three negative effects (Close et al. 2002; Close et al. 2009; Crow 2011 pers. comm.). These include:

- Loss of lamprey from the ecological circle and the tribal way of life. The tribes consider the lamprey as their sacred elder and without them the circle of life is unbalanced.
- Loss of cultural heritage, especially for young tribal members—many have never even seen a lamprey. As a consequence of declining harvest within interior Columbia River tributaries, many young tribal members have not learned how to harvest and prepare lamprey and are losing historically important legends associated with these fish.
- Loss of fishing opportunities in traditional fishing areas. Among other things tribal members are forced to travel long distances to lower Columbia River tributaries, such as the Willamette River, for severely limited lamprey harvest opportunities.

In 1855 CRITFC's member tribes relinquished millions of acres of Columbia basin lands in treaties to the United States but retained their rights to fish at "usual and accustomed places" on both their reservations and their ceded lands (Figure 2). Fishing rights were not limited to salmon and steelhead but included lamprey, sturgeon and other species.

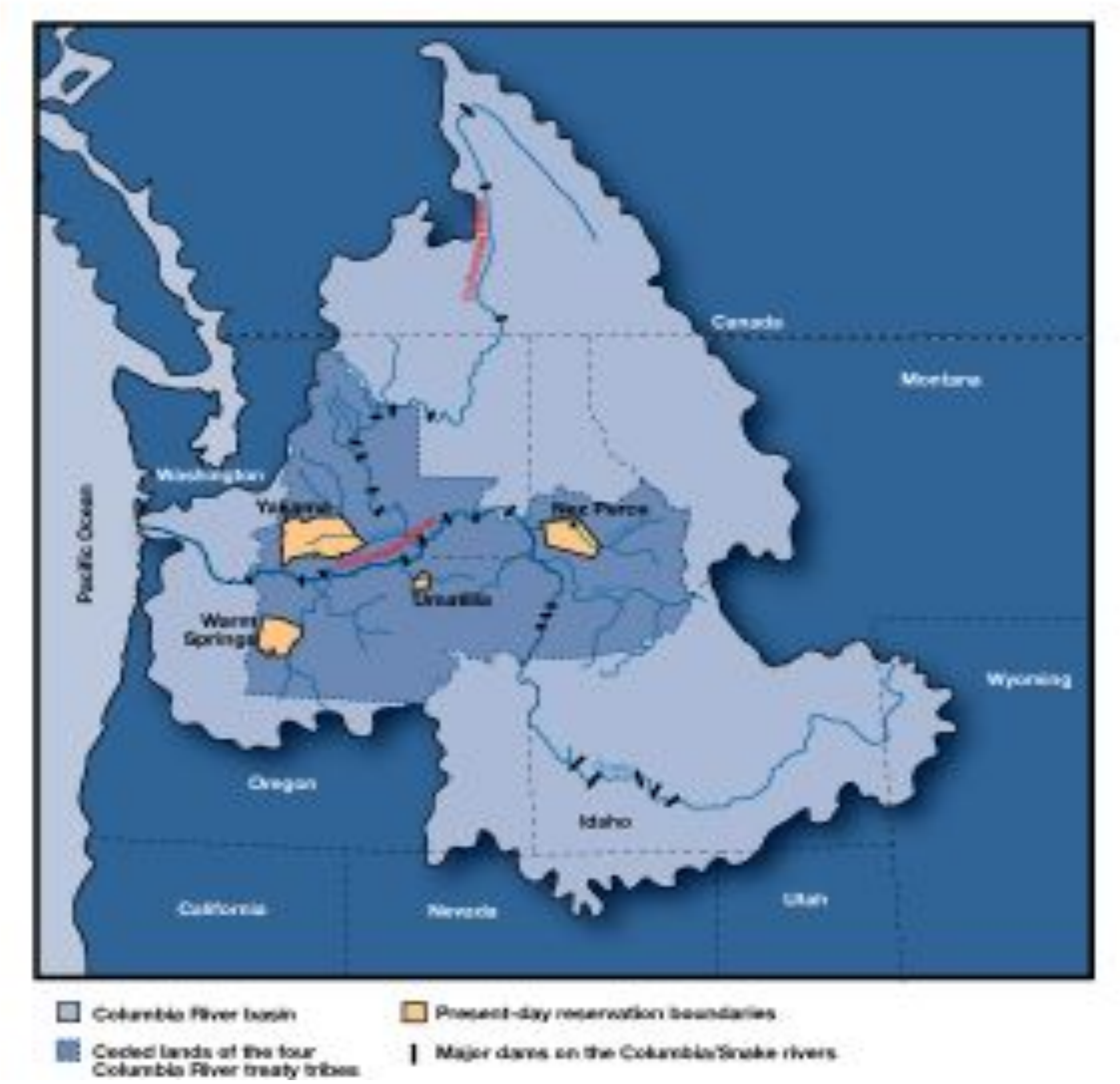

Figure 2. Columbia basin showing historical tribal ceded lands, current reservation boundaries and major federal and FERC-licensed dams affecting Pacific lamprey.

To the four Columbia River Treaty Tribes, restoration of lamprey populations is as necessary to the restoration of the ecological health of the Columbia River and its tributaries as are salmon and other native fish populations. In the Columbia River treaty tribes' anadromous fish restoration plan, *Wy-Kan-Ush-Mi Wa-Kish-Wit* (Nez Perce et al. 1995), the tribes' objectives were to halt the declining trends in salmon, sturgeon and lamprey populations originating upstream of Bonneville Dam in seven years and to increase Pacific lamprey populations to naturally sustainable levels within 25 years to support tribal harvest opportunities.

Firm substantive commitments to restore Pacific lamprey are crucial. In 2004, CRITFC and its member tribes sponsored a Tribal Regional Lamprey Summit to focus attention on the severe decline of lamprey and to identify factors and critical uncertainties contributing to these declines. Tribal elders and researchers briefed representatives of federal and state agencies about the importance and current status of lamprey, which resulted in a consensus to take immediate action to restore lamprey. However, since the conclusion of this summit, Columbia River lamprey populations have continued to decline. Currently, only a few dozen adults manage to migrate past the uppermost dams on the Columbia and Snake rivers where forty years ago, before the series of dams were completed on the Snake and Upper Columbia reaches, tens of thousands may have migrated to these areas. Unless effective actions are taken immediately, the risk of local extirpation of lamprey from vast traditional tribal fishing areas is extremely high.

Since the 2004 Tribal Regional Lamprey Summit, some restoration actions have been implemented within the Columbia River basin. For example, the U.S. Army Corps of Engineers (USACE or Corps) and Grant PUD have implemented structural and operational modifications at adult fishways to improve adult lamprey passage. In addition, for some tributaries, the U.S. Bureau of Reclamation (BOR) has funded construction of passage systems and has assisted the tribes in conducting inventories of problem passage areas.

Several important initiatives have been undertaken and completed in recent years aimed at restoration of Pacific lamprey in the Columbia River basin. For example, in 2005, the Columbia Basin Fish and Wildlife Authority's (CBFWA) Columbia River Basin Lamprey Technical Working Group (CRBLTWG) listed a number of critical uncertainties regarding lamprey conservation (CRBLTWG 2005). In 2008, CBFWA submitted comments to the Northwest Power and Planning Commission that identified the severe downward trend in Columbia River lamprey populations and recommended nine specific strategies and a set of detailed implementation measures to reverse the decline (CRBLTWG 2008). In 2008, CRITFC and its member tribes completed the draft Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin and held a second regional Tribal Lamprey Summit to present the draft Plan and to seek regional support in implementing plan actions. Further, in 2008 the USFWS sponsored a Conservation Initiative designed to "…facilitate communication and coordination relative to the conservation of Pacific lamprey throughout their range" from Mexico to Alaska (Luzier et al. 2009)

These efforts by the USFWS were followed by the release of 1) *Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (Entosphenus tridentatus)* (USFWS 2010) and, 2) *Pacific Lamprey (Entosphenus tridentatus) Assessment and Template for Conservation Measures* (USFWS 2011). These documents outline the current distribution and abundance of lamprey populations, identified threats and factors for decline, and developed future research, monitoring and evaluation needs for lamprey throughout their Pacific Northwest historical range.

In addition, in 2009 the Corps developed a 10-year passage plan (USACE 2009) for lamprey as called for under the 2008 Fish Accords between CRITFC and three of CRITFC's member tribes, the Corps, Bonneville Power Administration (BPA) and the BOR. Through the Accords, BPA provided funding for CRITFC and three of its member tribes for lamprey restoration projects (MOA 2008). In 2010, the BOR issued a *Draft Assessment of U.S. Bureau of Reclamation Projects in the Columbia River Basin: Effects on Pacific Lamprey (Lampetra tridentata)*. This report focused on inventories of water diversion projects and potential lamprey impacts from these projects (BOR 2010). Many of the elements of these actions and plans have been incorporated into this tribal lamprey restoration plan.

The tribes applaud these and other efforts and are committed to their success. However, the tribes also recognize and continue to advocate that the lamprey's current dilemma demands a heightened level of political will and a change in institutional priorities, in addition to technical innovation to realize timely and cost-effective implementation of critical actions.

The tribes believe making necessary improvements at basin mainstem hydroelectric projects, resolving biological uncertainties and improving lamprey productivity throughout the Columbia basin will require regionally coordinated efforts from tribes, federal and state fishery agencies and closely coordinated funding contributions from federal and private/public hydro projects licensed under the Federal Energy Regulatory Commission (FERC).

The Tribal Pacific Lamprey Restoration Plan is a call to action. The rapid declines in lamprey populations must challenge resource managers to accelerate coordination and collaboration, both in terms of establishing priorities and in acquiring necessary funding. While regional initiatives are being developed and adopted, substantive actions based on current knowledge must be implemented immediately to prevent the impending loss of Pacific lamprey across its remaining range within the Columbia basin.

The goal of this Plan is to immediately halt Pacific lamprey decline and ultimately restore lamprey throughout their historic range to levels that support their unique cultural and ecological values. The Plan objectives provide an explicit and timely path to address critical uncertainties, threats and limiting factors while implementing specific restoration actions that can be implemented in the next seven years and beyond for both the mainstem Columbia and Snake rivers and associated tributaries.

While the Plan's time line focuses on the next seven years, actions must be taken immediately. As one tribal fisheries manager put it, "For some of us our seven years was up ten years ago." The tribes strongly encourage the region to collaboratively engage in further development and implementation of this *Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin*.

Now is the time to take action.

2 Plan Vision and Goals

Plan Vision:	Pacific lamprey are widely distributed within the Columbia River basin in numbers that fully provide for ecological, tribal cultural and harvest values.
Plan Goal:	Immediately halt population declines and prevent additional extirpation in tributaries. Reestablish lamprey as a fundamental component of the ecosystem. Restore Pacific lamprey to sustainable, harvestable levels throughout the historical range and in all tribal usual and accustomed areas.
Numeric Goals:	**Columbia River Basin**
	2012 - Halt decline
	2020 - 200,000 adults (based on 2002–2003 Bonneville Dam counts)
	2035 - 1,000,000 adults (from 1950s–1960s Bonneville Dam counts)
	2050 - Restore lamprey to sustainable, harvestable levels throughout their historic range

3 Background

3.1 Ecological Significance

Salmon restoration may not be possible without lamprey restoration.
— Charlie Corriano, Oregon Department of Fish and Wildlife

Biodiversity must be sustained simply because humans have a moral obligation to ensure the natural, evolutionary existence of species and ecosystems whose values do not depend on their human usefulness.
— Winter and Hughes 1996

Evidence suggests that Pacific lamprey, in existence for over 500 million years, are one of the foundational species of the Columbia basin, and have set the ecological stage for development of the basin's native freshwater fish community (Brown et al. 2009). The U.S. Environmental Protection Agency's (USEPA) Science Advisory Board has listed loss of biodiversity as one of the four greatest risks to natural ecology and human wellbeing (USEPA 1990). Current losses in global species diversity are similar to those that define boundaries between geological eras when massive alterations in the Earth's biota occurred. Biological diversity, or biodiversity, can be defined as "the variety of life and its processes" (USDOI and USDA 1992). The potential loss of Pacific lamprey to Columbia basin biodiversity threatens the basin's ecological framework.

As with the American eel (*Anguilla rostrata),* Pacific lamprey are a significant contributor to the nutrient supply in oligotrophic streams of the basin as adults die after spawning and their carcasses are a key contribution to the aquatic and terrestrial food web (Beamish 1980; MacGregor et al. 2010; Brown et al. 2009).

Juvenile lamprey are filter feeders, and as such, contribute to cleaning algae and sediment from rocks in streams and riparian areas, preparing these habitat for successful production of other aquatic biota (Crow pers. comm. 2010; Brown et al. 2009).

From the perspective of a predatory sea mammal, bird or fish, lamprey have at least three virtues: 1) they are easier to capture than adult salmon, 2) they are higher in caloric value per unit weight than salmonids and 3) they migrate in schools. Pacific lamprey are extraordinarily rich in fats, much richer than salmon. Caloric values for lamprey ranges from 5.92–6.34 kcal/gm wet weight (Whyte et al. 1993) whereas salmon average 1.26–2.87 kcal/gm wet weight (Stewart et al. 1983).

Due to these desirable traits, Pacific lamprey have been shown to be a high value prey item for a variety of organisms. Roffe and Mate (1984) noted that Pacific lamprey were the most abundant food item for seals and sea lions, while Beamish (1980) reported that spiny dogfish and sablefish fed actively on adult lamprey. Close et al. (1995) suggested that lamprey are an important buffer from marine mammal predation for upstream migrating adult salmon and as a result of dwindling lamprey stocks, marine mammal predation on salmonids may be more severe. Merrell (1959) found that juvenile lamprey were 71% by volume of the diet of gulls and terns below McNary Dam. Larval stages and spawned out carcasses of lamprey were important dietary items for white sturgeon in the Snake and Fraser rivers (Witty pers. comm. 2002; Galbreath 1979; Semkula and Larsen 1968). In addition, juvenile lamprey have been found in the diets of northern pike minnow *(Ptychocheilus oregonensis)* and channel catfish *(Ictalurus punctatus)* in the Snake River system (Poe et al. 1991). Pfeiffer and Pletcher (1964) found salmonid fry were eating emergent ammocoetes and lamprey eggs.

3.2 Cultural Context

The eel was part of the July feast…because along with the salmon…this is what our older people tell us…that when the time began the foods were created. The foods were here before us…and they said that the foods made a promise on how they would take care of us as Indians, and the eels was one of those who made a promise to take care of us.
—Umatilla Tribal elder

The natural resource missions of CRITFC's member tribes focus on protection and enhancement of "First Foods" such as water, salmon, deer, cous root, huckleberry and lamprey. These foods are central to the perpetual cultural, economic and sovereign benefit of the tribes. Salmon are not the only first food fish. Lamprey or eels are also considered as a first food and are served at tribal longhouse ceremonies when they are available. The First Food serving ritual in the longhouse reminds people of the promise the foods made to the people and the people's reciprocal responsibility to respectfully use and take care of the foods (Jones et al. 2008). As demonstrated by the declining Columbia basin lamprey population, humans have failed to carry out this reciprocal responsibility, thus the tribes' culture and way of life has been greatly affected.

The tribes adamantly desire to restore healthy abundant lamprey fisheries at all of the tribes' usual and accustomed fishing areas recognized by treaties with the United States. Since time immemorial, lamprey have been of great importance to American Indian tribes of the Pacific Northwest (Close et al. 1995; Close and Jackson 2001). Indigenous peoples from the coast to the interior Columbia and Snake rivers harvested lamprey for subsistence, religious, medicinal and spiritual purposes for many generations (Close et al. 1995). Harvesting lamprey for ceremonial and subsistence use has been and is critically important to the four CRITFC member tribes. Tribal people of CRITFC's member tribes traditionally harvested lamprey in the mainstem Columbia and Snake rivers and their tributaries, harvesting enough at Celilo and Willamette Falls to last families for a year (Crow pers. comm. 2008).

In the 1970s, tribal members began noticing serious declines in the numbers of lamprey migrating into the interior Columbia River basin. Tribal members associated lamprey declines with degraded habitat conditions, chemical eradication, fish poisoning operations and dams (Close et al. 2004). Currently, tribal members have limited opportunities to harvest lamprey within the Columbia River basin, with most collection locations restricted to the lower portions of the Columbia River basin (Close et al. 2002). When the few opportunities for lamprey harvest do occur, younger tribal members often collect eels for tribal elders with supervision and training from adult tribal members.

Without lamprey to catch, prepare and preserve, younger tribal members can no longer gain associated technical knowledge and cultural experiences including important connections with elders. The loss of traditional tribal fishing areas and traditional ecological knowledge surrounding the eel threatens the significant loss of tribal culture (Close et al. 2002).

For example, a tribal story goes:

I have heard it said that long ago, before the people, the animals were preparing themselves for us. The animals could talk to each other during this time. The eel and the sucker liked to gamble, so they began to gamble. The wager was their bones. The eel began to lose but he knew he could win. The eel kept betting until he lost everything. That is why the eel has no bones and the sucker has many bones (Close et al. 1995).

3.3 Tribal Harvest

The right to resort to…fishing places…was a part of larger rights possessed by the Indians upon exercise of which there was not a shadow of impediment and which were not much less necessary to the existence of the Indians than the atmosphere that they breathed…
—United States v. Winans 198 U.S. 371,381 (1905)

Harvesting lamprey for ceremonial purposes and subsistence is critically important to the four CRITFC tribes. Due to declining adult lamprey numbers, tribal fishing opportunities are extremely limited. Tribal harvest is primarily focused at Willamette Falls during July when hydro operations dewater the falls. In 2010, the Confederated Tribes of the Warm Springs conducted a tribal creel census at Willamette Falls. With stray rates applied, tribal lamprey harvest was estimated between 4.4%–7.3% of the total adult escapement estimates at the falls (22,000–36,000 adults; Baker and Graham 2011).

Due to the extremely low numbers of adult lamprey in the Columbia River basin, the tribes will not harvest lamprey for tribal consumption at mainstem dams. As lamprey populations increase in the future, the tribes may decide to resume mainstem harvest at these locations.

3.4 Institutional Context

Changes in institutional priorities are needed. The region needs to acknowledge policy and institutional barriers that are independent from scientific and economic issues that prevent federal, state and local agencies from taking action to restore lamprey. Among other things, these agencies need to work with the tribes to educate the general public about the lamprey as a vital part of the Columbia River ecosystem.

Pacific lamprey conservation within the Columbia basin has not been a fisheries management priority. Instead, these fish have often been lumped into a multispecies context and it has been assumed that measures taken to restore salmon would carry along lamprey as a less charismatic species. Although these primitive fish share many of the same habitats as salmonids listed under the Endangered Species Act (ESA) and are an integral part of ecosystems on which these fish depend, Pacific lamprey have been little more than add-ons to conservation plans. Unfortunately, the efforts to help salmon and other native fish have not resulted in flourishing lamprey populations; in fact, some bioengineering measures for salmon have proven detrimental to lamprey (Bleich and Moursund 2006; Starke and Dalen 1998).

Through ignorance, Pacific lamprey have been generally and erroneously lumped into a similar category as invasive sea lamprey and other undesirable fish (Brown et al. 2009). This resulted in lamprey being discriminated against by many state and federal agencies and the general public and consequently lamprey were purposely eliminated in entire Columbia basin watersheds. This misunderstanding continues today. For example, the FERC has disregarded or discounted Pacific lamprey restoration actions in environmental impact statements and new license proceedings and license conditions for non-federal hydroelectric projects, because of confusion with the eradication of the sea lamprey at Midwest hydro projects. This is especially problematic given the dire state of Columbia basin lamprey and the fact that licenses are awarded for a 30–50 year time period.

Some hydroelectric projects now undergoing FERC relicensing are not being considered for lamprey passage by federal fishery agencies that have mandatory passage authorities under the Federal Power Act. These projects include the Hells Canyon Complex and Enloe Dam on the Similkameen River. Because FERC licenses are for 30–50 years, achieving the long term tribal lamprey restoration goal to restore lamprey to all historical areas will be difficult unless passage at these dams is considered in current licensing proceedings.

The CRITFC tribes' anadromous fish restoration plan, *Wy-Kan-Ush-Mi Wa-Kish-Wit* (Nez Perce et al. 1995), recognized that lamprey restoration "…*depends on institutional structures that efficiently coordinate the actions and resources of relevant government agencies and enlist the support and energy of individuals and non-government agencies* [emphasis added]." Redirection of funding and personnel by sovereign entities as well as local governments is needed in order to implement goals, objectives, actions, monitoring and evaluation in an active, adaptive management framework (Walters 1986; Walters and Holling 1990; Hilborn 1987). When policy makers, technical experts or implementers differ on restoration approaches and actions, dispute resolution processes must be timely so that progress is not stalled.

Existing Columbia basin management forums and processes established for salmon restoration must be expanded to include actions for Pacific lamprey. This includes but is not limited to, the NPCC's Fish and Wildlife Program, state programs for species of concern, license conditions issued by the FERC, requirements for permits issued under the Clean Water Act, the Fish and Wildlife Coordination Act, the National Environmental Policy Act and the Corps' Columbia River Fish Mitigation Program. The Fish Accords (MOA 2008) between CRITFC, three of CRITFC's member tribes, and three federal agencies provide a good start towards working partnerships and actions to restore Pacific lamprey, but in themselves will not be enough to reverse the ongoing decline.

The tribes recommend that all federal and state agencies and FERC license holders establish specific funding streams and other resources to implement lamprey actions as an important step toward making institutional reforms for lamprey restoration. Among other things, this includes expedited establishment of one full time scientist/manager per each entity who focuses entirely on lamprey restoration and who coordinates with tribes, other agencies and other basin forums such as the CRBLTWG.

As evidenced by the drastic reduction of eels observed in the upper portions of the Snake and Columbia rivers, the current state of our Pacific lamprey management can be characterized as simply watching once widespread and abundant populations dwindle to functional extinction.

Recovering lamprey must be a regional management priority.

3.5 Pacific Lamprey Life History

Eel will never tell us all of his secrets.
—Elmer Crow Jr. Vice Chair, Nez Perce Fish and Wildlife Committee

Fossil records indicate that lamprey have existed for nearly 450 million years (Schwab and Collin 2005; Bond 1996) while salmon have existed for 40 million years (Wilson and Williams 1992). Despite their persistence through time and their considerable ecological overlap with salmon, our understanding of the life history of Pacific lamprey remains incomplete. There appears to be between and within-basin variation in the timing of specific segments of life history, including spawning, incubation, early rearing, metamorphosis, juvenile outmigration, ocean residency and adult return migration (Figure 3).

Spawning by adult lamprey generally occurs within the Columbia River basin during the late spring and early summer (March–July) when water temperatures are between 10˚C and 15˚C (Beamish 1980; Beamish and Levings 1991; Close et al. 2003; Brumo 2006). Adults appear to spawn in low-gradient run and pool-tail out habitat (USFWS 2011). Both males and females engage in nest formation by: 1) rock lifting using their buccal funnels, most often to the downstream edge of the nest, 2) combining rock lifting and digging and 3) vibrating their tails rapidly to remove sand and small rocks and stacking gravel substrate (Pletcher 1963). During copulation, eggs are fertilized by the male and then covered with fine substrate before another spawning event is initiated (Pletcher 1963). Absolute fecundity varies between 98,000–238,400 eggs per female (Kan 1975) and unlike salmon, eggs are released in a series of short spawning events, with generally 100–500 eggs per event (Kan 1975). Pacific lamprey are likely semelparous and generally die within 3–36 days after spawning (USFWS 2006).

Pacific lamprey age at time of spawning is difficult to estimate due to their complex and variable life history, difficulties in aging ammocoetes, lack of direct information on ocean residency time, plasticity of maturation timing in relation to freshwater temperatures and migration rates (Clemens et al. 2009). Field observations of ammocoetes and macropthalmia suggest that freshwater age and timing of metamorphosis is diverse and varies regionally, perhaps associated with factors like water temperature and migration distance (Kostow 2002). Scientists have developed some aging techniques using statoliths, although they require sacrificing the animal. For these reasons it is difficult to track individual year-classes throughout their life cycle, and thus modeling population dynamics is problematic. Also, the current lack of precision on aging estimates complicate management actions based on these methods (Meeuwig and Bayer 2005).

Depending on water temperature, eggs hatch after approximately 15 days and spend another 15 days in redds until they emerge and drift downstream to suitable rearing habitats (Pletcher 1963, Brumo 2006). Dispersion from redds to suitable burrowing habitat is dependent on flow and stream gradient (Potter 1980). In general, ammocoete habitat occurs in low velocity, low gradient areas containing soft substrate and organic materials (Pirtle et al. 2003; Graham and Brun 2006). Ammocoetes may remain burrowed in soft substrates for up to seven years (Close et al. 1995). While burrowed, ammocoetes are blind and sedentary, filter feeding on diatoms and other organic material suspended in the water column (Moore and Mallatt 1980). Ammocoetes gradually move downstream during high flow and scouring events as evidenced by observations during the spring and winter (Graham and Brun 2006).

Similar to salmonids, larval lamprey go through a "smolting" process where they undergo morphological and physiological changes to prepare for their parasitic ocean phase (Close et al. 1995). These changes generally occur during downstream migrations between July and October (Richards and Beamish 1981; Hammond 1979). During metamorphosis, ammocoetes develop eyes, an oval mouth, functional teeth and a tongue, and the size of their oral disc increases (Yousson and Potter 1979). They also transform from a brown to a silver appearance. Internal changes include foregut development for osmoregulation (Richards 1980; Richards and Beamish 1981), blood protein changes (Richards 1980), disappearance of the bile duct and gallbladder (Bond 1996), and development of a unidirectional respiratory system (Lewis 1980). Once metamorphosis is complete, ammocoetes are considered macropthalmia or "transformers."

Macropthalmia migrate to the ocean in the fall and spring, taking advantage of periods of high river discharge (Richards and Beamish 1981; Beamish and Levings 1991; van de Wetering 1998; Graham and Brun 2006; Bleich and Moursund 2006). Both habitat use and time spent in the estuary preparing for the ocean life stage are uncertain.

Adult Pacific lamprey are thought to remain in the ocean for approximately 18–40 months, feeding parasitically on a variety of fish before returning to freshwater as adults (Kan 1975; Beamish 1980). Through spatial and vertical sampling at specific Bering Sea locations, Orlov et al. (2008) discovered that while some lamprey were found in pelagic areas (< 100 meters), lamprey concentrations were greatest at bottom depths (< 500 meters) where there was increased prey abundance. The individual lengths varied from 12–85 centimeters indicating that the adult lamprey spend several years in the sea. Pelenev et al. (2008) studied the lamprey distribution from lamprey scars on five species of salmon and found the highest occurrence of lamprey-scarred salmon at Bering Sea locations including the Navarin area and off southeastern Kamchatka (Pelenev et al.

2008). Beamish (1980) indicated that walleye pollock (*Theragra chalcrogramma*) and Pacific hake (*Merluccius productus*) were the primary prey of Pacific lamprey, although lamprey have also been observed feeding on other fish species and marine mammals (Beamish 1980; Scott and Crossman 1973). Pacific lamprey may use olfactory perception, vision and electroreception to choose their prey (Close et al. 1995) and subsequently ventrally attach themselves near the pectoral area of prey (Beamish 1980; Scott and Crossman 1973).

After their ocean phase, adults return to freshwater to spawn (Cummings 2007). In the Columbia River, returning adults enter freshwater from February to September (Kan 1975; Beamish 1980), although most migrate through the system between June and September, according to adult daytime and nighttime counts at Bonneville and The Dalles (DART 2010). Adults spend a winter prior to spawning, sexually maturing in deep river pools with cover, such as boulders and organic debris before completing their March–July spawning migrations (Beamish 1980; Robinson and Bayer 2005). If larval lamprey live in freshwater from 4–7 years before metamorphosis, rear in the ocean for another 3–4 years and enter and hold in freshwater for another year before spawning, then the average life cycle of Pacific lamprey in the Columbia River system may be about 8–12 years.

The degree to which Pacific lamprey "home" to potential spawning streams remains unclear. Much of the current understanding of lamprey homing and the guidance mechanisms stem from comparisons to sea lamprey of the Great Lakes and Atlantic Coast. Although there appear to be critical life history differences between these two species (Clemens et al. 2010), enough similarities exist to provide logical comparisons. The current theory indicates that returning adults respond to an unknown combination of environmental and physiological factors that help guide lamprey into potential spawning streams. Specifically, returning adults appear to respond to adult and larval pheromones (Bergstedt and Seelye 1995) that provide a measurable attraction mechanism. Adult Pacific lamprey, like sea lamprey, appear to be attracted to spawning sites by pheromones released by ammocoetes based on their production of bile acids (Yun et al. 2004; Fine et al. 2004). Research is currently being conducted to isolate these compounds as well as investigate how they may be used to improve adult returns.

The overall lack of lamprey homing knowledge is also reflected in the limited, sometimes contradictory understanding of Pacific lamprey genetic and population substructure. A study by Goodman et al. (2008) analyzed 81 tissue samples from lamprey along the Pacific Ocean coastline and found little evidence of genetic variability among drainages indicating high levels of gene flow among geographic regions. In contrast, Lin et al. (2008) analyzed tissue from seven different Northwest rivers, including four in the Columbia basin, and found clear genetic differences among populations around the Pacific Rim and in the Pacific Northwest. More recently, Docker et al. (2010) analyzed samples from 21 locations along the Pacific Coast and found low levels of genetic differentiation providing support for a lack of natal homing in Pacific lamprey. Although increasing evidence appears to indicate low genetic differentiation among regional lamprey populations, more work is needed to better understand lamprey genetics.

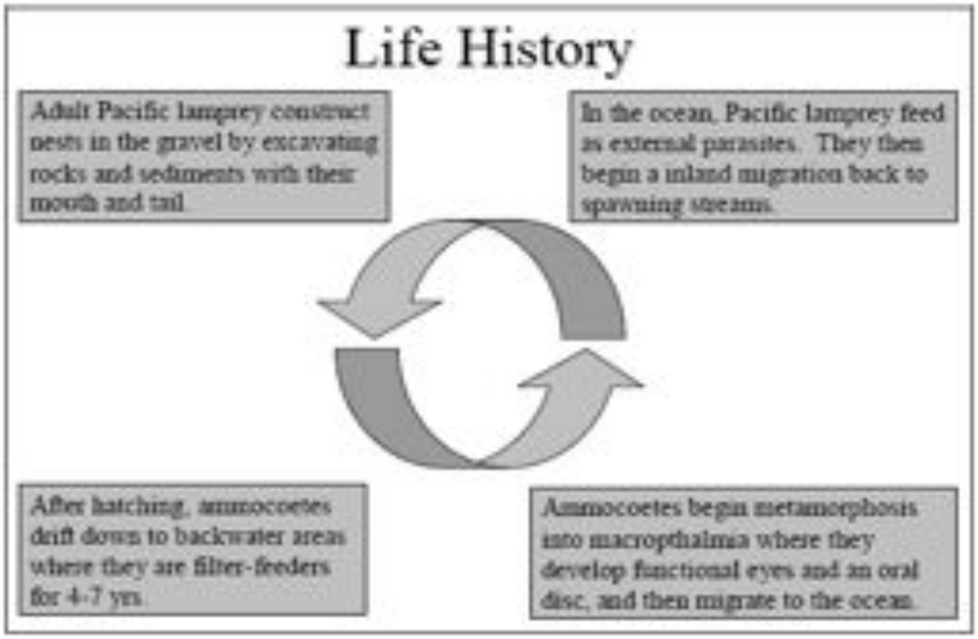

Figure 3. Generalized life history of Pacific lamprey (Cummings 2007).

3.6 Historical Abundance and Status

Over the past 30 years lamprey populations entering the Columbia River basin have declined concurrent with a suite of anthropogenic changes, including the construction and operation of mainstem and tributary dams, irrigation and agricultural projects, urban development and habitat loss (Close et al. 1995; Kostow 2002; Moser and Close 2003).

Investigators have used oral histories of Pacific lamprey and traditional ecological knowledge from tribal elders to gauge the relative decline of lamprey populations (Close and Jackson 2001; Close et al. 2009). These oral histories provide a baseline to measure lamprey decline that predates other methods and provides historical lamprey distribution and abundance information throughout the basin. During the late 1800's, approximate commercial harvests of 100,000–500,000 lamprey adults were recorded at Willamette Falls (Crow pers. comm. 2007) with harvest locations described as being completely covered by lamprey (Kostow 2002). There is also documentation of non-tribal processing of nearly 27 tons of lamprey in 1913 (Crow pers. comm. 2007). More recently, tribal harvests of lamprey at Willamette Falls have been reduced in relation to observed lamprey abundance at this location (Kostow 2002; Jackson pers. comm. 2010).

Quantitative records of adult abundance within the Columbia River basin began in 1938 with annual daytime adult counts at lower Columbia River hydroelectric facilities. Counts at Bonneville Dam ranged from 50,000 to 400,000 from 1938 to 1969. In the early 1960's, daytime adult counts reached 300,000–350,000 at The Dalles Dam, 25,000 at McNary Dam, and 17,500 at Rocky Reach Dam. Adult counts were not conducted between 1969 and 1993 (Figure 4; Close et al. 1995).

Since resuming counts in 1994, adult populations entering the Columbia River have exhibited a downward trend with daytime counts at Bonneville Dam declining from 117,000 in 2003 to 6200 in 2010 (Table 1; DART 2010). Due to the fact that many lamprey were observed passing through dams at night, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) initiated night counts at Bonneville Dam in 1998 and 1999 (Close et al. 2000) to obtain more accurate estimates of adult passage. However, it was not until about eight years later that the Corps conducted night lamprey counts at all Bonneville Dam fishways.

While adult salmon and steelhead have been counted for years at the Willamette Falls fishway, adult lamprey were never enumerated there until 2010. Under Fish Accord Project funding, the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) conducted a mark-recapture and creel census study that produced adult passage estimates of 22,000–36,000 after adjusting for the potential of tagged lamprey failing to return to the fishway (Baker and Graham 2010).

Adult lamprey migrations appear to decline as the run moves upstream with reductions of 92% occurring between Bonneville Dam and The Dalles Dam in 2010. Although not well understood, the main sources of between-dam attrition are believed to be mortality and turnoff into tributaries (Naughton et al. 2011). In addition, the number of adults entering either the mid-Columbia River or free-flowing portions of the Snake River appears to be extremely low according to 2010 adult counts of 1,114 and 114 at Priest Rapids and Ice Harbor dams respectively (Table 1; DART 2010).

Although adult counts provide the majority of information regarding Columbia River populations, recent juvenile abundance and distribution data appear to correspond with declining populations within the basin. Surveys of juvenile abundance and distribution have been conducted in tributaries of the Columbia River (Torgerson and Close 2004; Graham and Brun 2005; Jolley et al. 2009), the lower Snake River (Moser and Close 2003), and the Clearwater and Salmon Rivers (Cochnauer et al. 2005). Within the lower Snake River, few ammocoetes were found during surveys of the Walla Walla, Tucannon, and Grande Ronde Rivers in 1999 (Moser and Close 2003). From 2003 to 2004 only 27% of perennial streams sampled within the Deschutes River drainage contained larval or juvenile lamprey (Graham and Brun 2005). In addition, extensive surveys within tributaries of the Clearwater River from 2005 to 2009 suggest dramatic declines in juvenile abundance, distributional range and annual recruitment (Cochnauer and Claire 2009).

Pacific lamprey were likely historically distributed throughout the Columbia and Snake river basins (Hammond 1979, Petitt, pers. comm. 2000; Crow pers. comm. 2007; Close et al. 1995; Kostow 2002; USFWS 2011). Although historical adult abundance estimates from commercial and tribal harvests as well as adult daytime counts at hydroelectric facilities are incomplete and not scientifically rigorous, it is hard to deny that adult lamprey populations within the Columbia River basin are extremely depressed. The possibility that these populations may soon reach unsustainable levels throughout the

Columbia River Basin, as evidenced by the historic lows in adult counts observed in 2009–2010 (Table 1; DART 2010), is of significant concern to the tribes

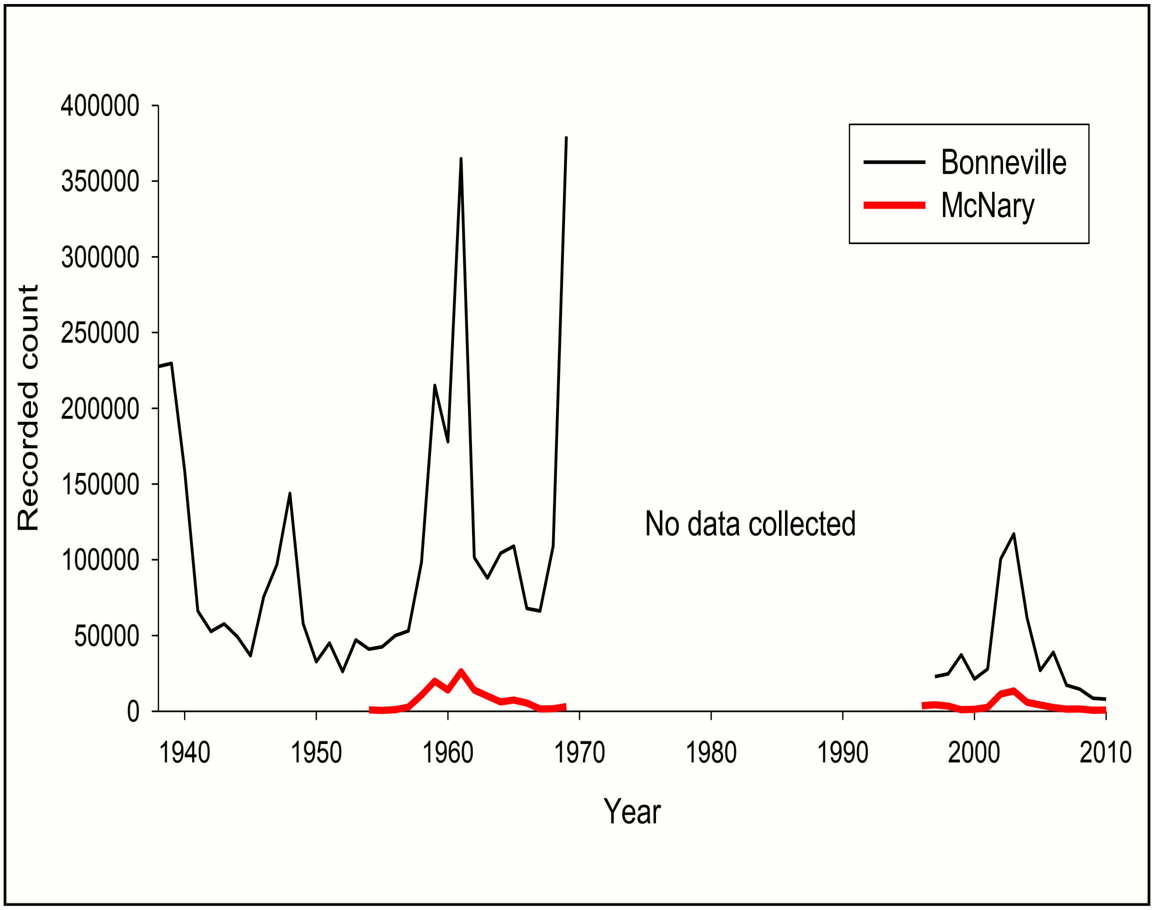

Figure 4. Adult Pacific lamprey counts at Bonneville and McNary dams from 1938 to 2010. Data based on daytime counts from Kostow 2002, DART 2011, USACE 2010, and Pennington 2010.

Table 1. Recent adult lamprey counts at Columbia River mainstem dams (data from USACE 2010 and DART 2010).

Year	Bonneville	The Dalles	McNary	Priest Rapids	Wells*	Ice Harbor	Lower Granite
2000	19,001	8,050	1,281	1,468		315	28
2001	27,947	9,061	2,539	1,624	261	203	27
2002	100,476	23,417	6,116	4,007	338	1,127	128
2003	117,027	28,995	13,325	4,339	1,408	1,702	282
2004	61,780	14,873	5,888	2,647	291	805	117
2005	26,625	8,361	4,158	2,598	212	461	40
2006	39,925	6,894	2,139	3,273	21	255	35
2007	37,170*	6,077	3,389	3,419	32	288	81*
2008	45,104*	4,599	1,530	5,083*	7	266	61*
2009	19,429*	2,318	676	2,714*	9	57	12*
2010	23,608*	1,726	833	1,114*	9	114	15*

Note: 24 hour counts denoted by *; all others 16 hour daytime counts.

3.7 Critical Uncertainties, Threats, and Key Limiting Factors

Two overarching challenges to Pacific lamprey restoration include climate change and the continued human population growth in the Pacific Northwest (ISAB 2007a; ISAB 2007b). Further, regional groups have identified several critical uncertainties, threats and limiting factors to Pacific lamprey restoration. The tribes concur with most of these uncertainties, threats and limiting factors, which are summarized below.

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

- Poor habitat
- Fish poisoning operations
- Water pollution
- Dam passage
- Ocean conditions

CRBLTWG (Columbia River Basin Lamprey Technical Workgroup). 2005. Critical uncertainties for lamprey in the Columbia River basin: Results from a strategic planning retreat of the Columbia River Basin Lamprey Technical Workgroup. Columbia River Basin Lamprey Technical Workgroup.

- Lamprey status
- Biology/ecology
- Population delineation
- Passage
- Population dynamics
- Limiting factor analysis
- Restoration activities

Mesa, M.G., and Copeland, E.S. 2009. Critical uncertainties and research needs for the restoration and conservation of native lampreys in North America. Pages 311–321 *in* L.R. Brown, S.D. Chase, M.G. Mesa, R.J. Beamish, and P.B. Moyle, editors. Biology, management, and conservation of lampreys in North America. American Fisheries Society, Symposium 72, Bethesda, Maryland.

- Population status
- Systematics
- Passage
- Species identification
- General biology and ecology

Luzier, C.W. and 7 coauthors. 2009. Proceedings of the Pacific Lamprey Conservation Initiative Work Session–October 28–29, 2008. U.S. Fish and Wildlife Service, Regional Office, Portland, Oregon.

- Artificial barriers
- Dewatering and flow management
- Dredging
- Chemical poisoning and toxins
- Ocean conditions
- Poor water quality
- Disease
- Overutilization
- Predation
- Stream and floodplain degradation
- Non-native species
- Translocation
- Climate Change
- Extirpation
- Lack of awareness

USFWS. 2011. Pacific lamprey (*Entosphenus tridentatus*) assessment and template for conservation measures. United States Fish and Wildlife Service, Portland, Oregon. 282 pp.

- Passage
- Dewatering and flow management
- Stream and floodplain degradation
- Water quality
- Harvest/overutilization
- Predation
- Translocation
- Disease
- Small effective population
- Lack of awareness
- Climate change

Table 2. Linkage of Pacific lamprey threats/limiting factors, uncertainties, and recommended plan objectives/actions by life history phase

Pacific Lamprey Life History Phase		Threats and Key Limiting Factors	Critical Uncertainties and Research Needs	Plan Objectives
Adult Freshwater	Adult mainstem upstream migration	Mainstem passage Poor water quality and environmental stressors Predation	• Individual and cumulative impacts of adult passage through the hydro system, including mortality • Route-specific passage by adult lamprey at main stem Columbia and Snake River dams • Specific locations of difficult passage for adult lamprey • Passage effectiveness standards for adult lamprey at mainstem dams	Obj. 1 Mainstem passage and habitat Obj. 4 Contaminants and water quality Obj. 6 Research, monitoring, and evaluation
	Adult tributary upstream migration	Passage at irrigation diversion dams Water quantity and quality	• Adult upstream migration passage issues • Contaminants of most concern at all lamprey life stages • Life stages of highest uptake and concentration of contaminants • Effects of contaminant accumulation in tribal consumption of adult lamprey	Obj. 2 Tributary passage and habitat Obj. 4 Contaminants and water quality Obj. 6 Research, monitoring, and evaluation
	Adult holding and spawning in tributaries	Habitat degradation Population limitations	• Tools and strategies in a regional supplementation plan • Environmental stressors	Obj. 2 Tributary passage and habitat Obj. 3 Supplementation and augmentation Obj. 4 Contaminants and water quality Obj. 6 Research, monitoring, and evaluation
Juvenile Freshwater	Juvenile rearing	Channelization Habitat degradation Water quality and environmental stressors	• Temporal and spatial locations of high quality migratory, spawning and rearing habitat • Mortality in egg-ammocoete-macropthalmia life stage • Trophic relationships	Obj. 2 Tributary passage and habitat Obj. 4 Contaminants and water quality Obj. 6 Research, monitoring, and evaluation

Pacific Lamprey Life History Phase		Threats and Key Limiting Factors	Critical Uncertainties and Research Needs	Plan Objectives
	Juvenile outmigration	Passage at irrigation diversion screens Mainstem passage Water quality and quantity Predation	• Juvenile passage information without advanced juvenile tag technology • Advanced juvenile tag technology • Route-specific passage by juvenile lamprey at mainstem Columbia and Snake River dams • Individual and cumulative impacts of juvenile passage through the hydro system, including specific locations of difficult passage • Mortality	Obj. 2 Tributary passage and habitat Obj. 4 Contaminants and water quality Obj. 6 Research, monitoring, and evaluation
Saltwater	Juvenile-to-adult rearing	Reduction of ocean prey Unknown ocean conditions	• Spatial and temporal habitat needs for adult and juvenile lamprey, trophic relationships • Individual and cumulative impacts to adult and juvenile lamprey through the mainstem, estuary and ocean • Mortality	Obj. 6 Research, monitoring, and evaluation

Note: Obj. 5 Outreach and Education ties to all lamprey life history stages throughout the table.

4 Objectives and Actions

Specific Plan objectives and actions are organized in six sections: (4.1) Mainstem Passage and Habitat, (4.2) Tributary Passage and Habitat, (4.3) Supplementation/ Augmentation, (4.4) Contaminants and Water Quality, (4.5) Public Outreach and Education and, (4.6) Research, Monitoring and Evaluation. Each of these six sections is accompanied by a Plan objective. Shaded boxes summarize recommended actions by section and/or subsections. These objectives and actions are organized from a life history paradigm with threats, limiting factors, critical uncertainties and research needs listed in Table 2.

4.1 Mainstem Passage and Habitat

Objective 1: Improve lamprey mainstem passage, survival and habitat

The overarching goal of this objective is to achieve the same rate of juvenile and adult passage survival through the hydrosystem area without delayed passage impacts as if the hydrosystem was not present. It is important that passage improvements that have proven successful at mitigating impacts to lamprey at certain dams be immediately implemented, monitored and evaluated at upstream dams in an active adaptive management context (Walters and Holling 1990; Hilborn 1992).

The tribes believe that mainstem passage is the most urgent problem-facing lamprey in the Columbia River basin. As has been found in other river systems such as the Great Lakes (Haro and Kynard 1997) and in Europe (Laine et al. 1998), passage impediments throughout the basin likely have considerable negative impacts on upstream production. In its report on critical uncertainties for lamprey, the CRBLTWG prioritized passage improvements as a second rank critical uncertainty in the overall effort to restore lamprey and the USFWS identified improved passage as a key action (CRBLTWG 2005; USFWS 2010).

Over the past 15 years (1997–2011), basic passage research, using radio-telemetry and PIT-tag techniques, has been conducted at several Columbia River basin dams to monitor adult passage through dams and reservoirs (Figure 5 and Figure 6; Mesa et al. 2009b). This cumulative body of information, specifically baseline passage studies from 1997 to 2010, indicates that adult Pacific lamprey have a difficult time successfully ascending fish passage structures at mainstem hydroelectric facilities. Adult passage efficiencies are averaging less than 50% at most facilities (Moser et al. 2002b; Clabough et al. 2011; Keefer et al. 2009a; Cummings et al. 2007; Mesa et al. 2009b; Nass et al. 2003; Bioanalysts 2005). In addition, adults that do pass successfully often have increased passage times, which may affect long-term migration success of adult lamprey within the system (Moser et al. 2002a; Keefer et al. 2009a). Finally, radio tag data indicates that as many as 18%, of adults that successfully pass a dam fallback through the dam and many of these fish are not detected again (Peery pers. comm. 2011).

These studies are supplying a wealth of information vital to the preservation of Pacific lamprey. It is important that they be continued and expanded to all dams and reservoirs in the basin. Due to the extremely small numbers of adults at dams at the upper ends of the basin (e.g., Wells and Lower Granite), few passage studies have been conducted at these sites. Furthermore, minimal research has been conducted combining adult dam passage studies and evaluating the effects of difficult and delayed passage timing on spawning success into tributaries. These remain key research needs.

Millions of dollars have been spent on dam fishways, juvenile screen passage systems and irrigation screening systems that were designed and constructed for adult and juvenile salmon. Unfortunately, the biological and swimming capacities of lamprey were never considered. In the free flowing river environment, adult lamprey have a demonstrated ability to quickly traverse great distances (Hatch and Whitaker 2009). However, lamprey as anguilliform type swimmers, are not as efficient as teleost-type swimmers like salmon in negotiating high velocity areas (CRBLTWG 2004). This leads to low adult lamprey passage efficiencies into fishway entrances and the inability of juvenile lamprey to avoid impingement on dam turbine intake screens and other components of dam screen bypass system.

Increased research and monitoring has improved the lamprey knowledge base and stimulated a paradigm shift to a multi-species view of fish passage. For example, in their 1999 review of the Corps' Columbia River Fish Mitigation Program, the Independent Scientific Advisory Board of the Northwest Power Planning Council advocated creating a "biodiversity standard" for passage fixes that would benefit all native fish species. They recommended passage standards, targets, designs and evaluations that focus on protecting biodiversity and best fit natural behavior patterns and river processes (ISAB 1999). However, many of these recommendations have not been acted on and passage structures continue to be designed and operated primarily for ESA-listed salmonids.

Table 3 and Table 4 below summarize recommended adult and juvenile actions to improve passage and habitat and to address key critical uncertainties.

Table 3. Actions and schedules for adult lamprey at federal dams and reservoirs

	Bonneville	The Dalles	John Day	McNary	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Survey fishways	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on
Peer-reviewed passage progress reports	2011–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on
Annual inspections, protocols, and reports	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on
Prioritization of passage improvements	2012	2013	2014	2012	2012	2013–on	2013–on	2013–on
Grating replacement or plates over gratings	2012	2012	2012	2012	2013	2013	2013	2013
24–hour video counting and other passage estimates	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on
Reduce fishway night flows (depends on RME results)	2012	RME	2013	2012	2012	RME	RME	RME
Rounding corners	2013	2012	2013	2013	2012	2012	2012	2012
Ramp installations	2012	2012	2012	2012	2012	2012	2012	2012
Ladder dewatering improvements	All years	All years	All years	All years	All years	All years	All years	All years
Fishway entrance improvements	2013	RME	2012	2012–2013	2012–2013	2013–2014	2013–2014	2014–2015
LPS installations and evaluations	2012–2015	RME	RME	2012–2014	RME	RME	RME	RME
Assess mainstem and estuary habitat	2012–2014	2012–2014	2013–2015	2013–2015	2014–2016	2014–2016	2013–2016	2014–2016
Assess water quality and toxics effects on adult lamprey	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on	2012–on
Conduct predation literature review	2012	2012	2012	2012	2012	2012	2012	2012

Table 4. Actions and schedules for juvenile lamprey at federal dams and reservoirs

Action	Benefit	Schedule
Remove or modify turbine intake, raceway, and turbine cooler screens that cause juvenile impingement	Reduces direct and indirect juvenile mortality	2012–2018
Implement improved flow regimes	Reduces fish travel time and increases outmigration survival	2011–2018
Implement improved juvenile monitoring protocols	Establishes baseline information for improvement to juvenile passage	2012–2018
Compile and evaluate existing literature and data on juvenile migration at mainstem dams	Establishes baseline information and identifies specific locations of difficult passage	2011–2012
Use existing tagging technology and other tools to determine impacts on juvenile lamprey	Establishes baseline data for near-term impacts	2011–2018
Develop route specific dam passage and survival estimates	Identifies specific locations of improvements for juvenile passage	2012–2018
Expedite development of juvenile lamprey tagging technology	Acquires baseline and post-action data to monitor and evaluate mitigation actions	2011–2014
Survey reservoirs and estuary habitat for juvenile lamprey	Determines presence and absence of juveniles and characterizes mainstem rearing habitat	2011–2018
Compile a literature review on predation of juvenile lamprey	Assesses effects on juvenile mortality	2011–2018
Compile a literature review on contaminant accumulation in juvenile lamprey	Assesses effects on juvenile mortality	2012
Determine water quality and toxic effects on juveniles and implement actions	Reduces juvenile mortality	2011–2018
Create annual, peer-reviewed progress reports on juvenile research	Reduce juvenile mortality	2011–2018

Figure 5. Radio telemetry arrays for the USGS adult lamprey study at the Willamette Falls Hydroelectric Project (USGS 2006).

4.1.1 Adult Mainstem Passage

Adult Mainstem Passage Implementation and Actions

a. *Obtain accurate counts of adult lamprey passing mainstem dams*
b. *Continue to apply near-term structural improvements to known problem areas to facilitate adult passage at mainstem dams*
c. *Continue to identify and implement long-term structural and operational improvements to mainstem dams to improve adult passage*
d. *Continue to develop regional passage standards and metrics for adult lamprey at mainstem hydroelectric facilities*

4.1.1.a Obtain accurate counts of adult lamprey passing mainstem dams

There is an immediate need to establish and maintain accurate and timely 24-hour adult lamprey counts at mainstem dams. Accurately quantifying adult lamprey passage at mainstem dams would provide an index of population abundance over time. However, to date, obtaining these counts and indices are problematic for a number of reasons. First, multiple studies and existing video counting records indicate primarily nocturnal passage by adult lamprey (Moser et al. 2002b; Keefer et al. 2009a), while historically the majority of adult counting effort has occurred during the day (Moser et al. 2000; Moser and Close

2003; Moser et al. 2006). The proportion of nighttime passage is variable from dam to dam as well as seasonally (Clabough et al. 2009). Therefore, quantifying passage throughout the entire migratory season, including 24-hour counting, is important for accurate enumeration.

Second, due to their smaller size and ability to climb vertical structures, Pacific lamprey can utilize alternative routes of passage that bypass traditional counting structures, such as going through picketed leads in areas behind salmonid count windows (Peery and Fryer 2010; Eder et al. 2010). The anguilliform swimming style and sporadic downstream movements of lamprey make real-time adult counts difficult to obtain. These differences in lamprey behavior likely lead to count inaccuracies and an underestimation of adult passage. In addition, lamprey tend to pass at the lower portion of the fishway where they are difficult to detect due to poor lighting and the interference of other fish, such as shad (Fryer 2007; Clabough et al. 2008). These issues need to be addressed at all individual counting stations and future counting protocols need to account for alternative routes of passage, provide estimates of nighttime passage and use minimally invasive techniques such as video monitoring to obtain adult passage estimates.

There have been some major adjustments in lamprey counting and monitoring practices within the Columbia River basin since counts resumed in 1997. For example, in 2007, the Corps established 24-hour video counts at Bonneville, The Dalles, John Day and McNary dams (Table 1). In addition, adult lamprey that have been radio or half duplex PIT-tagged and detected at individual dams can be used to corroborate the video counts (Peery 2007). In 2011, CRITFC, USFWS and the USACE tested lamprey passage with Automated Visual Event Detection (AVED) software at The Dalles Dam and increased video monitoring. Further, Grant PUD recently installed a new count window that eliminates the picketed lead section around the counting station (Clement 2010).

In addition, through their lamprey Fish Accord project, the CTWSRO is engaging in a multi-year, mark-recapture, video and creel census study to enumerate adult lamprey at Willamette Falls (Baker and Graham 2010). For the first time, lamprey passage estimates and tribal harvest estimates are now available at this important index site (See Section 3.3 Tribal Harvest and Section 3.6 Historical Abundance for more information).

Further, Keefer et al. (2011) devised another method of estimating adult lamprey counts at Bonneville Dam based on a correlation between historical lamprey migration timing and river discharge and temperature. For example, 17.5˚ C is associated with 32.0% of the daytime ladder count at Bonneville, on average. These projects contribute to more timely and more accurate adult passage estimates.

These and future efforts will assist in monitoring all known passage locations during a 24-hour time period and utilize a variety of minimally invasive techniques in an effort to improve passage estimates while reducing count complexity (USACE 2010). The Corps, mid-Columbia public utility districts and other FERC license holders, the state departments of fish and wildlife, tribes and others need to continue developing and improving these counts and make them regionally available on a real time basis.

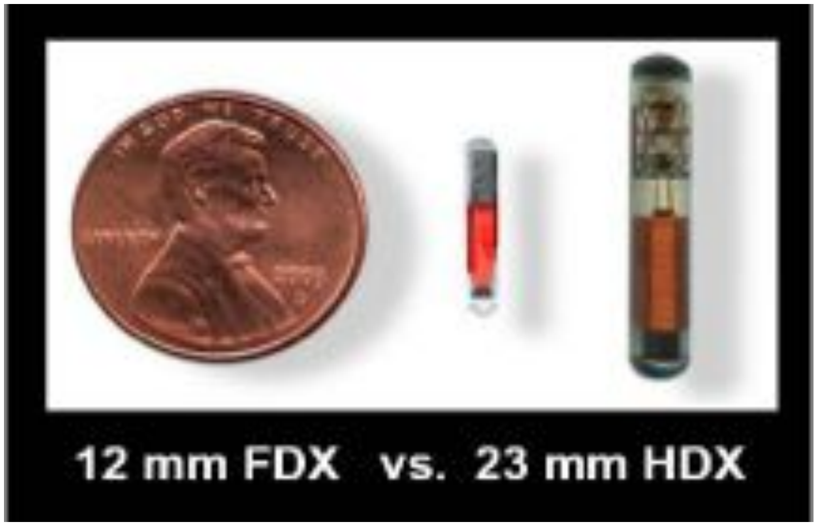

Figure 6. Full duplex (left) and half-duplex PIT-tags (Cummings 2007).

4.1.1.b Continue to apply near-term structural improvements to known problem areas to facilitate adult passage at mainstem dams

The tribes have identified improvement of adult passage efficiency at mainstem dams (e.g., reduction in passage times and energy expenditures) as a top priority for lamprey restoration. Although improvements to mainstem fish passage facilities have been extensive, these structures were designed primarily for salmonids. The migration behavior and swimming capacities of lamprey were not considered. In general, adult lamprey have difficulty navigating high velocity areas. In addition, they often display the ability to access typically inaccessible locations within fishways, such as areas below diffuser gratings, holes or cracks in fishways or auxiliary water channels that do not have exits. There are some structural improvements and protocol changes that should be implemented immediately to facilitate adult passage in relation to these general lamprey behaviors.

A variety of minor structural alterations to fishways have been devised to facilitate lamprey passage, based primarily on the lamprey's limited ability to navigate high velocity locations and their tendency to congregate in blind corners and pockets within fishways (Stansell 2002; Moser et al. 2002b; Moser et al. 2006). These changes have included ramping concrete lips, rounding sharp corners, plating over diffuser grating, modifying head differentials over weirs, installing orifices and passage structures through serpentine weirs, restricting access to "dead ends" and raising picketed leads within count stations (Figure 9, Figure 10, Figure 11 and Figure 12; USACE 2011). These minor structural modifications are being implemented in an on-going basis with priority given to passage locations shown to be the most problematic for adult lamprey. For example, because so many adult lamprey pass through the picketed lead sections behind fishway count windows, the Corps has raised some of the pickets 1.5 inches to facilitate lamprey passage through these areas (Tackley 2011). As another example, in 2010, the Corps installed and video monitored orifice slots in the tilting weir section near the exit of the McNary Oregon shore fishway to facilitate lamprey passage (Eder et al. 2010). On average, 50% of adults observed at orifice slots passed successfully with minimal effects on salmonids (Eder et al. 2010).

Figure 7. Flow control structure with adult lamprey ramp over the concrete cap in the distance at Willamette Falls (Heinith 2010).

Figure 8. Adult lamprey fishway ramp at Willamette Falls (Shibahara 2011).

In 2007, in conjunction with FERC relicensing, Portland General Electric completely rebuilt the fishway at the River Mill Dam on the lower Clackamas River incorporating features, like rounded weir corners, that were demonstrated at other dams to be beneficial for adult lamprey passage. At the Willamette Falls Hydroelectric Project, along with a downstream flow control structure, experimental lamprey ramps were installed over the concrete cap on top of the falls after annual flashboard installation (Figure 7). These ramps have been structurally improved and slick algae below the ramps is periodically removed to facilitate lamprey passage. In the last two years, lamprey passage over the ramps has been observed and construction of a new fishway ramp over the existing fish ladder was recently completed (Figure 8; Shibahara pers. comm. 2011).

Diffuser grating, within fish ladders at mainstem dams, covers holes where auxiliary water is added to fishways to meet adult salmon passage criteria. However, these gratings present lamprey passage problem, as they reduce the adult lamprey's ability to attach to the fishway surface, particularly before and after movement through orifices at the bottom of fishway weirs and within fishway transition pools (Figure 9 and Figure 10). Based on experiments at Bonneville Dam, reduction in diffuser gratings from 1 inch to 0.75 inch has virtually eliminated trapping of adults below main fishway channels (Moser et al. 2007b). Replacement of 1-inch grating with 0.75 inch grating has been successful at the John Day North Shore fishway counting station and needs to be implemented at other dam fishways. Unfortunately, there are two problems that need to be addressed. First, obstruction of large areas of diffuser grating with plating may negatively alter fishway hydraulic conditions with respect to salmonid passage criteria. Second, new gratings with smaller gaps are very costly. In 2009–2010 Grant County PUD video monitored plating along the sides of the Wanapum and Priest Rapids fishways, that create a lamprey "road" where adults can more easily attach as they proceed up the fishway (Figure 12; Clement pers. comm. 2010). In addition, the Corps' Walla Walla District has installed similar plates over diffuser gratings at the Ice Harbor Dam fishways (Fryer et al. 2010).

Although the Corps, the tribes and other interested parties have determined that replacement or plating of diffuser gratings is a priority, few fishways have been modified because of conflicts with salmon passage criteria. The tribes and others continue to recommend installation of smooth metal plates about 16 inches wide over gratings along the fishway sides and other difficult passage areas (e.g., transition pool orifice entrances) to provide better adult lamprey attachment and to expedite passage at all appropriate mainstem dams.

Installing Lamprey Passage Systems (LPS) has proven to be a "rough and ready measure" to improve lamprey access over specific problematic passage areas such as serpentine weir wall dividers in adult fishways (Moser et al. 2006; Moser et al. 2008). These structures consist of a series of ramps and long metal boxes, connected to a consistent flow of water, which allow adults to utilize their "burst and attach" swimming strategy to efficiently ascend barriers (Figure 13). Currently, these structures exist at two Bonneville Dam fishways (Bradford Island and Cascade Island). Monitoring efforts indicate significant use by adults with counts ranging from 7,365 adults at Bradford Island fishway to 2,152 adults at the Washington shore fishway (Pennington 2010). Although these structures can be logistically difficult to implement, they avoid the cumulative costs of many minor changes to existing fishways and reduce potential impacts on salmonid passage, making them a potential long-term strategy to improving lamprey passage. Unfortunately, a proposed LPS at the Bonneville Washington shore entrance, a primary passage location, was postponed due to logistical problems in 2010. LPS may become a future, long-term adult fishway passage strategy.

Consistent with the provisions of the Fish Accords, the Corps' Walla Walla and Portland districts have worked closely with tribal staffs to create a list and tentative schedule of prioritized improvements at Corps dam fishways. Below and in Table 2 are the tribal recommended actions and schedule for all mainstem Columbia and Snake River dams, which include the Corps' list and a number of additional actions. The schedule and priority for these actions will likely be modified as a more complete understanding of adult lamprey passage is obtained.

1. Fishway surveys and inspections: Survey and inventory all fishways for potential structural changes that would improve adult lamprey passage (e.g., rounding blunt

corners, strategic plating of diffusers, closing blind end fishway areas, filling cracks, identifying alternative passage routes and problem areas within transition pool and picketed lead sections). Evaluate all fishways for potential installation of LPS. Written reports should document findings and remedies.

2. Peer-reviewed passage reports: Provide annual reports of all lamprey related research within the mainstem Columbia and Snake Rivers.
3. Ladder dewatering improvements: Evaluate and improve fish ladder dewatering procedures with the goal of minimizing negative effects on lamprey (e.g., improved salvage operations, gradual dewatering protocols, minimization of blind corners).
4. Diffuser plate installation: Install plating over diffusers at strategic locations within transition pools to increase surface area for lamprey attachment and upstream movement. Evaluate and make these changes permanent if appropriate.
5. Ramp installation: Install ramps at areas of difficult passage (e.g., sills and lips). Evaluate and make these changes permanent if appropriate.
6. Diffuser grating replacement: Replace all 1 inch gap diffuser grating with ¾ inch gap grating; of highest priority is the replacement of grating in fish counting areas and auxiliary water systems (AWS) where lamprey stranding and mortality are the highest.
7. Evaluate blind corners: Identify and evaluate potential locations within fishways that may cause delays and increase passage times and modify these areas as appropriate.
8. Round blunt corners: Round corners at areas of high velocity (e.g., entrance slots and orifices).
9. Reduce nighttime fishway velocities: Implement and evaluate reduced nighttime fishway velocities. Make these changes permanent at specific fishway entrances if appropriate.
10. Develop standardized and peer-reviewed protocols for prioritization of short and long term passage actions (i.e., use CRBTLWG passage efficiency metrics for designing fishway passage improvements).
11. Adult passage estimates: Implement 24-hour video counting at all known and alternative routes of passage at fish passage facilities within the mainstem Columbia and Snake Rivers.
12. Fishway entrance improvements: Develop and evaluate potential major modifications to fishway entrances such as variable width weirs (i.e., keyhole entrances) at mainstem dams.
13. LPS installations and evaluations: Identify potential locations for LPS at all mainstem fishways, especially locations of difficult passage and high adult use. Implement and evaluate as appropriate.

Figure 9. Serpentine weir section at Bonneville Dam Oregon shore fishway (Moser et al. 2004).

Figure 10. Vertical slot flow control structure at Little Goose Dam fishway as a lamprey passage barrier (Fryer 2009).

Figure 11. Floor diffuser grating and submerged orifice at the dewatered John Day Dam fishway (Richards 2007).

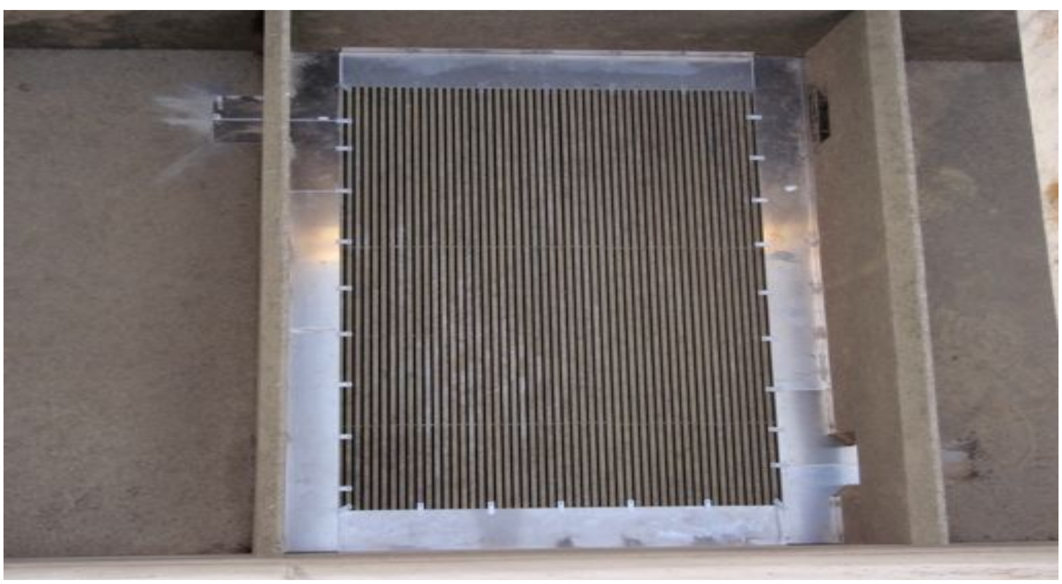

Figure 12. Plates installed at Priest Rapids fishway to assist adult lamprey passage over a diffuser grating section. Note the rounded corners on the submerged orifices at the bottom of the weirs to also assist passage (Clement 2010).

Figure 13. Lamprey passage structure over the Bonneville Dam Oregon shore serpentine fishway section. A lamprey passing upstream can be seen at the upper portion of the bottom of the structure (Moser et al. 2004).

4.1.1.c Continue to identify and implement long-term structural and operational improvements at mainstem dams to improve adult passage

From 1997 to 2008, basic passage research was conducted at several Columbia River basin dams to monitor and evaluate adult lamprey passage. This research identified potential structural and operational barriers to lamprey passage, has improved the understanding of Pacific lamprey upstream migration life history and provides a general framework for improving passage by addressing known limitations. In general, the goal has been to improve lamprey passage by focusing on the areas where passage efficiency is the poorest and where the affected numbers of lamprey are the highest, a concept central to the Corps' Ten Year Passage Plan (USACE 2009; USACE 2011).

Some major structural modifications have been implemented at Corps dams and mid-Columbia public utility dams. In 2006 Grant County Public Utility District installed a slotted keyhole fishway entrance at Priest Rapids Dam (Figure 14), which modifies fishway entrance velocities over a range of dam tailwater elevations and improves lamprey entrance efficiencies by providing areas of low velocity at bottom entrance locations.

Other major structural changes include modifications to the Cascade Island fishway at Bonneville Dam in 2008–2009, which included a variable-width entrance weir (keyhole entrance) and bollards ("artificial rocks") designed to provide reduced near-flow water velocity refuges for lamprey (Clabough et al 2011; Figure 15). The Corps plans to install a similar structure at John Day North entrance in 2011–2013 (USACE 2010). Post-modification research suggests that changes to the Cascade Island fishway entrance improved lamprey movement into the fishway (Clabough et al. 2011). In addition, modifications to the John Day North Fish Ladder count station in 2009–2010 were made with lamprey passage in mind, including adding ramps to concrete sills, rounding corners, raising picketed leads, and modifying count station floors to eliminate a one-foot rise at submerged weir orifices (USACE 2010). Fishway entrances and other points in these fishways should be monitored closely, preferably by non-intrusive methods (e.g., video and DIDSON cameras). Depending on the results, these major structural changes should be implemented wherever possible at other dams within the basin.

Fishway operational changes are also being evaluated to improve lamprey passage efficiency and reduce passage times. In 2007, the Bonneville Power Administration reduced nighttime flows at the Bonneville Dam North shore fishway, and such decreased flows resulted in increased entrance efficiencies (Johnson et al. 2010). However, attraction flows to the fishway entrance were reduced which may have impacted attraction into the entrance. Minimal improvements in entrance efficiencies at other fishways under reduced nighttime flows (Johnson et al. 2010) suggest that operational changes may need to be implemented and monitored on an individual fishway basis.

Similar to adult salmon, adult lamprey returning from their marine phase may fix on freshwater cues in the Columbia River estuary plume, which may be intensified by the spring freshet. Managing flows for a more natural hydrograph will not only benefit salmon, but will also benefit adult lamprey. Potential tools to increase flows and establish a more natural hydrograph are flow augmentation, reducing water withdrawals, reservoir drawdown, and achieving flood control upper rule curves at storage reservoirs before the spring freshet (CRITFC 2008; ISG 1996). Specific research needs to be conducted to quantify these effects. The additional stressor of climate destabilization will likely require consideration of modifying flood control rule curves through improved forecasting methods to create additional storage for spring and summer flow augmentation (WGA 2008; Low et al. 2011).

Figure 14. Slotted "key hole" fish ladder entrance installed at Priest Rapids Dam (Lauver 2006).

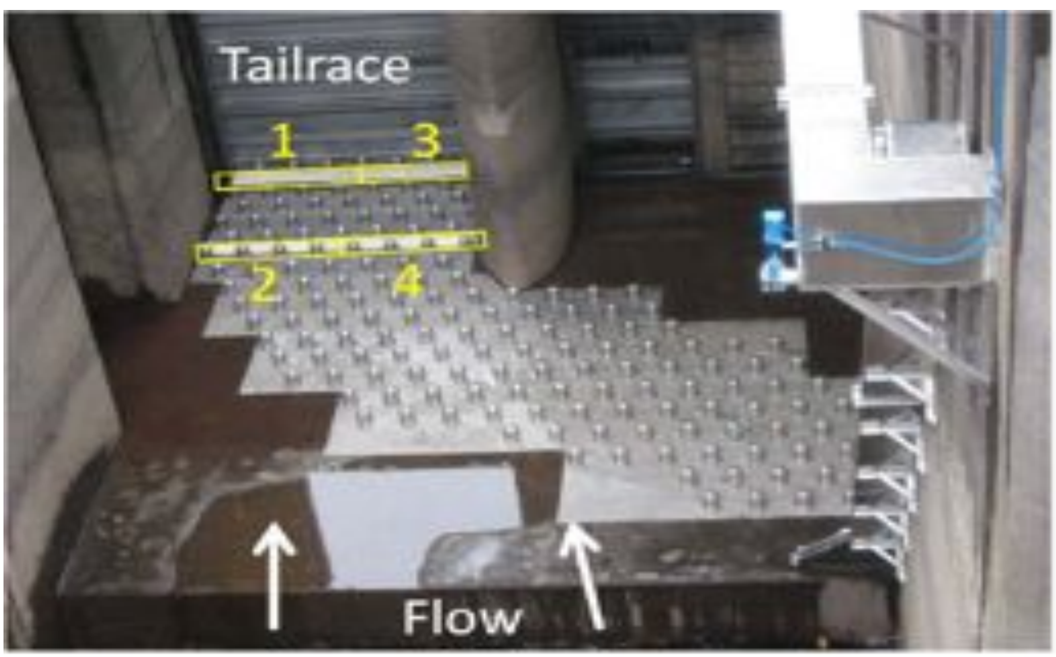

Figure 15. Modified Cascade Island fishway at Bonneville Dam. Bollards break up velocities, smooth floor plating for lamprey attachment and LPS structure on the right, all to improve adult lamprey passage (Tackley 2011).

4.1.1.d Continue to develop regional passage standards and metrics for adult lamprey at mainstem hydroelectric facilities

The Columbia River basin lacks consistent qualitative performance standards for adult lamprey passage among federal and FERC licensed hydroelectric projects, which is due in part to limited information. During several FERC relicensing proceedings, these standards were identified as key areas for the USFWS to pursue, but little has occurred to date to establish these standards. Instead, in several recent FERC settlement agreements, which have subsequently been incorporated into FERC licenses, the parties have adopted a placeholder phrase of "safe, timely and effective qualitative goal without serious injury or mortality" (i.e., 2004 Willamette Falls Hydroelectric Project Settlement Agreement).

Unfortunately, these more specific passage goals are not consistent among FERC licensed hydro projects, which is especially problematic given the depressed status of lamprey and that licenses are awarded for 30–50 years. For example, passage goals and objectives in the 401 Water Quality Certifications issued by state water quality agencies for new licenses are often more rigorous than FERC staff mandated conditions.

This creates conflicts with basin-wide management actions and proposed infrastructure improvements. Although these inconsistencies are partly a result of the limited biological information available for lamprey, providing the best passage environment in plans that are consistent with regional passage goals and in actions, such as those contained in Mid-Columbia PUD FERC licenses, is critical for basin-wide lamprey restoration.

Developing passage standards for adult lamprey will likely be a long-term process and require a coordinated effort from lamprey managers and researchers throughout the basin. In 2007, a subgroup of the CBFWA Lamprey Technical Working Group was tasked with developing basin-wide adult lamprey passage standards and objectives for measurable and biologically relevant metrics (CRBLTWG 2007). The tribes recommend establishment of an adult dam passage standard of 80% by 2020, which has been achieved at The Dalles Dam (Moser et al. 2002a).

This group had made significant progress on two phases to establish regional passage standards: identifying potential research metrics and determining which metrics were measurable with scientific rigor (CRBLTWG 2010). These include passage efficiency into fishways, passage effectiveness through fishways, passage timing, fallback and fallout through floating powerhouse orifices. A significant proportion of the overall objective remains incomplete and has been complicated by limited passage information at specific facilities, varying data collection methods, and an incomplete understanding of lamprey life history. Despite these limitations, the passage metric subgroup continues to meet regularly to further develop passage metrics and standards for Pacific lamprey.

4.1.2 Juvenile Mainstem Passage

Juvenile Mainstem Passage Implementation and Actions

a. *Continue to apply near-term structural and operational improvements to known problem areas in order to facilitate mainstem passage*
b. *Increase juvenile lamprey monitoring at dams*
c. *Utilize juvenile tag technology and other methods to obtain route-specific passage and survival at mainstem dams*
d. *Identify and implement longer term structural and operational improvements to mainstem dams to improve juvenile passage and survival through dams and reservoirs*

4.1.2.a Continue to apply near-term structural and operational improvements to known problem areas in order to facilitate mainstem passage

Juvenile lamprey, both ammocoetes and macropthalmia, are often found impinged on turbine cooling strainers, trashracks in front of turbines, screens and pipes in salmon bypass systems and sampling areas (WDFW 2011; Dykstra 2011). About 25% of juvenile lamprey are estimated to be lost from extended length turbine intake screen impingement (Figure 16; Starke and Dalen 1998; USACE 2010). Impingement is an issue anytime screen velocities exceed lamprey swimming ability. Burst, sustained and critical swimming speeds for juvenile lamprey are far less than those displayed by juvenile salmonids (Dauble et al. 2006). Laboratory studies indicate that lamprey impingement on screens occurs when screen mesh is large enough for them to get stuck tail first while attempting to remove themselves (Moursund et al. 2000). While it was previously believed that the shorter traveling turbine intake screens do not impact lamprey, recent evidence indicates that these screens can cause significant juvenile lamprey mortality (Figure 17; Condor 2011). Many more juvenile lamprey are lost to bird and fish predation as well as juvenile salmon and steelhead predation in salmon transportation raceways. Juvenile lamprey that survive passing into collection channels of juvenile salmonid bypass systems appear to pass in high numbers through the rest of the screen bypass system (Bleich and Moursund 2006). However, juvenile lamprey have died in significant numbers after being impinged on screens at the outfalls of transportation raceways (Figure 18; Fryer 2009). The Corps is attempting to modify raceway screens to reduce this impact.

Through the short-term "hopper list" of passage improvement measures, the Corps is funding some improvements (USACE 2011). For example, the Corps is extending the length of screen bypass system outfalls so that juveniles exiting these systems are not stranded and desiccated on shorelines. The Corps is also delaying installation of fixed bar screens and vertical barrier screens at McNary Dam to improve lamprey passage. Unfortunately, the screens are installed before the peak of lamprey migration in an to attempt to keep ESA-listed juvenile salmon out of turbines, thus resulting in significant negative impact to migrating juvenile lamprey (Figure 16).

One of the first priorities for increasing survival of juvenile lamprey is to remove or modify dam structures that have a documented negative impact on juvenile lamprey such as turbine intake and vertical barrier screens and turbine cooling strainers. Studies also indicate that juvenile salmon that pass through these routes experience delayed mortality and lower smolt-to-adult survivals than through a combination of spill and turbine passage (Tuomikoski et al. 2010; Buchanan et al. 2011; Petrosky and Schaller 2010).

The lack of knowledge pertaining to route specific passage and survival rates for juvenile lamprey does not preclude taking steps to address known passage threats. Given the difficulties that juvenile lamprey have with powerhouse passage, an immediate operation to increase spill and surface bypass such as spillway weirs and sluiceways at mainstem dams would likely keep juvenile lamprey from powerhouse turbine and screen system passage. This is because juvenile lamprey rely on water velocity and river flow to move downstream. If more of the river is put through non-powerhouse routes, more juvenile lamprey should pass through these routes. Additionally, increasing turbine efficiency should reduce harmful shearing and cavitation in the turbine environment and improving general turbine draft tube hydraulics should be investigated. Greater efforts to control bird and fish predation in dam forebays and tailraces could also provide juvenile lamprey with immediate survival and passage benefits.

Figure 16. Impingement of lamprey macropthalmia (e.g., transformers) on a John Day Dam extended length bar screen (Starke and Dalen 1998).

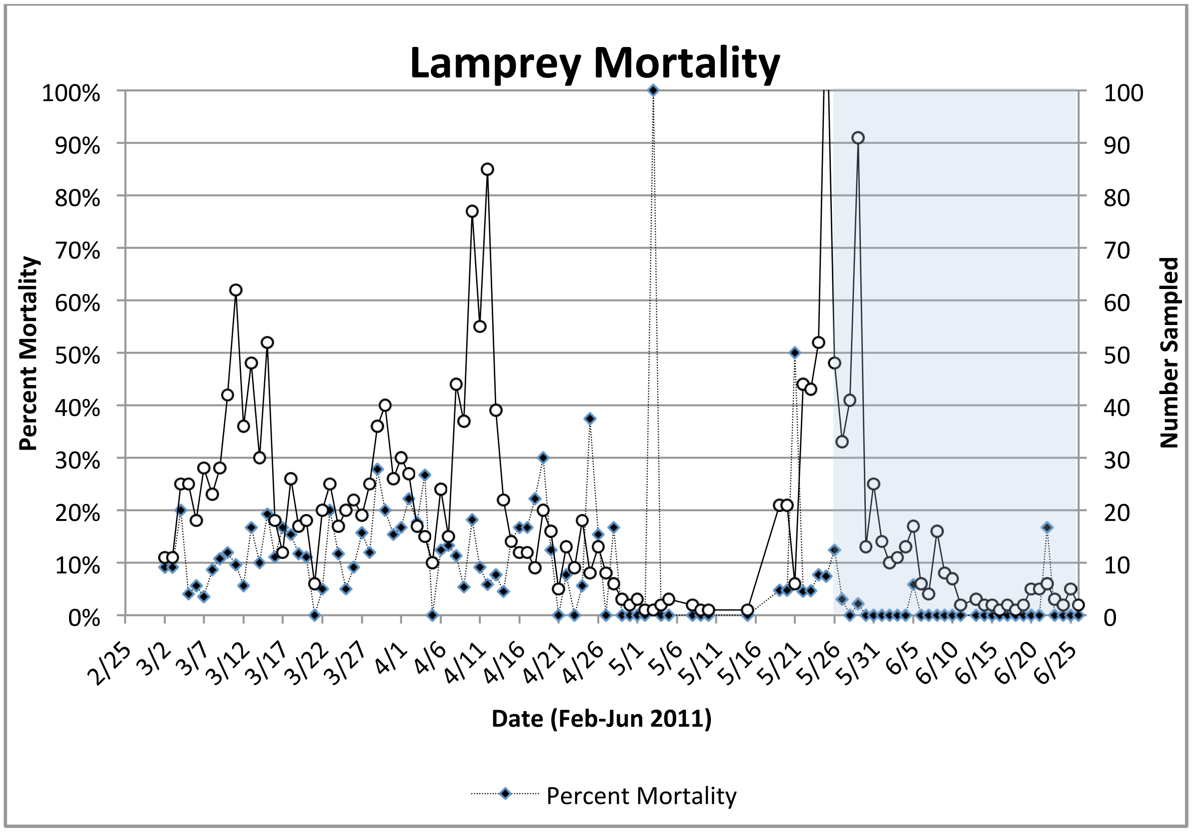

Figure 17. Juvenile lamprey mortality estimated from Bonneville Dam screen bypass sampling. The shaded area represents the period when traveling turbine intake screens were removed due to debris concerns (Condor 2011).

Figure 18. Screens at the end of salmon transportation raceways (Fryer 2009). Modifications are needed to reduce juvenile lamprey impingement.

4.1.2.b Increase juvenile lamprey monitoring at dams

For many years, juvenile lamprey were found in dam screen bypass systems and transportation facilities for juvenile salmon, but were not counted or identified to the species level. These data were combined to create general juvenile lamprey migration rates through mainstem dams (Figure 19). In 2011, increased efforts to incorporate lamprey species identification and counts and condition by Smolt Monitoring Program personnel have been implemented in the general sample reporting (PSFMC 2011; ODFW 2011; WDFW 2011). However, many lamprey are found on screens, in raceways and across system separators and are not counted in the samples (PSFMC 2011; ODFW 2011;WDFW 2011). Juvenile lamprey can be found in these systems during freshets, which can occur anytime of the year. Many lamprey are found in bypass system debris (ODFW 2011; WDFW 2011). Significant numbers of juvenile lamprey recently have been found impinged on turbine cooling water strainers and in turbine trash racks and various areas in the screened bypass systems (Cordie 2010; Dykstra 2011). More effort is needed to enumerate lamprey in these systems and determine ways to reduce system impacts.

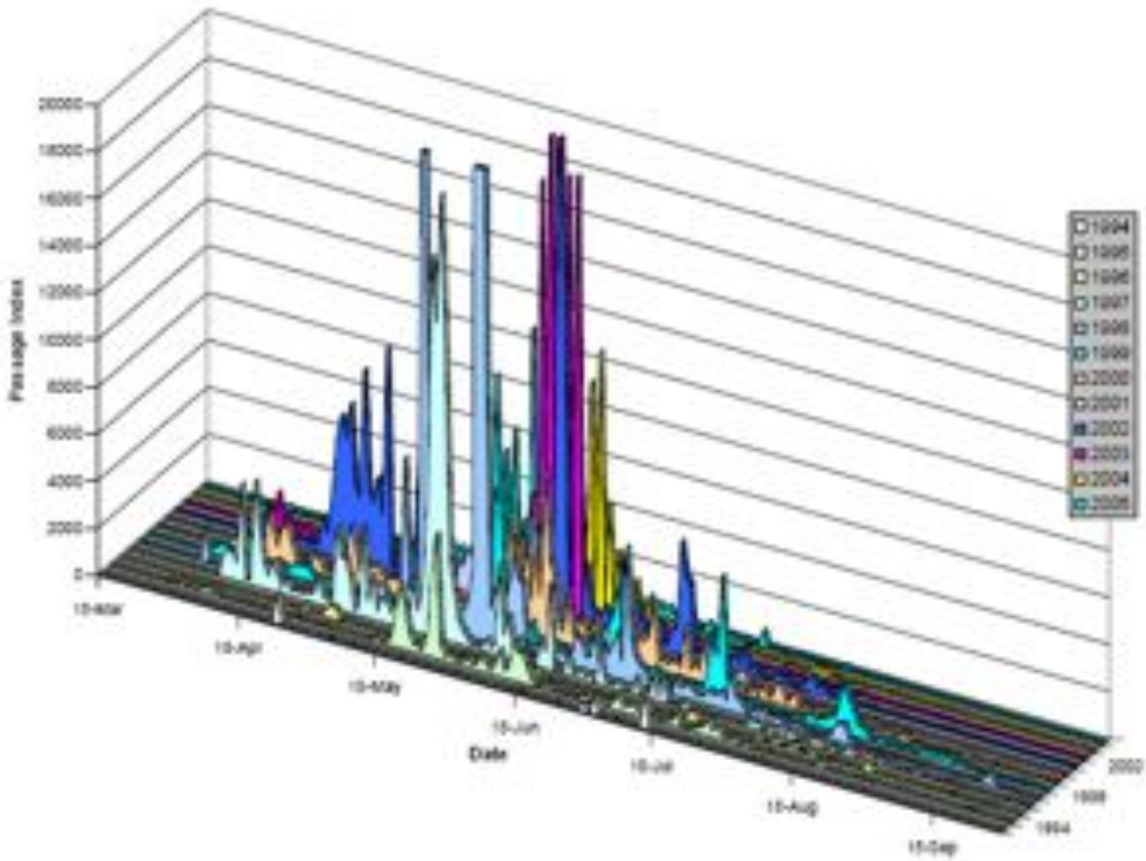

Figure 19. Juvenile lamprey run timing at McNary Dam from 1994–2005 (Bleich and Moursund 2006).

4.1.2.c Utilize juvenile tag technology and other methods to obtain route-specific passage and survival at mainstem dams

Existing tag technology/methods

There are few estimates of general and route-specific dam passage rates and survival for juvenile lamprey (Bleich and Moursund 2006). These deficiencies can be attributed primarily to gaps in active tagging technology and the fact that juvenile lamprey are difficult to tag due to small body cavity size and compatible tag material (Figure 20). Schreck et al. (2000) conducted a review of potential internal and external tags, for juvenile lamprey and concluded that battery size was a limiting factor for internal radio tags and that Passive Integrated Transponder (PIT) tags could not be detected within the current monitoring environment (i.e., over large expanses such as turbines or spillways). They also found that juveniles were able to extricate themselves out of external tags after several hours, and that the physical properties of water limited transmission ranges needed to effectively track juvenile lamprey (Schreck et al. 2000).

In 2006, further studies concentrating on the use of PIT tags indicated that juveniles >120 mm total length could be effectively tagged although mortality increased significantly with increasing water temperatures (Mueller et al. 2006). In a companion report, tagged individuals were successfully monitored passing through McNary and John Day dams although small sample sizes prevented robust statistical analysis (Bleich and Moursund 2006). Over the last few years, research has been conducted to determine physiological effects to lamprey with various tag shapes and sizes (Peery and Loge 2010).

PIT tag technology has been used effectively to monitor the movement, behavior and survival of juvenile salmon and steelhead within the Columbia River basin over the past 20 years (NPCC 2007). However, due to a variety of limitations (e.g., short detection range, tag orientation, site-specific conditions, etc.), a large number of tags are needed if statistically relevant conclusions from these tag data are desired (McMichael et al. 2010). Unfortunately, low abundance of juvenile lamprey and the logistical difficulties in obtaining them prevent the collection and tagging of the sample sizes required for PIT tag analysis if precise statistical estimates are required. Artificial propagation research could create relatively large juvenile lamprey sample sizes without "mining" the existing, dwindling population. Research has been recently conducted to develop standard tagging protocols for juvenile lamprey using PIT tags (Mesa et al. 2010; Mesa et al. 2011). However, larval and juvenile lamprey are prone to fungal diseases after tagging that often result in mortality (Mesa et al. 2010), so tagging protocols will need to incorporate strict measures to reduce lamprey exposure to fungal diseases.

Over the longer term, the development of acoustic technology for juvenile lamprey (e.g., JSATS), which requires the use of fewer tags due to increased detection efficiencies, may be critical in obtaining a better understanding of juvenile outmigration (McMichael et al. 2010). However, this technology has only recently been developed for juvenile salmon and is currently unavailable for use in juvenile lamprey because the tags and especially the batteries are too large for lamprey. More funding and effort will be required to expedite the development of lamprey specific tags. Research is currently underway to determine the biological criteria needed for an active transmitter for juvenile migrants (Peery and Loge 2010). Although these types of studies improve the knowledge base for tagging juvenile lamprey, they also highlight the need for more work. In short, acoustic telemetry application for juvenile lamprey remains undeveloped and uncertain and may not be available for field use until years into the future. Thus, for the near term, the use of existing tagging technologies and other tools are required to determine short-term impacts on juvenile lamprey, such as route specific dam passage.

Potential Near Term Tag Methods

Given the difficulties with internal active tagging technology and the dire need to resolve juvenile lamprey critical passage and survival uncertainties, the use of external tags may be an avenue to pursue as an immediate means to create dam route specific passage and survival rate estimates. Schreck et al. (2000) found that it took several hours for a juvenile lamprey with an external radio tag to extricate itself from the tag. Heisey et al.(1992) demonstrated that fish can pass through a dam passage route and be captured in the dam tailrace in less than 10 minutes.

Using the research by Schreck et al. (2000) and others, a balloon combined with radio tag technology primarily developed to estimate juvenile salmon survival rates through different dam passage routes could be used to estimate juvenile lamprey survival (Heisey et al. 1992). Lamprey could be fitted externally with the Turb'N Tag and introduced into turbine penstocks, spillways or bypass systems (Mathur et al. 1996; Heisey et al. 1992). The Turb'N Tag inflates after route of passage and buoys fish to the surface for recapture and examination; after removal of tags, fish are held to assess long-term effects. The method is applicable to a wide range of species and size and allows predetermination of statistically valid sample size, level of significance, and power of the test to determine need for mitigation measures (Mathur et al. 1996; Heisey et al. 1992). If enough data is gathered, route specific passage and survival indices could be developed in the near future. In addition, re-evaluation of PIT tag methods may provide an avenue to estimate juvenile lamprey passage, although many hurdles exist as described in the above section.

Fyke Net, Hydroacoustic and Screen Data

Regional lamprey scientists are discussing another approach to gaining additional information to obtaining, analyzing and summarizing juvenile lamprey approach and passage information by compiling and assessing historical fyke net and hydroacoustic data and perhaps instituting limited fyke net monitoring (Figure 21). Turbine, dewatering and raceway screens should be periodically inspected for juvenile lamprey impingement. Screens should be pulled before automated screen-sweeps remove impinged lamprey, and underwater video cameras should be mounted on screens. The Corps should coordinate closely with the tribes on these actions.

Figure 20. Inserting a PIT-tag into a juvenile lamprey (Bleich and Moursund 2006).

Figure 21. Fyke net removed from a turbine gatewell at John Day Dam (Moursund et al. 2003).

4.1.2.d Identify and implement longer term structural and operational improvements to mainstem dams to improve juvenile passage and survival through dams and reservoirs

During their juvenile outmigration, most lamprey within the Columbia River basin must pass through a series of dams and reservoirs before reaching the marine environment. At each individual hydroelectric project, passage must occur at the powerhouse through turbines or screened bypass systems, spillways, or through surface or sluiceway passage. Juvenile passage appears to vary annually and among facilities and river conditions (Bleich and Moursund 2006), although detailed temporal and spatial knowledge of juvenile outmigration remains limited. Juveniles appear to migrate past these facilities during freshets. However, where the bulk of juvenile passage is occurring and what specific physical and environmental variables guide these movements is uncertain. This overall lack of information limits the ability to accurately determine direct and cumulative effects of juvenile lamprey passage at hydroelectric facilities and to devise passage improvements.

For many years, the majority of juvenile lampreys were assumed to approach and pass dams near the bottom of turbine intakes. Among other things, this conclusion arose from the fact that juvenile lamprey lack a swim bladder, in contrast to juvenile salmon (Long 1968). However, some historical data indicates that juveniles may travel higher in the water column than previously believed. For example, juveniles at Priest Rapids were found in vertical fyke nets nearly equally from top to bottom (Carlson 1995) and 86% of juveniles found on the John Day Dam extended length turbine screens, were within the upper and lower 10% of the screen face (Figure 22). These data indicate the potential variability in juvenile outmigration patterns and life histories and highlight the need to better understand juvenile migration patterns at all mainstem Columbia and Snake River dams. This is due to structural and hydrologic variation that likely influences the timing and depth of juvenile passage. Macropthalmia appear to migrate higher in the water column than ammocoetes and therefore may be more susceptible to turbine screen impingement.

Despite the data and technological limitations, there is enough data available to highlight some problem passage areas and suggest potential solutions. Impingement of juvenile lamprey on turbine gatewells and vertical bar screens designed for juvenile salmon passage has been a documented source of juvenile mortality since being observed in the mid-1990's (Starke and Dalen 1995). Specifically, photographs of extended length vertical bar screens at John Day Dam provided evidence that large numbers of juveniles (n > 200) were being impinged and killed across the entire face of these structures (Figure 16). These findings were surprising given the fact that these observations were made in February, previously believed to be a relatively low juvenile migration period according to existing dam passage data from screen bypass system monitoring (Bleich and Moursund 2006). Juvenile lampreys appear to migrate during freshets that occur anytime of the year and thus are susceptible to screen impingement outside the spring and summer period.

In response to this observed impact, the Corps conducted underwater observations of extended length screens at McNary Dam as well as impingement studies at John Day Dam. These observations noted that 98% of juveniles were unable to free themselves from impingement at typical screen face velocities (Moursund et al. 2000). As evidence of impingement persisted, recommendations were made to mitigate these impacts by reducing screen gap size from 3.175 mm to 1.75 mm (Moursund et al. 2006; ISAB 2008). Due to several issues, the 40-foot extended length, fixed bar screens were never installed at John Day Dam although they had already been installed at McNary, Lower Granite and Little Goose dams with the larger gaps that cause impingement. The tribes requested that the Corps remove the screens during the peak of the juvenile lamprey migration as an interim measure before the screens could be replaced. Unfortunately, replacing the existing turbine intake screens with smaller gapped turbine intake screens could cost tens of millions of dollars (Clugston pers. comm. 2009). This appears highly unlikely as the overall Corps' annual budget for lamprey passage improvements under the Fish Accords is about $5 million. At this point, the screens remain and are likely a limiting factor for lamprey restoration.

The inadvertent transportation of juvenile lamprey with juvenile salmon downstream in trucks or barges has an unknown impact on lamprey, except there have been observations of juvenile salmon and steelhead preying on lamprey and vice versa. Moser and Russon (2009) attempted to use light to segregate lamprey juveniles out of the collection channel facilities and found that macropthalmia were stimulated by bright light, but only for short periods. They concluded that vertically oriented stainless steel mesh screens might function best to separate juvenile lamprey in screened bypass raceways constructed to hold juvenile salmon for truck or barge transportation. Although Corps biologists have concentrated on finding methods for safely routing juveniles into tailrace areas, more work is needed in these passage locations.

In laboratory studies, Moursund et al. (2000) concluded that juvenile lamprey ammocoetes were likely less affected by turbine sheer and pressure changes than juvenile salmon. However, turbine blade strike and cumulative effects were not examined. Due to lack of appropriate tagging technology, no studies have been conducted to date regarding juvenile lamprey survival through actual dam turbines or spill.

The need to establish route specific survival rates is critical and should be expedited by using available technology as well as developing effective advanced juvenile tags as quickly as possible. In the meantime, development of juvenile passage standards should be a regional priority, which will require consolidation of all known juvenile lamprey passage data, cooperation with the tribes, as well as input from regional experts such as the CRBLTWG. As information for juvenile passage improves it will be easier to establish survival targets for juvenile lamprey similar to those of juvenile salmon (i.e., 93%–98% NOAA 2008).

Because many lamprey tend to migrate at a variety of depths in the water column, surface bypass systems with deep slots like those installed at Wanapum Dam could be a passage solution that would benefit both juvenile lamprey and juvenile salmon (Figure 23). The structure consists of a 75-foot deep slot located between the powerhouse and spillway that can pass water at 20 kcfs. The structure has been successful in achieving a 95% or better juvenile salmon survival rate (Timko et al. 2011). The tribes strongly recommend that the Corps and other mainstem dam operators consider this passage technology in their configuration and operations planning processes required in the 2008 FCRPS Salmon Biological Opinion (NOAA 2008).

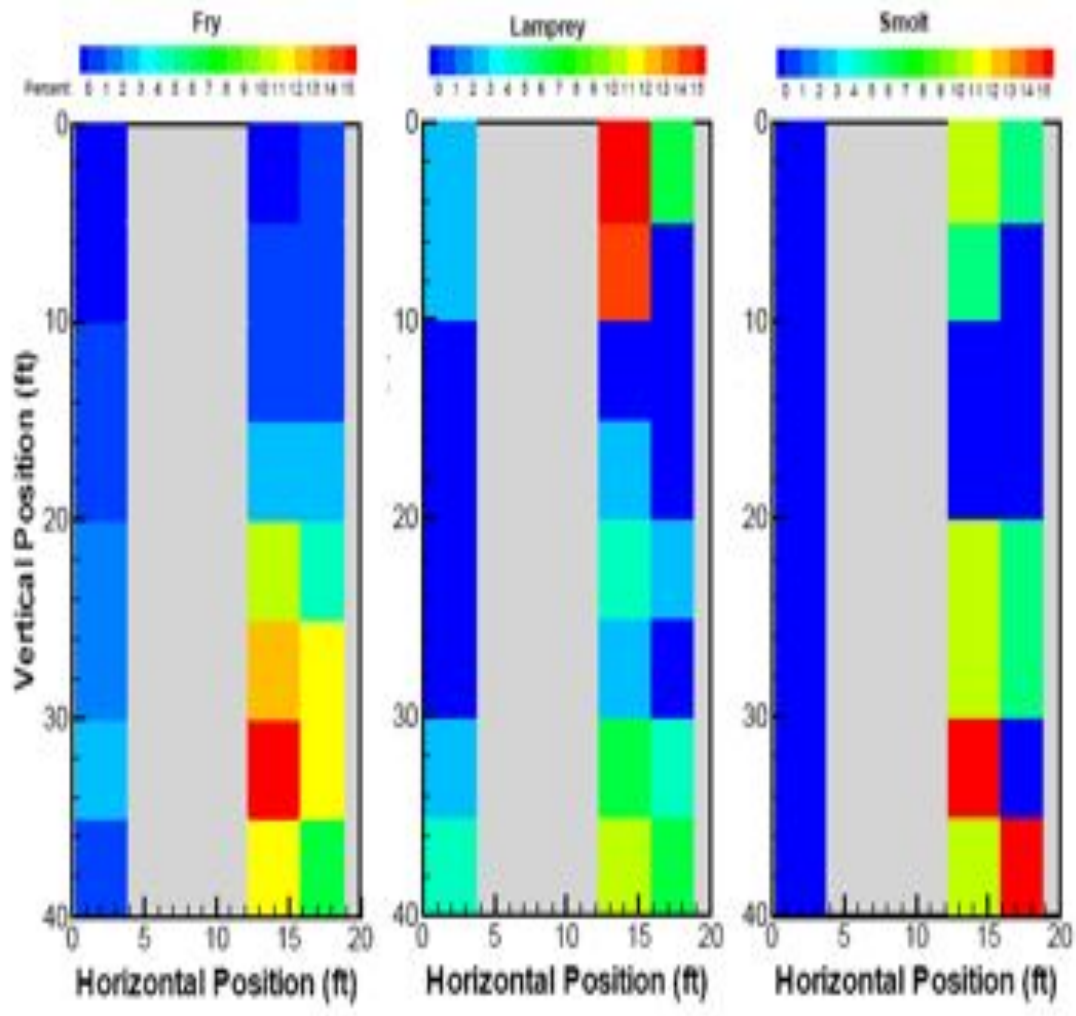

Figure 22. Juvenile salmon and lamprey vertical and horizontal distribution on a turbine screen as denoted by underwater cameras. Gray areas not sampled. Units in feet. (Moursund et al. 2003).

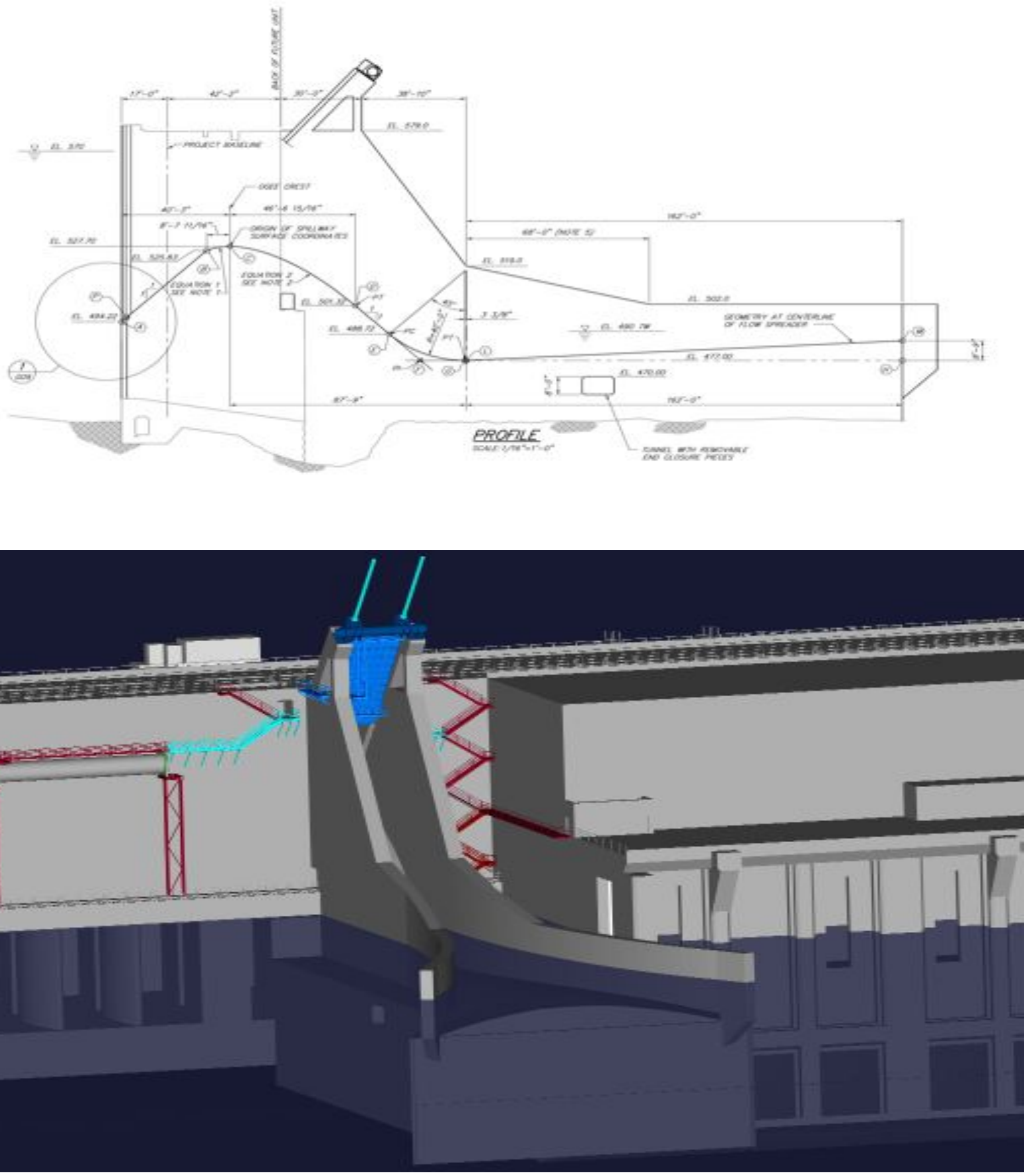

Figure 23. Wanapum Dam deep slot bypass structure (Dotson 2010).

4.1.3 Mainstem and Estuary Habitat

Mainstem and Estuary Habitat Actions

a. *Identify lamprey life histories and impacts through temporal and spatial assessments of mainstem and estuary habitats*
b. *Evaluate and reduce avian, piscivorous, and mammalian predation*
c. *Apply USFWS best management practices relative to mainstem dredging activities*

4.1.3.a Identify lamprey life histories and impacts through temporal and spatial assessments of mainstem and estuary habitats

The more than 200 dams on the mainstem Columbia River have dramatically altered the pre-European river hydrograph (Hamlet 2002). Average historical peaking flows around 550 kcfs have been reduced to about 300 kcfs. As the result of flood control, hydropower production, and irrigation and municipal water withdrawals, peak flows were especially diminished following the installation of major dams in British Columbia and the United States as required under the Columbia River Treaty (Hamlet 2002). Loss of the peak flows has likely increased the juvenile lamprey travel time through the hydrosystem and may have affected adult lamprey migration by altering thermal regimes and reducing mainstem habitat.

Most of the available adult lamprey life history information in the mainstem Columbia River has been obtained through various radio-telemetry studies already referenced in the mainstem passage section of this Plan. However, because of the depth of the Columbia River, detection of radio-tagged adult lamprey in reservoir environments is difficult. Driven by the large loss and unknown fate of adult lamprey between Bonneville and The Dalles dams based upon differences in counts, the Corps began funding acoustic telemetry research (JSATS) in 2010 to determine the fate of adult lamprey in the Bonneville pool (Naughton et al. 2011). In the shallower Willamette River, detailed research on adult behavior, migration and habitat preference is currently being conducted (Clemens et al. 2011).

Within the Columbia River basin, juveniles appear to outmigrate through the mainstem and estuary from March to August in approximate correlation with spring discharge (Bleich and Moursund 2006). Although there is considerable variation in passage rates and run timing through the system, available data indicates that peak passage rates coincide with late spring and early summer freshets (Figure 19). Juvenile lamprey are relatively weak swimmers when compared with juvenile salmon (Moursund et al. 2000) and may take advantage of high flow events to minimize energy use prior to their physiological transition to saltwater.

Given that juvenile lamprey travel time appears related to water particle travel time, increases in freshet flows will likely reduce lamprey travel time (Bleich and Moursund 2006). Thus, managing flows to a peaking hydrograph will benefit juvenile lamprey as well as juvenile salmon. Flow augmentation, reducing water withdrawals, reservoir drawdown and achieving upper rule curves at storage reservoirs before the spring freshet are all potential tools to increase flows and establish a peaking hydrograph (ISG 1996; ISAB 2001; Bunn and Arthington 2002).

The USFWS Fisheries Assistance Office staff are sampling larval lamprey at considerable depths in the Willamette and Lower Columbia rivers, employing a combination electrofishing/suction apparatus used to sample larval lamprey in the Great Lakes (Jolley et al. 2010; Jolley et al. 2011a; Jolley et al. 2011b). These researchers found a juvenile lamprey in bottom sediments while randomly surveying the Columbia River near Portland International Airport indicating the possibility that juveniles may be rearing in mainstem and periodically "disturbed" areas, such as those scheduled for dredging or construction projects (e.g., Columbia River Crossing). The tribes recommend that lamprey surveys of project areas that will be disturbed by pile driving or dredging, for example, occur well before such project activities begin. Specifically, the following actions should be conducted:

- Conduct seasonal larval surveys within the entire project footprint before, during, and after project completion using a systematic sampling design such as that employed by Jolley et al. (2010), Jolley et al. (2011a) and Jolley et al. (2011b).
- Conduct multiple surveys throughout the year to assist in understanding temporal changes in lamprey abundance and distribution.
- Assure that mitigation efforts are designed to provide a variety of habitats for lamprey (e.g., backwater and depositional areas for larval and juvenile lamprey).
- Consider obtaining other information from these surveys (e.g., lamprey distribution, toxicology loads, and genetic data).

There are key uncertainties surrounding lamprey estuary and marine life histories, as noted by the ISAB (2009). The tribes are actively involved and soliciting partnerships with other agencies in the region to examine marine life history threats and uncertainties.

CRITFC is collaborating with the Corps to gather any data available on lamprey impacts from mainstem and estuarine dredging. CRITFC is collaborating with CMOP on modeling lamprey habitat preferences in the estuary based on water quality and physical and biological limiting factors (e.g., salinity, velocity, depth and temperature). Improved lamprey tagging technology may create the potential to link lamprey movements through mainstem, estuary and ocean habitats by the use of observational and forecasting systems, as demonstrated by Truelove et al. (2007), Bottom et al. (2005) and Fresh et al. (2004). As there is little empirical lamprey saltwater habitat information specific to the Columbia basin, CRITFC proposes to hold a regional marine lamprey habitat and life history workshop with regional experts to begin to gather data and information on these issues. Analysis of lamprey prey populations should be included in these investigations, particularly fish populations such as Pacific hake and salmon (Orlov et al. 2008; Pelenev et al. 2008).

4.1.3.b Evaluate and reduce avian, piscivorous and mammalian predation

Over the last few years the Corps has documented accelerating predation on adult lamprey by California and Stellar sea lions below Bonneville Dam (Figure 24; Stansell 2007). Under an amendment of the 1972 Marine Mammal Protection Act, Washington State and Oregon gained authority to capture and remove a limited number of particularly persistent California sea lions[1] that prey on salmon, sturgeon and lamprey in the Bonneville Dam tailrace. More recent litigation resulted in court orders that removed this authority.

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[1] Stellar sea lions are granted higher protection than California sea lions under existing laws and regulations and, unlike California sea lions, cannot be captured or euthanized.

However, legislation has passed through part of Congress to restore the state authorities to capture and euthanize some problematic sea lions. It is important that the effort to reduce lamprey predation from sea lions be increased and perhaps even expanded to areas above and below Bonneville Dam.

Avian predation on lamprey has been observed in dam forebays and tailraces however there has been little quantification of the true impact. Predation on lamprey appears to be greater below powerhouse turbines and screened bypass outfalls than spillways (PSMFC 2011; ODFW 2011; WDFW 2011). There appears to be some data obtained at bird colonies with respect to lamprey predation. For example, using a bioenergentics approach developed by Roby et al. (2003), consumptive rates of lamprey ammocoetes were calculated from 33,000–121,000 by East Sand Island Caspian Terns from 2004–2007 and from 140,000–2.72 million from 2004–2006 by East Sand Island Double Crested Cormorants (Figure 25). Efforts to gain more qualitative and quantitative data on lamprey predation must be accelerated including focused surveys of avian and piscivorous predation.

A literature review summarizing published and gray literature related to the temporal and spatial aspects of lamprey predation is recommended to assist in devising remedies to reduce this key limiting factor.

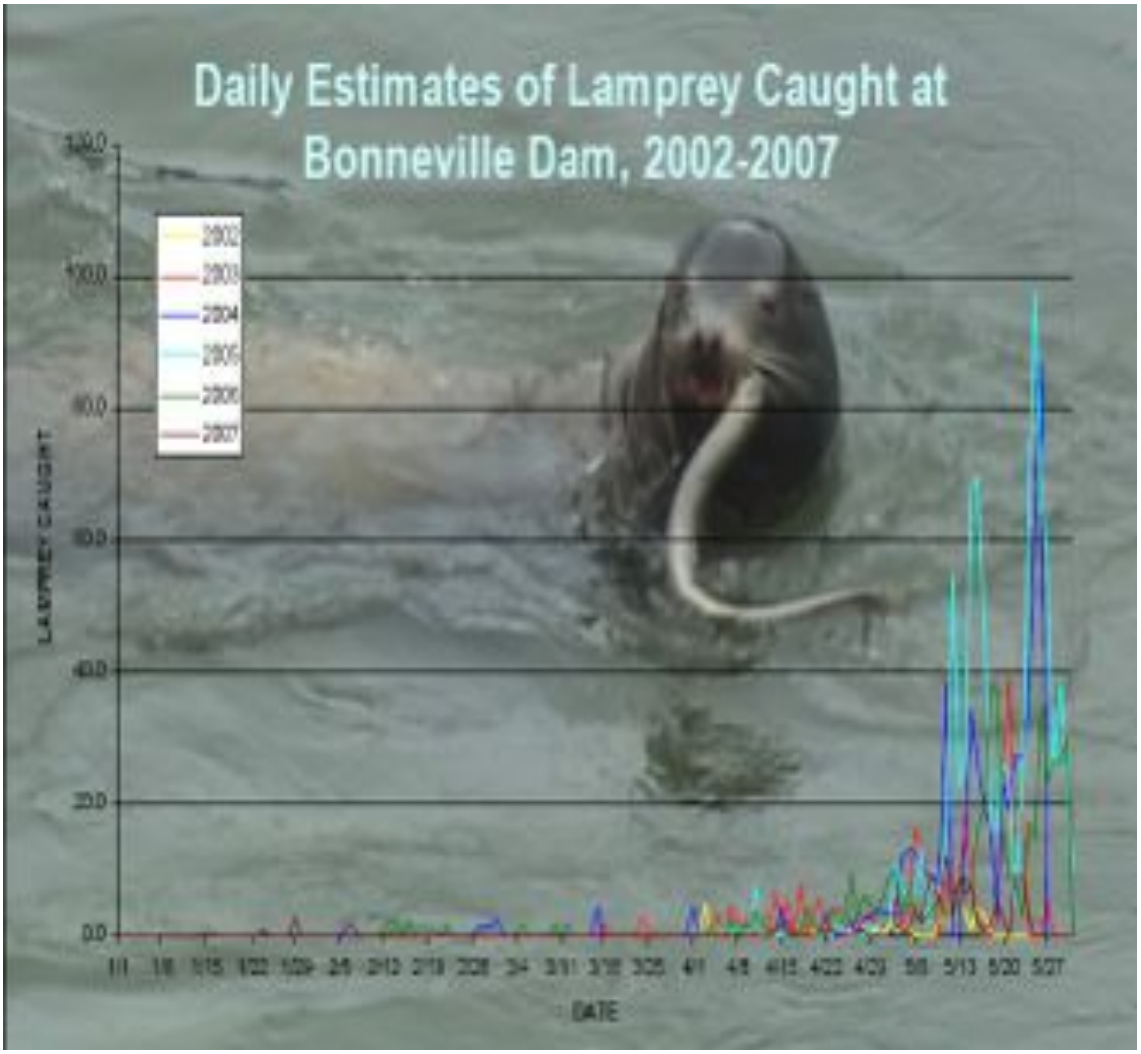

Figure 24. Lamprey predation estimates from USACE observations at Bonneville Dam (Stansell 2007).

Figure 25. Avian predation on juvenile lamprey on Crescent Island in the Mid-Columbia River (Evans 2008).

4.1.3.c Apply USFWS best management practices relative to mainstem dredging activities

The effects of mainstem Columbia and Snake River dredging on juvenile lamprey are largely unknown, since dredging activities in the past have not been adequately monitored. In 2010, the CRBLTWG established a subcommittee to address dredging impacts on juvenile lamprey and recommended sampling and physical assessment of proposed dredging areas for the presence of juvenile lamprey before dredging occurs. Sampling and assessment techniques are described in the USFWS Best Management Practices (USFWS 2010) and in more detail in Jolley et al. (2010). The tribes strongly recommend that the Corps, ports and others engaged in dredging actions follow these guidelines and closely coordinate these activities with the tribes, the USFWS and state fishery agencies. In addition, all existing sediment management plans and procedures established by the Corps and others should be revised to contain the USFWS guidelines.

4.2 Tributary Passage and Habitat

Objective 2: Improve tributary passage and identify, protect, and restore tributary habitat

Pacific lamprey were once abundant throughout the Columbia River basin. Many tribes, including CRITFC member tribes, traditionally relied on the annual return of lamprey for food and medicine. The Nez Perce, Umatilla, Warm Springs and Yakama tribes are implementing conservation, research, and restoration activities on their ceded lands within Columbia River tributaries. Each tribe has developed a plan that includes research, monitoring, and evaluation, as well as objectives, locations, status, and schedules of these proposed activities. These plans are designed to ultimately address passage and habitat issues faced by Pacific lamprey within the tributary environment and are summarized in Appendix A.

4.2.1 Tributary Passage

Tributary Passage Implementation and Actions

a. *Implement structural and operational changes within tributaries to improve adult passage*
b. *Implement structural and operational changes within tributaries to improve juvenile passage*

4.2.1.a Implement structural and operational changes within tributaries to improve adult passage

Low-elevation diversion dams for irrigation or municipal uses affect the migration of adult Pacific lamprey. For example, in 2005 the CTUIR documented that low-elevation irrigation diversion dams were problematic for successful adult upstream passage. These results demonstrated that adult migration passage rates were worse than that through mainstem dams (Close et al. 2008). To address these impacts, in 2008 the CTUIR began development of lamprey-specific passage structures (e.g., LPS) to improve passage effectiveness at low-elevation diversion dams within the Umatilla River. These structures demonstrated increased passage success at Threemile Falls Dam on the Umatilla River (Figure 26). Similarly, the Yakama Nation, in coordination with the BOR and the USFWS recently began a three-year evaluation of adult passage over irrigation diversions in the Yakima River basin. If passage over these structures is determined to be problematic, LPS may be installed in this basin as well.

As noted in the adult mainstem passage section of this Plan, since 2005 similar LPS have been in place at Bonneville Dam and they have proven to increase overall passage success (Moser et al. 2006). The tribes believe it would be beneficial for adult lamprey if potential passage is assessed at all channel-spanning irrigation diversions. Based on the assessments, LPS and other appropriate passage structures in tributaries that have irrigation and other water withdrawal projects should be constructed and evaluated.

The tribes recommend that the U.S. Forest Service coordinate inventories and implementation of passage improvements specific for lamprey at culverts in forest management lands with the tribes and other agencies.

Further, the tribes recommend the establishment of tributary land and riparian conservations easements for lamprey in coordination with salmon and wildlife conservation easements throughout the basin.

Figure 26. LPS system installed for adult lamprey passage over Three Mile Dam, Umatilla River, Oregon (Jackson 2011).

4.2.1.b Implement structural and operational changes within tributaries to improve juvenile passage

High Head Dam Passage

Juvenile lamprey passage through mainstem facilities at high head dams needs additional research. The Confederated Tribes of the Warm Springs have demonstrated successful juvenile salmon passage at the Pelton-Round Butte tower facility (Houslet pers. comm. 2011) and this concept may be considered for juvenile lamprey passage at Lake Billy Chinook in the Deschutes Basin and at other tributary high head dam sites. The recent removals of Powerdale Dam in the Hood River and Condit Dam in the White Salmon River offer availability of good tributary habitat previously blocked for nearly 100 years.

Tributary Screens

Juvenile lampreys are impacted by low-elevation water diversion screens within tributaries. Juveniles migrate downstream from the tributaries during high flow periods and passively migrate past low-elevation irrigation and other water withdrawal facilities. State-of-the-art screens designed for salmonids have not proven effective at reducing juvenile lamprey entrainment. In 2009, the CTUIR electrofished behind the drum screens at Westland and Maxwell diversion dams in the Umatilla River and found the presence of larval lampreys at these sites, indicating the screens failed to keep lamprey out of the irrigation facility (Figure 27; Jackson 2009). In 2010 the Yakama Nation initiated preliminary juvenile surveys in several irrigation ditches and found many lamprey (primarily brook lamprey) within the ditches and behind the screen systems. More comprehensive surveys are planned over the next few years to determine the extent of juvenile entrainment behind these screen systems.

Juvenile entrainment behind irrigation screens presents a major problem for recovery of lamprey within various tributaries where multiple irrigation projects exist. Specifically, there is no protection for juvenile lamprey once they are behind drum screens—they are literally pumped out onto agricultural fields, resulting in mortality (Figure 28). Further assessment of juvenile lamprey impacts from drum and belt screens is warranted (Figure 29 and Figure 30). The tribes need assurance that juveniles can safely migrate out of tributaries. A former screen trap operator for the Oregon Department of Fish and Wildlife, stated that lamprey were highly visible and present at irrigation projects within the Umatilla River. He further stated that the large lamprey presence created a "nuisance to irrigation operations" (Jackson et al. 1996).

The USGS is currently leading a multi-agency funded investigation to develop screening criteria that would benefit juvenile lamprey and juvenile salmon survival at these projects (Rose and Mesa 2011). The tribes recommend that additional funding be provided to finish design and prototype development. The tribes also recommend that responsible agencies support expedited implementation of recommendations that are developed from this screen criteria research. Given there are thousands of irrigation and other water diversion screens that need to be modified to improve lamprey passage, a multiyear funding and screen implementation schedule should be developed as soon as possible. In addition, the tribes urge the NPCC, BPA and other funding entities to cease installation of screens that meet salmon criteria but do not protect juvenile lamprey. Regional funding sources should be applied to installation of screens that meet both salmon and lamprey criteria.

According to the Fish Accords, the BOR was to complete an inventory of their projects and evaluate potential impacts to lamprey, beginning in the Yakima and Umatilla basins and subsequently proceed to assess other diversion structures in other basin tributaries. In December 2010, the BOR released a draft *Assessment of U.S. Bureau of Reclamation Projects in the Columbia River Basin: Effects on Pacific Lamprey (Lampetra tridentata).* This draft report is a good start towards defining impact assessments and in some cases implementing restoration actions in the Umatilla and Yakima basins. However, it remains unclear what future actions the BOR will fund and implement to improve lamprey passage and habitat in these two basins and in other basins where BOR water withdrawal facilities exist.

The tribes recommend that the BOR, private irrigation districts and other water users within the Columbia River basin investigate and implement operational and structural changes that will facilitate safe juvenile lamprey passage past screened irrigation and other water withdrawal projects. Immediate actions should include the gradual ramping down of flow in irrigation canals in the fall to reduce lamprey stranding and desiccation and implementing juvenile lamprey salvage during the ramping down period. Complete inventories of all Columbia basin tributary diversion facilities and evaluation of their impacts on lamprey needs to be finalized in an expedient manner. The focus of these activities should be on reducing juvenile entrainment, improved screen design and adult passage improvements. The tribes strongly encourage BOR to closely refine tribal/BOR evaluations to prioritize actions so that appropriate near term and longer term funding can be established in a timely manner. These efforts should be expedited to accommodate other regional planning efforts for lamprey recovery.

The tribes also encourage BOR to assist the tribes in addressing lamprey impacts on private irrigation district facilities. Such work should be closely coordinated with the tribes, USFWS, local irrigation districts and state fishery agencies and should include periodic inspection and maintenance of seals, screens and remote power sources to insure compliance.

Figure 27. CTUIR biological staff sampling for larval lamprey behind Umatilla River irrigation diversion dams (Jackson 2009).

Figure 28. Drum screen at irrigation diversion (BOR 2003b).

Figure 29. Traveling belt screen (BOR 2003b).

4.2.2 Tributary Habitat

Tributary Habitat Implementation and Actions

a. *Restore and protect migratory, spawning, and rearing habitat*

4.2.2.aRestore and protect migratory, spawning, and rearing habitat

Just as habitat degradation in Columbia basin tributaries has impacted salmonid production (e.g., stream channelization, sedimentation, overgrazing, etc.), it has also been damaging to lamprey. Spawning habitat requirements for Pacific lamprey appear similar to steelhead as lamprey require high quality tributary streams with clean water and abundant streambed gravels. Human development that modifies streams diminishes these critical habitat characteristics, which results in negative impacts on salmon and lamprey. Numerous restoration planning efforts such as subbasin plans (NPCC 2009) and ESA Recovery Plans (NOAA 2008) have identified extensive habitat restoration needs that will benefit salmon, lamprey and other native species.

As noted in the lamprey life history section of this Plan, juvenile lamprey-rearing habitat differs from salmonids in that larval and juvenile lamprey dwell primarily in low velocity, sediment laden stream sections where they filter feed. Although salmonids do not live and rear in sediments, a healthy and diverse river system that is not heavily affected by channelization or dewatering will contain both salmonid and lamprey rearing habitats.

The tribal mission for tributary habitat restoration programs is based on recreating natural river floodplain conditions described in a Umatilla River Vision (Jones et al. 2008). These concepts can be used to guide stream habitat protection and restoration in all Columbia basin tributaries. A brief summary of this document follows:

> *The CTUIR DNR's First Foods-focused mission aims to maintain a functional Umatilla basin by embracing an expansive view of "water quality" that includes a functional river and associated processes for the sustained longevity of First Foods. This mission calls attention to the maintenance of water quality by focusing on the ecological health of the Umatilla River, which provides riverine First Foods (water and salmon). A target vision for a healthy Umatilla River reflects a river that is highly dynamic and shaped by not only physical and biological processes but also interactions and interconnections among those processes. Such a vision requires that managers incorporate several attributes of the Umatilla River into management and restoration strategies. Strategies should emphasize the importance of: 1) hydrology (including the timing, volume, and quality of water flows); 2) geomorphic processes; 3) longitudinal, lateral, and vertical connectivity among habitats and across the network; 4) the health of the riparian vegetative community; and 5) the health of the native aquatic species. Within this framework, habitat monitoring and restoration efforts can concentrate on improving the ecological functionality of the Umatilla River, which ultimately sustains First Foods.*

With respect to field evaluations of lamprey and their tributary habitats, the tribes recommend that agencies implement and comply with field actions found in the USFWS Best Management Practices for Lamprey (USFWS 2010).

Tributary Flows

Additional flow in tributaries appears important for juvenile migration. Juvenile lamprey sampling in screw traps indicate that high flow decreases juvenile lamprey migration time in the Umatilla River (Jackson pers. comm. 2011) and may stimulate initial downstream migrations (Everson 2002). More migration studies are recommended to elucidate the environmental conditions that trigger lamprey movement within and through tributary systems.

4.3 Supplementation/Augmentation

Objective 3: Supplement/Augment interior lamprey populations by reintroduction and translocation of adults and juveniles into areas where they are severely depressed or extirpated

As previously mentioned in this Plan, the tribes believe the most urgent threat facing adult lamprey is surviving upstream and downstream passage (e.g., fall back through dams) through the hydrosystem and tributary barriers. Despite a variety of structural and operational changes that have improved passage at a few locations (USACE 2011), most of the annual adult run is still "lost" at each successive hydroelectric dam and reservoir. As noted in Objective 1 of this Plan, adult Pacific lamprey passage efficiency past mainstem dams averages only about 50% per dam and passage success is less for smaller lamprey (Moser et al. 2002; Keefer 2009c). Data reported by Moser et al. (2002a) indicate that the mean annual passage rate from below Bonneville Dam to areas above John Day Dam was only 3%. All available indices indicate severely declining numbers and precarious status of the species (USFWS 2011).

The cumulative effect of successive passage losses may be especially pronounced for lamprey productivity in interior Columbia River basin tributaries (e.g., Yakima, Umatilla, Walla Walla, Okanogan, Methow, Wenatchee, and Snake River tributaries) where adult lamprey must ascend at least 3–8 dams and numerous smaller tributary passage barriers to access upstream spawning habitat. Extremely few adult lamprey appear to be entering these areas as evidenced by low annual adult counts at Lower Granite (n = 15) and Wells dams (n = 9) (DART 2010). Declining adult returns to these areas reduces larval recruitment in spawning streams. This may limit future adult returns to these areas if returning adults are attracted to pheromones produced by larval and juvenile lamprey. For example, Cochnauer and Claire (2002) found only 541 ammocoetes in sampling 70 sites in five major tributaries of the Lower Snake River. These results were corroborated by additional surveys in the Grand Ronde, Tucannon and Walla Walla rivers (Moser and Close 2003). In 2010–2011, Yakama Nation surveys in the Yakima basin revealed low ammocoete abundances (Luke pers. comm. 2011). In addition, in the Deschutes River, ammocoete surveys in 2003–2004 indicated that only 27% of streams in the watershed contained larval or juvenile lamprey (Graham and Brun 2005).

In view of the depressed status of the lamprey in Idaho streams still accessible to adult lamprey, Cochnauer et al. (2005) proposed translocation of pre-spawn adults from downstream Columbia River locations and supplementation with hatchery spawned ammocoetes into suitable habitat as a recovery strategy that should be considered. This proposal was made prior to the record low, daytime count of 10 adults passing Lower Granite Dam in 2009. As noted elsewhere in this Plan, adult lamprey counts are even lower in the Upper Columbia.

Considering the current adult lamprey returns, especially in the interior basin watersheds, the existing passage environment and other long term threats, the tribes do not believe that natural recolonization and restoration will be enough to halt the lamprey decline. Alternative management strategies, including translocation, propagation, reintroduction, and augmentation, will be required for short and long-term preservation of this species in the Columbia basin (PRTA; George et al. 2009). These methods are especially important to lamprey restoration, considering emerging evidence of an association between juvenile lamprey pheromones and adult returns (Sorensen et al. 2005; Close et al. 2009; Docker et al. 2010).

Since 2000, the CTUIR and the Nez Perce Tribe have been actively translocating adult lamprey to bypass difficult migration corridors, reestablish populations in severely depressed or extirpated locations, and maintain lamprey presence within interior portions of their historical range (Close et al. 2009; Nez Perce 2010). Monitoring and evaluation for these actions has been detailed in the: 1) *Restoration Plan for Pacific Lamprey (Lampetra tridentata) in the Umatilla River, Oregon* (Close 1999); 2) results of the implementation of this plan (Close et al. 2009); and 3) *Translocating Adult Pacific Lamprey within the Columbia River Basin: State of the Science* (CRBLTWG 2011). In addition, the Yakama Nation is assessing a similar translocation approach in various ceded area watersheds and expects to initiate translocation programs in 2012 and 2013. These approaches can be used as the foundation for continuing monitoring and evaluation of lamprey supplementation/augmentation efforts.

The tribes recognize and acknowledge valid questions raised by others in the Columbia basin about adult lamprey collection and translocation and whether these efforts are ultimately a “threat” to lamprey restoration (USFWS 2011; Luzier et al. 2009; ISAB 2009). However, the tribes consider translocation a necessary tool to provide successful passage over mainstem dams and tributary barriers until adequate passage is achieved. As noted below in Section 4.3.1a, the tribes have established conservative translocation guidelines for removing up to 4% of an annual adult migration based on prior adult lamprey counts at Bonneville Dam. Without translocation, the ecological threat of local extirpations, including the loss of juvenile pheromones that likely guide adults into preferred spawning areas, is virtually certain. In short, a closely monitored and evaluated translocation strategy is an important, interim measure that is critical to the long term restoration of Pacific lamprey—the benefits outweigh the risks. By implementing these types of programs, the tribes are attempting to preserve and enhance: 1) the ecological integrity of basin watersheds and, 2) the potential for future harvestable returns of adult lamprey in areas traditionally fished by Columbia River basin tribes.

Development of a regional supplementation program is also important in lamprey to restoration efforts. Among other things, artificial propagation would:

- provide researchers with an alternative supply of study organisms for passage and survival studies addressing known threats and critical uncertainties; and
- eventually allow managers to augment and reestablish lamprey throughout much of their historical range using artificially propagated fish.

Existing regional and international research indicates that artificial propagation of lamprey can be achieved, although many unknowns specific to Pacific lamprey do exist (Greig and Hall 2011).

The tribes believe that it is important to: 1) develop a regional research and supplementation/augmentation plan, 2) establish basic artificial propagation protocol that include both translocation and artificial propagation as critical components, and 3) concurrently develop aquaculture facilities. These actions will be initiated in 2012 in coordination with management and academic communities.

4.3.1 Supplementation/Augmentation

Supplementation Implementation and Actions

a. *Continue translocation in accordance with tribal guidelines*
b. *Develop and implement lamprey translocation as a component of a regional supplementation plan*
c. *Develop and implement lamprey artificial propagation as a component of a regional supplementation plan*

4.3.1.aContinue translocation in accordance with tribal guidelines

As noted in the above general description of this objective, as part of a detailed and peer-reviewed restoration plan for Pacific lamprey in the Umatilla River, the CTUIR has been actively translocating adult lamprey into the Umatilla River from Lower Columbia mainstem dams since 2000 (Close 1999). This initial plan included selecting an appropriate donor lamprey group for translocation, identifying suitable and sustainable habitat within the basin for holding, spawning, incubation and rearing. Adult spawning success, juvenile growth, density, outmigration and adult returns are key monitoring and evaluation components (Close 1999). Translocation efforts have been successful at increasing adult spawning activity, larval recruitment, and larval distribution in the Umatilla River and have provided important Pacific lamprey life history information (Close et al. 2009; CRBLTWG 2011; Appendix A). For example, juvenile lamprey originating from the upper portion of the Umatilla River have been detected downstream near the river mouth at Three Mile Dam (Jackson pers. comm. 2011). One hundred adult lamprey entered the Umatilla River in 2011—the most in recent years—indicating that the Umatilla translocation program may be assisting in increasing adult returns to that river (James pers. comm. 2011). The Umatilla lamprey translocation program provides a foundational framework for adult lamprey translocation, on which the Nez Perce and Yakama tribes have based their translocation programs (McIlraith 2011; Appendix A).

On careful deliberation, CRITFC's member tribes adopted *Tribal Guidelines for Translocation*. These were adapted from the Umatilla Lamprey Restoration Plan (Close 1999) and are consistent with international translocation guidelines (IUCN 1998; George et al. 2009). They are included in a regional review of lamprey translocation and have been modified in response to declining adult returns at lower Columbia dams (CRBLTWG 2011).

Tribal Guidelines for Translocation

Prior to implementing translocation collection efforts each year, representatives from each CRITFC member tribe will present a plan that includes all pertinent information (e.g., collection location, timing of collection, number of adults to be collected, release location, monitoring actions, consistency with Columbia basin Accords), to CRITFC policy representatives for review and comment. Collection plans will be presented for review by each individual tribe at the March CRITFC Commission meeting each year.

For lamprey targeted for collection, especially during the active migration season from mainstem dams, the following guidelines will be applied:

1. The target or recipient subbasin formerly (or currently) sustained a Pacific lamprey population. Where data is lacking, tribal oral histories may be used.
2. The problems that lead to the reduction or demise of Pacific lamprey in a recipient subbasin have been or are being addressed (e.g., dewatering, passage barriers, chemical treatments, etc.). The tribes have a checklist for each translocation site. *See* Appendix A, showing individual ceded area plans.
3. The existing recipient subbasin Pacific lamprey population has been determined to be below a harvestable, sustainable level and cannot recover without supplementation/augmentation.
4. Implement the following to minimize impacts on donor populations:
    a. Collection of donor lamprey for translocation should occur at mainstem dam locations, which are as near as possible to receiving tributary locations. It is understood that collection at Snake River and upper Mid-Columbia dams is likely not possible due to extremely low counts in recent years.
    b. Maximize opportunities to collect lamprey at current specific mainstem dam locations where migration is likely to be delayed or blocked, for example, behind picketed areas or "pockets." As passage actions remove such impediments, collection opportunities should diminish.
    c. Total collection of adult lamprey during the active migration at Columbia River dams by the CRITFC tribes shall not exceed 4% of the two-year running average of the total adjusted count[2] of upriver annual adult lamprey population based on total counts past Bonneville Dam (1% per tribe per year). Should additional adult lamprey be available from

[2] Adjusted count refers to the total adult lamprey passing over Bonneville Dam via multiple passage routes including 24-hour night counts at fish counting stations and LPS counts.

dewatering dam passage facilities, these may be in addition to the 4% collection rate.

d. At any project other than Bonneville Dam (because the 4% applies to Bonneville Dam), the total collection of adult lamprey during the active migration at any Columbia River dam by the CRITFC tribes shall not exceed 10% of the two-year running average of the total estimated upriver annual adult lamprey population based on total estimated counts past that dam. Should additional adult lamprey be available from dewatering dam passage facilities, these may be in addition to the 10% collection rate.
e. Considering the above guidelines (a–d), each year CRITFC Commissioners will review the four tribes' specific collection plans.
f. If Columbia River mainstem lamprey counts continue to decline, tribes implementing translocation may collect at least 100 lamprey each to maintain programs as long as the sum of the annual tribal proposals reviewed by the CRITFC Commission does not exceed the 4% guideline in 4.c. above.
g. If the sum of the annual tribal proposals reviewed by the CRITFC Commission exceeds the 4% guideline 4.c. above (i.e., tribal collection programs cannot receive a 100 lamprey minimum), the CRITFC Commission will convene a discussion to consider use of the Willamette River as a source for lamprey translocation above Bonneville Dam.
h. The CRITFC Lamprey Task Force will review Bonneville Dam counts for an in-season run size update. Collection levels might be adjusted if historic data indicates that the actual returns will differ significantly (more or less) than the 2-year average on July 7.

5. Disease clearance or screening will be conducted before translocation takes place on the donor population; a fish pathologist will approve the results. (The process will be similar to that used for salmonid transfers). Ongoing translocation projects will incorporate this safeguard.
6. Regulatory requirements will be addressed (NEPA, ESA, fish collection permits, USACE FPOM, etc.), if applicable.

4.3.1.b Develop and implement lamprey translocation as a component of a regional supplementation/augmentation plan

Current and future translocation actions will be guided by the lessons learned from ongoing tribal efforts (Close et al. 2009; McIlraith 2011) as well as the existing body of knowledge related to species reintroduction (IUCN 1998; George et al. 2009). In general, tribal translocation strategies will: 1) utilize historical and tribal records of basin lamprey distribution, abundance and habitat to determine out planting priorities; 2) use the best available knowledge to evaluate if translocation is necessary; 3) choose donor sources wisely and make efforts to minimize negative effects on donor groups; 4) monitor and improve collection, transport, and holding protocols and facilities; 5) evaluate and select target streams, release locations and timing of releases using the best available knowledge; 6) closely monitor and evaluate translocations at a variety of spatial and temporal scales; and 7) accurately record and efficiently share translocation results with the region.

These considerations will be incorporated into a supplementation plan developed by the tribes in coordination with other regional entities.

4.3.1.c Develop and implement lamprey artificial propagation as a component of a regional supplementation/augmentation plan

It is not likely that fragmented, isolated or non-existent lamprey groups within the Columbia River basin will naturally recolonize the upper portions of their range given the paucity of adult returns and the numerous threats to lamprey, including the existing mainstem environment. Therefore, the long-term restoration of Columbia River basin lamprey populations may require the structured release of artificially propagated lamprey in priority areas to achieve a variety of management and conservation objectives (George et al. 2009). Artificially produced lamprey could offer an alternative source of research animals to naturally produced lamprey and also offer lamprey for supplementation or reseeding priority watersheds.

Using existing information and ongoing research, the tribes propose to create a regional lamprey supplementation plan and guidelines that incorporate the propagation and release of lamprey as a strategy to conserve and reestablish populations throughout their historical range. Regional groups, including CRITFC and its member tribes, are already addressing some of the general objectives listed below. The basic outline of the artificial propagation component for a regional supplementation plan would include these general objectives.

- 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, population substructure, and source populations.
- Assessment of appropriate release locations and strategies for propagated lamprey within the region.
- Monitoring and evaluation of supplementation using artificially propagated lamprey.

In April 2011, CRITFC and the Yakama Nation sponsored an international forum on the restoration and propagation of lamprey in an effort to begin a regional dialogue regarding propagation as a lamprey conservation tool (Greig and Hall 2011). Workshop proceedings indicate that successful lamprey propagation can be implemented at broad scales. The workshop proceedings also assist in providing a technical basis for the development of a regional supplementation plan (Greig and Hall 2011).

As part of the FERC license requirement for the Rocky Reach Hydroelectric Project, Chelan County Public Utility District funded a literature review consolidating the most current information on techniques, protocols and existing facilities for culturing lamprey within the Columbia River basin (GeoEngineers et al. 2011). The development and implementation of a regional supplementation plan will utilize this review and other appropriate information, including information collected from other pilot propagation efforts by the USGS at their Cook, Washington facilities, the USFWS lamprey propagation facilities at Eagle Creek Hatchery, and at the Oregon State University lamprey laboratory facilities. The tribes believe that propagation may be an important strategy in lamprey conservation and given its complex nature, immediate actions will be required for future use of artificially propagated lamprey.

4.4 Contaminants and Water Quality

Objective 4: Evaluate and reduce contaminant accumulation and improve water quality for lamprey in all life stages

The Columbia River is water quality limited for DDT, DDE, PCBs, arsenic, mercury and PAHs (USEPA 2010). These contaminants have been found in various fish species in rivers throughout the Columbia River basin. The states, tribes and federal government and non-governmental organizations (NGOs) are all engaged in efforts to restore and improve the water, land and air quality of the Columbia River basin and have committed to work together to restore critical ecosystems. The Columbia River Toxics Reduction Working Group, a multi-entity group led by USEPA, helped determine the list of contaminants that should be sampled for lamprey evaluations.

The prevalence of toxic pollutants in traditional foods held sacred by American Indians has been an increasing concern for tribal members throughout the Pacific Northwest. In the early 1990's initial surveys performed by CRITFC indicated that tribal members consume 6–11 times more salmon and other fish than non-tribal members and that tribal members might be facing an increased health risk in consuming fish containing dioxin and other toxic pollutants (CRITFC 1994).

The health implications to tribal members from ingesting Willamette River adult Pacific lamprey containing a number of contaminants was evaluated in 2004. The Siletz tribe, through an USEPA grant, requested that the Oregon Department of Human Services (ODHS), as part of the Superfund Health Investigation and Education Program, investigate the risks to tribal members from ingesting lamprey collected at Willamette Falls (Stone 2005). Several pollutants were identified in the samples, with levels of mercury, DDT, Chlordane, Dieldrin and PCBs considered a health risk, particularly to pregnant women and children (Stone 2005).

Recently, the Oregon Environmental Quality Commission adopted new state water quality standards, which will regulate more than 100 pollutants including mercury, flame retardants, PCBs, dioxins, plasticizers and pesticides. CRITFC's survey of tribal members (CRITFC 1994) was one of the foundation reports used in setting a health-based fish consumption rate of 175 grams per day. The new water quality standards increase the health protection for tribal people who consume fish from the Columbia basin at higher rates than those established for the general populace (CTUIR 2011).

The effects of degraded water quality on lamprey may be similar to those observed in salmon with some exceptions. For example, lamprey have a higher lipid content than salmon in which toxics are known to accumulate. In addition, lamprey spend about five to seven years in the freshwater environment. Thus their exposure period for toxins is considerably greater than for salmon. Like salmon, Pacific lamprey must migrate through a complex hydroelectric corridor and estuary, rear in the ocean, and return again through the estuary and back through the corridor as adults. Movements through this variable environment expose lamprey to thermal and chemical pollution. Although the effects of decreasing water quality have not been evaluated for lamprey, this information may be critical for their long-term restoration. For example, water temperature likely plays a role in determining the timing of adult lamprey migration, maturation and spawning (Keefer et al. 2009b; Clemens et al. 2009). Laboratory analyses have generated water quality parameter tolerance limits for lamprey, including temperature, salinity, pH, turbidity and dissolved oxygen (GeoEngineers et al. 2011). This Plan notes that it is vital to evaluate the synergistic relationships between water quality factors such as temperature and dissolved oxygen, metals, pesticides and other pollutants

4.4.1 Contaminant Accumulation

Contaminant Accumulation Implementation and Actions

a. *Conduct literature review on the effects of toxics on lamprey*
b. *Conduct toxicology studies and assessments in partnership with other entities*
c. *Partner with appropriate entities and forums to reduce pollutants and chemical contaminants throughout the basin*

4.4.1.a Conduct literature review on the effects of toxics on lamprey

A key objective of this Plan is to evaluate toxic pollutant levels in lamprey throughout the basin, assess the health impact of tribal ingestion of lamprey, and take actions to reduce toxic pollutants in lamprey. The tribes recommend a full literature review on contaminant effects on lamprey to obtain a baseline understanding of the issue. This review should be conducted with appropriate partners with scientific expertise in toxicology, such as water quality agencies and health organizations.

It is widely recognized that chemical contaminants are a potential factor contributing to salmon declines in the Pacific Northwest (Johnson et al. 2006). Both pelagic and benthic contaminant sources have been identified, particularly in older and larger salmon (Johnson et al. 2006). Since the body of juvenile salmon contaminant research is greater than lamprey, there may be the potential to use some juvenile salmon studies as a surrogate for lamprey in the near future.

Existing evidence indicates that toxic contaminants in the lamprey environment may be a limiting factor to lamprey populations (Palstra et al. 2006). The synergistic and cumulative effects of contaminant body burden in the adult and juvenile lamprey life stages are not fully understood. However, it has been shown that contaminant levels increase throughout their lives with a range of effects in adults spanning from direct mortality to a host of sublethal effects at the cellular and organism level including endocrine disruption (Geeraerts and Belpaire 2010). Palstra et al. (2006) suggest that persistent organic pollutants in the environment, such as dioxin-like polychlorinated biphenyls (PCBs), coincide with the collapse of eel populations worldwide.

Other contaminants of concern include (PCBs), polybrominated diphenyl ether (PBDE) flame retardants, organochlorine pesticides, pharmaceuticals and personal care products, waste indicators, semi-volatile organics, and others. Many of these compounds are of particular concern relative to Pacific lamprey because the compounds have the potential to pose both an ecological threat to the organism, and a threat to human health via consumption of adult lamprey (Stone 2005). Geeraerts and Belpaire (2010) identified some of these compounds as likely 'key elements' in recent declines of European eel stocks. Many of these compounds tend to be hydrophilic and not expected to associate with sediments and organic matter, and therefore do not have the high potential for bioaccumulation in high lipid organisms such as the lamprey, as compared to the potential for bioaccumulation of highly lipophilic compounds such as PCBs and PBDEs (e.g., Santillo et al. 2005). Also, many of these emerging contaminants do not have established analytical methods, especially for extraction from biological tissues. Nonetheless, a surprising number of these compounds have been detected in sediments of the lower Columbia River basin (Nilsen et al. 2007).

4.4.1.b Conduct toxicology studies and assessments in partnership with other entities

Understanding the impacts of contaminants to Pacific lamprey will require wide ranging expertise and collaboration. As larvae and juveniles, lamprey spend several years in freshwater rivers before entering the Pacific Ocean as adults. Ammocoetes primarily reside in sediments at a depth of 1–2 feet and feed on microscopic plants and animals filtered from mud and water. This feeding strategy makes the juvenile life stage particularly susceptible to bioaccumulating organic contaminants that tend to bind to sediment and organic matter (Stone 2005). It is thought that larval lamprey use currents during freshet events to move downstream to new sediment areas. They may do this every few months, stopping at 4–5 spots for a period before they are large enough and make the transformation to macropthalmia as they are physiologically and morphologically changing in preparation to enter salt water and go to sea. It is likely that the most profound impact of contaminant burdens is manifested in the period of migration just prior to and during reproduction when the life-long lipid stores are metabolized in place of eating.

In 2009, CRITFC engaged in a collaborative study with USEPA, the Oregon Department of Environmental Quality (ODEQ), and the Oregon Department of Human Services (OHS) to build on the foundation of other studies that evaluate the toxic load in lamprey and possible impacts to tribal members who consume Pacific lamprey (Stone 2005). The sampling and analytical protocols for this work are described in the project's Quality Assurance Project Plan (QAPP; Heinith 2010). A total of 10 adult lamprey composite samples from Willamette Falls, John Day and Sherar's Falls on the Deschutes River were obtained by the tribes during July and August 2009. Concern about low numbers of adult lamprey limited samples to these areas and sample sizes. The samples were analyzed for key toxic contaminants targeted in the 2009–2010 Mid-Columbia QAPP and past studies by ODEQ in association with the 2009–2010 Mid-Columbia Toxics Study. The data indicates that adult lamprey from all sample sites have high concentrations of PCBs and tetra and penta PBDEs (ODEQ 2011). CRITFC, ODEQ, OHS and USGS are engaged in exploring methods to relate the containment load to lamprey health and potential ecological effects.

In 2011, CRITFC and the USGS began conducting a three-year study to assess both legacy and emerging toxic contaminants in juvenile lamprey as recommended by the ISAB (2009). The main focus of the effort is to provide reconnaissance-based information to improve understanding of exposure and bioaccumulation of organic contaminants in juvenile Pacific lamprey in the Columbia River basin and to gain insight into how these contaminants may affect life history attributes. The tribes will focus on juvenile lamprey in contaminant studies because juveniles are an important life stage where little is known about contaminant burden and because adult numbers are declining so rapidly that samples are becoming hard to obtain. Juveniles are still present in sufficient numbers for wider collection at dams, in tributary and mainstem surveys and in salvage efforts when irrigation facilities are dewatered in the winter. Custom research methods have been successfully modified to determine occurrence of several of these compounds in fish tissues for other USGS projects in collaboration between Nilsen (USGS Oregon Water Science Center) and the USGS National Water Quality Laboratory. A selected subset of tissue and sediment samples for wastewater indicators and pharmaceuticals will be screened as part of this effort.

Analyzing several sediment samples the Columbia River basin for the full range of compounds will provide valuable information on whether the identified sample locations have comparable sedimentary occurrences of compounds compared to results from the lower Columbia River basin (Nilsen et al. 2007). The existing resources may be used to focus on analyzing a wider suite of tissue and/or sediment samples for these compounds in future years. Included in Analytical Schedule 8093 for this research is oxyfluorofen, the main active ingredient in Goal, the herbicide spilled into Fifteenmile Creek, Oregon in August 2000. CRITFC is working with the Warm Springs Tribes to obtain and analyze sediment and juvenile lamprey samples from this area. Detailed future laboratory studies combined with statistically robust field collections will be necessary to understand the true picture of contaminant impacts at different life stages, but are beyond the current scope of this reconnaissance effort.

Existing models have linked the sublethal impact of contaminants to juvenile salmon population productivity and growth rate (Baldwin et al. 2009). Baldwin et al. (2009) found that juvenile salmon exposed to sublethal acetylcholinesterase levels had reduced feeding rates, growth and size at maturity. Their results indicated that a four-day exposure to representative pesticides would reduce juvenile salmon growth and size at ocean entry, key factors to population productivity (Petrosky and Schaller 2010; Lichatowich and Cramer 1979). The tribes will explore the potential modification of these models for lamprey.

CRITFC also proposes to use the USEPA model AQUATOX to simulate the interaction between pollutants and aquatic life (AQUATOX 2011). This model simulates the environmental fate and ecological effects of toxic chemicals at several trophic levels, including attached and planktonic algae, submerged aquatic vegetation, several types of invertebrates and fish. CRITFC has been in contact with the model developers expressing interest in simulating the effects of bioaccumulation of toxics in lamprey. Data from the ODEQ and USGS studies will be used to populate and calibrate the model.

It is important to assess the synergistic effects of contaminants with temperature, pH, salinity, dissolved oxygen and other water quality factors on lamprey survival and productivity. The literature indicates that impacts of contaminants on lamprey are determined not only by the type of contaminant, but also by the synergistic interaction of these contaminants with various water quality parameters (Geeraerts and Belpaire 2010). The impact also depends on the lamprey developmental stage and may affect lamprey at the subcellular, molecular, organism, population, and community levels (Lawrence and Elliott 2003).

4.4.1.c Partner with appropriate entities and forums to reduce pollutants and chemical contaminants throughout the basin

As noted above, the state water quality agencies, tribes, and federal government and non-governmental organizations (NGOs) are jointly engaged in efforts to restore and improve Columbia basin water quality through the Columbia River Toxics Reduction Working Group led by USEPA. This effort includes evaluation of the specific effects of degraded water quality and toxic pollutants on biota, such as lamprey.

Related to this effort is a set of new rules pertaining to tribal fish consumption. Based on input from Oregon tribes, the Oregon Environmental Quality Commission increased the daily consumption rate of fish from 17.5 grams per day to 175 grams per day, the highest rate in the United States (CSGN 2011). Because high daily fish consumption rates increase health risks to tribal members, the consumptive load of contaminants in fish must be reduced by increased restrictions on pesticide and other pollutant inputs into Oregon streams and rivers. The Washington Department of Ecology is considering a similar change to their fish consumption rules.

CRITFC and its member tribes will continue to establish regional partnerships to reduce contaminant pollutants into Columbia basin waters.

4.4.2 Water Quality

Contaminant Accumulation Implementation and Actions

a. *Conduct a literature review on the effects of mainstem, estuarine and ocean water quality on lamprey*
b. *Increase water quality monitoring efforts in the mainstem and estuary in partnership with other entities*
c. *Partner with appropriate entities and forums to improve water quality throughout the basin*

4.4.2.a Conduct a literature review on the effects of mainstem, estuarine and ocean water quality on lamprey

Many of the water quality improvements recommended for salmon will likely benefit lamprey. For example, cool water releases from storage dams, fishway temperature controls, gas abatement structures, and reductions of oil in dam seep holes are actions that should be taken to improve water quality for adult lamprey (CRITFC 2008).

Some literature exists regarding the effects of water quality on lamprey life histories and productivity. For example, adult migration data indicate that as temperatures increase during the summer, adult migration rates also increase, peaking around July 24 at Bonneville Dam. However, as with adult salmon, high temperatures may also act as a thermal block for adult lamprey migration. Ocker et al. (2000) noted that fewer adults successfully passed Bonneville Dam when temperatures exceeded 19.5° C. In studies tracking radio-tagged adult lamprey, Courter et al. (2011) found there was variability in adult lamprey migration movements related to Willamette River temperatures. They reported that early spring migration peaked at temperatures of 11° C, while early summer movement peaked at 21° C. Lamprey are found in water temperatures that are considered lethal to salmonids. For example, juvenile lamprey have been documented in the John Day River at 24° C temperatures (Jackson pers. comm. 2011).

A thorough literature review on the effects of water quality on lamprey is needed to better focus specific actions to improve water quality conditions.

4.4.2.b Increase water quality monitoring efforts in the mainstem and estuary in partnership with other entities

The Corps is expanding its CE-QUAL-2 temperature model to encompass river reaches where Corps dams are present. The mid-Columbia PUDs and USEPA have developed mainstem temperature models and the USGS routinely collects tributary and mainstem temperature data. The output from these models, combined with sediment models and bathymetric information obtained through LIDAR and additional lamprey life history and habitat data, should assist in establishing key mainstem and estuary habitat refugia for lamprey.

A number of laboratory and captivity studies provide important information about lamprey tolerances, growth, behavioral and physiological responses to salinity, temperature and other water quality parameters and are summarized in a recent report on lamprey artificial propagation (GeoEngineers et al. 2011). These researchers suggest the following be monitored and evaluated in lamprey habitats: temperature, total suspended solids/organics (TSS), dissolved oxygen (DO), pH, ammonia, nitrate and salinity. In addition, research is needed to determine the effects of total dissolved gas on lamprey.

The tribes concur with the USFWS (2011) that disease and temperature could be key factors limiting lamprey productivity. Oregon State University researchers found hundreds of adult lamprey mortalities below Willamette Falls during an extremely warm period in August (Schreck pers. comm. 2009) They also noted that adult lamprey collected at Willamette Falls during periods of warm water temperatures contracted lethal fungal diseases in a laboratory setting during the following spring period before spawning (Schreck pers. comm. 2010). Regional lamprey temperature and pollution research needs to be expanded.

The tribes advocate for installation of better water quality monitoring systems at dams and other representative stations throughout the mainstem, tributaries and estuary with entities such as the USACE, BOR, USGS and public utility districts. The data produced by these stations and systems needs to be integrated into appropriate predictive models.

4.4.2.c Partner with appropriate entities and forums to improve water quality throughout the basin

Actions to mitigate for elevated temperatures found in reservoirs and fish bypass systems would likely benefit juvenile lamprey. For example, Dworshak Dam in the Clearwater River and Cougar Dam in the Willamette River have selected temperature withdrawal structures. Consideration of new temperature control structures or dam operations to reduce river temperatures should be explored at Grand Coulee and Brownlee dams (BOR 2003a; CTUIR 2006).

The tribes will continue to establish partnerships with other entities in the basin, such as the Columbia Basin Toxics Reduction Workgroup and water quality groups established under various 401 Water Quality Certification for FERC hydro-licenses to improve lamprey water quality.

4.5 Public Outreach and Education

Objective 5: Establish and implement a coordinated regional lamprey outreach and education program within the region

Much of the general public and traditional fishery managers view fish as a recreational or commercial commodity or as organisms with little intrinsic value (Winter and Hughes 1996). Unlike salmon, but similar to gars and bowfins, there is a general public ignorance and lack of appreciation for Pacific lamprey and the critical role they play in the ecosystem (Scarnecchia 1992). As expressed in Winter and Hughes (1996):

> Losses of biodiversity in aquatic ecosystems may be abetted by a public bias against cold-blooded animals resulting from the terrestrial orientation of humans (Hughes and Noss 1992). This bias may be the principal factor responsible for the lack of scientific and public awareness of the importance of biodiversity of small, cold-blooded, and largely unobserved aquatic organisms as compared with the large, warm-blooded animals that live on land with humans.

This is a fundamental barrier that must be overcome if actions in this Plan are to be successful. There are five key messages for lamprey education and outreach.

1. Pacific lamprey have a unique history and lifecycle unlike any other fish species in the Columbia River basin.
2. Pacific lamprey have an important role in tribal diets and cultures in the Columbia River basin.
3. The continued decline or extinction of Pacific lamprey would cause environmental, cultural, biological and economic damage in watersheds throughout the Columbia River basin.
4. The tribes are addressing Pacific lamprey decline through regional policies, the creation of a regional, comprehensive lamprey restoration plan, and through implementation of on-the-ground projects in lamprey research and restoration.
5. Failure to prevent the extinction of the Pacific lamprey would have unacceptable ecological, cultural, and economic consequences.

The tribes recommend the following:

- Raising the awareness of target audiences regarding the severely depleted status of Columbia basin Pacific lamprey (i.e., past abundance vs. current status, lack of lamprey in the middle and upper Columbia and Snake rivers).
- Raising awareness of lamprey importance to the ecosystem and to tribes.
- Educating target audiences about current lamprey limiting factors, threats and uncertainties and the current and future actions identified in this restoration plan.

- Supporting the education of policy makers, resource managers, industry and landowners on how to manage, protect and restore altered ecosystems to be as productive and as nearly natural as possible.
- Establishing and implementing outreach/educational partnerships with various media outlets, local interest groups and federal, state and county agencies.

4.5.1 Public Outreach and Education

Public Outreach and Education Implementation and Action

a. *Establish learning networks*
b. *Secure institutional and investment commitments*
c. *Communicate the importance of lamprey and the consequences of failure to act*

4.5.1.a Establish learning networks

The tribes believe that building relationships among stakeholders in the Columbia River basin is an important component to sharing lamprey information and knowledge. The tribes will continue to work towards bringing people and constituencies together to foster learning networks. This will allow the tribes to create credibility for lamprey restoration through sound science and through relating on-the-ground experiences with federal, state and private lands and explain any uncertainties about restoration actions, particularly in the face of additional impacts of climate change and population growth. The tribes will communicate the risk to the species, ecosystem services, economies, cultural values and social values as a consequence of failing to act to support restoration measures.

The tribes propose to network with schools, colleges, regional workshops, interest groups (e.g. watershed councils) and federal, state and local agencies to improve knowledge of lamprey status, cultural and ecological significance and opportunities to support lamprey restoration. This work is already contributing to increased lamprey awareness. For example, the Chief Operations Manager for Ice Harbor Dam now has his staff routinely inspect turbine water strainer screens for juvenile lamprey impingement as a result of a presentation about lamprey from a Nez Perce elder.

The tribes will encourage other regional partners to implement methods to reduce non-point source pollution on agricultural, commercial, and residential lands, including reduction of rip rap, siltation and the loss of large woody debris. Specific actions landowners could undertake include real estate development guidelines such as prohibitions on development in floodplains and dewatering of wetlands; the inclusion of riparian buffer strips along streams, rivers and lakes; and the use of best management practices on all lands (USFWS 2010).

The tribes will encourage others to partner to establish lamprey sanctuaries in representative types of marine, estuarine and freshwater habitats and greater protection and restoration of native ecosystems in those habitats. The recommended sanctuaries would include large core areas with buffers. For example, the tribes are encouraging others to consider establishing priority riparian conservation easements for lamprey in the Willamette basin that are currently being designated or evaluated as conservation easements for salmon restoration.

Agencies and non-governmental organizations need to encourage and support the education of policy makers, resource managers, industry and landowners on lamprey habitat and how to manage, protect and restore altered ecosystems to be as productive as possible to sustain and restore lamprey. This education will allow landowners to become advocates for lamprey at the local level and provide them with a vested interest in the recovery of the species. Recently, for example, members of the Sandy River Watershed Council identified lamprey spawning in the Sandy River as a result of CRITFC's lamprey presentation to that Council (Figure 30). Also, Willamette River watershed councils are assisting in maintaining remote adult lamprey radio telemetry stations for the CRITFC Willamette Adult Lamprey Migration and Habitat Study (Figure 31).

Figure 30. Adult lamprey spotted holding in the Sandy River by watershed council members (Sandy River Watershed Council 2010).

Figure 31. Map of radio-telemetry receiver stations (dark circles) in the Willamette River maintained for the CRITFC-Oregon State University adult lamprey migration and habitat study (Clemens et al. 2011).

4.5.1.b Secure institutional and investment commitments

The recovery of lamprey within the Columbia River basin will require certain commitments from everyone in the basin. The tribes continue to work with regional agencies, such as the BOR, various public utility districts, water districts, USFWS, Northwest Power and Conservation Council, the CRBLTWG and other institutions to secure commitments that will improve lamprey habitat and passage and other key components to this Plan. The tribes recommend that each agency task their respective outreach specialists to coordinate their agency's part in regional lamprey restoration efforts. The tribes will continue to hold regional lamprey summit meetings to increase focus on lamprey status and increase momentum on lamprey restoration issues. The tribes will join regional federal and state agencies, the NPCC and other entities to solicit institutional funding and grants for lamprey restoration from Congress and other federal and state sources.

4.5.1.c Communicate the importance of lamprey and the consequences of a failure to act

The ecological and cultural importance and status of lamprey must be consistently communicated to the general public, elected officials and public servants in agencies in the context of restoring the Columbia River ecosystem and maintaining biological diversity (ISG 1996; USEPA 1990; ISG 2000). Tribal efforts will be directed towards the education of policy makers, resource managers, industry, students, and the general public, particularly landowners. Among other things, this education will include conveying the importance of lamprey to the tribes and the region, and describing the role of lamprey in maintaining biodiversity in the overall ecological framework of the Columbia River basin. The tribes will work through regional focus groups such as the CRBLTWG, the USFWS Lamprey Conservation Assessment group, the USACE and the BOR to develop a scientific and cultural understanding of lamprey responses to restoration actions for the general public at the local and basin scales.

Outreach actions must emphasize the link between declines in basin-wide biodiversity and factors such as population growth, overconsumption, institutional shortcomings, and inadequately developed environmental ethics. As one agency representative recently stated, "salmon restoration will not happen without lamprey restoration." This will involve increasing public understanding of lamprey science and cultural significance of lamprey to tribal peoples.

4.6 Research, Monitoring and Evaluation

Objective 6: Conduct research, monitoring and evaluation of lamprey at all life history stages

Every recommendation of this Plan is made with the understanding that there are gaps in the definitive knowledge of the status, ecology and biology of the species. This Plan does not ignore this fact. Instead it attempts to rectify this deficit while recognizing the very real need for immediate action. Integrated with every step of this plan are recommendations for concurrent investigations designed to address the deficiencies.

No effort to restore a species can be complete without attention to evaluating and monitoring effectiveness. This Plan aims for an adaptive management framework where actions are initiated, monitored and evaluated in the face of considerable uncertainty (Hilborn 1987). Adaptive management cannot be accomplished without measuring both the progress and effect of Plan actions. Each step described above includes recommendations for monitoring after implementation, but a larger, more global effort is needed. Similarly, increased effort is needed to integrate this Plan seamlessly with plans initiated by other agencies and institutions.

The following plans outline key critical uncertainties and research that are important to assist in the development of a regional RME plan: the CRBLTWG "Critical Uncertainties" document (CRBLTWG 2008), the CBFWA recommendations to the Northwest Power and Conservation Fish and Wildlife Program (CRBLTWG 2005), the *Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (Entosphenus tridentatus)* (USFWS 2010), the *Pacific Lamprey (Entosphenus tridentatus) Assessment and Template for Conservation Measures* (USFWS 2011), the Corps' "10-year plan" (USACE 2009), and the BOR's *Draft Assessment of U.S. BOR Projects in the Columbia River Basin: Effects on Pacific Lamprey* (BOR 2010). The tribes concur that the following are priority needs:

- Assess mainstem dam fishways, especially entrances for lamprey passage bottlenecks and address these issues.
- Assess differences in dam counts between Bonneville and The Dalles dams and other critical index points in the hydrosystem.
- Develop juvenile active tag and assess passage and migration routes and survival through the tributaries, mainstem hydrosystem and estuary.
- Assess juvenile and adult mainstem and tributary habitat capacities, use and requirements (i.e., passage, screen impingement, entrainment, etc.) (See Appendix A; Jolly et al. 2010; USFWS 2010; USFWS 2011; Clemens et al. 2011; Schreck and Clemens 2011).

4.6.1 Research, Monitoring and Evaluation

a. Genetics and population substructure
b. Migratory cues
c. Marine life history
d. Natal origin
e. Climate change
f. Monitoring and evaluation on ongoing actions and research
g. Effective population size

4.6.1.a Genetics and population substructure

This Plan recognizes and calls for continued lamprey genetic composition research, particularly directed toward the remaining groups in the Columbia River basin with a goal of understanding potential genetic substructure and maintaining genetic integrity of those populations. Understanding life history and population structure is important for seeding streams where Pacific lamprey populations are depressed or non-existent because introduced lamprey should be able to adapt to the local environment (Close et al. 2009).

Lack of information about lamprey population structure, behavior and genetic philopatric status throughout the Columbia basin can compound potential management considerations and options. Reports of lamprey size differences among different river systems (e.g., Beamish 1980; Kostow 2002) and differences in allozyme allele frequencies between different drainages (Beamish and Withler 1986) indicate there may be some local adaptation and reproductive isolation among Pacific lamprey from different locations. Lin et al. (2008) found genetically significant differences between lamprey in the John Day and Deschutes Rivers. However, Goodman et al. (2008), using mitochondria DNA markers, did not find much evidence of genetic differentiation among Pacific Northwest Coast lamprey that could be explained by lack of homing ability, suggesting a lack of reproductive isolation between locations.

In subsequent work, Lin et al. (2008) used amplified fragment length polymorphism (AFLP) analysis of DNA and found that adult Pacific lamprey were genetically differentiated across their range and that gene flow among aggregations of Pacific lamprey from their natal region to other regions decreased as the distance to these locations increased. Lin et al. (2008) noted that this level of gene flow could occur through attraction mechanisms such as migratory pheromones or stream flows as long as ocean migration distances were restricted and habitats and historical aggregations of lamprey remained intact (Lin et al. 2008).

However, allozymes, AFLPs and mitochondrial DNA may not provide the resolution required to sufficiently study population structure in Pacific lamprey. Microsatellites are the marker of choice for detecting population structure in closely related populations (Chistiakov et al. 2006). Up until now, Pacific lamprey microsatellite markers were not available for use, but have recently been developed in the University of Manitoba laboratory through collaboration with Dr. Timothy Whitesel (USFWS–Columbia River Fisheries Program Office). The subsequent report, *Microsatellite Analysis on Pacific Lamprey along the West Coast of North America* (Docker 2010), indicated that among 965 lamprey genotyped from 21 sites in the Pacific Northwest, the levels of genetic differentiation among locations were low, indicating support for the hypothesis of lack of natal homing.

Research funded by CRITFC and being conducted by the University of British Columbia (UBC) addresses concerns raised by fisheries management agencies and others (ISAB 2009) about the reintroduction of adults and/or juvenile lamprey in the upper Columbia River basin to assist in Pacific lamprey restoration. UBC researchers propose to use microsatellite markers to clarify or define populations or aggregations in the Columbia River and along the West coast of North America. This research includes the following tasks:

- Isolate polymorphic microsatellite markers using Fast Isolation by AFLP of Sequences Containing repeats (FIASCO) and bioinformatics analyses.
- Isolate, clone, sequencing and bioinformatics analyses of 130 candidate microsatellite markers of Pacific lamprey.
- Primers for PCR will be used to amplify microsatellite sequences to discriminate polymorphic and monomorphic candidate microsatellite markers from Pacific lamprey samples already collected.
- Estimate levels of genetic diversity and degree of spatial genetic differentiation among populations or aggregations of Pacific lamprey from the Columbia River basin and rivers along the West Coast of North America.
- Collect additional tissue samples and extract DNA from adult lamprey in Columbia River basin and along the west coast. Approximately 20 samples from each river will be acquired for analyses.
- Estimate levels of genetic diversity among Pacific lamprey. Examine among and between-year variation at a variety of geographic locations.

An increased understanding of Pacific lamprey population structure in areas that still maintain enough lamprey for tribal harvest may assist in resolving genetic uncertainties. Ongoing research at the University of Manitoba is focusing on microsatellite genetic analysis from 234 adult lamprey tagged during 2009 and the 241 adults sampled in 2010 as part of Willamette River adult lamprey telemetry study (Clemens et al. 2011). The research goal is to determine whether any genetic variation in microsatellites coincides with distinct migration behaviors and spawning locations within the Willamette River basin. Microsatellite analysis will help to clarify the population structure of Pacific lamprey and inform any future management decisions.

Data and information will be shared with genetic researchers from the University of British Columbia and the region.

4.6.1.b Migratory cues

It has been well documented that sea lamprey are attracted to pheromones emitted by larval and juvenile lamprey (Johnson et al. 2005). Moser et al. (2008) proposed an experiment to determine if adult Pacific lamprey would be attracted to juvenile lamprey pheromones using a Y-maze experimental design with the ultimate objective to determine if adult lamprey could be attracted to specific passage areas. Unfortunately, not enough adult lamprey were collected (Moser et al. 2008). The tribes support additional research in this area. For example, water samples for ammocoete locations could be analyzed for migratory pheromones.

4.6.1.c Marine life history

Little is known about the estuary and ocean life history of Pacific lamprey and it is a critical uncertainty with respect to restoration. Acoustic tags and detection nodes are in development and may assist in tracking juvenile lamprey thorough the estuary and near ocean environment, similar to juvenile salmon tracking studies already being conducted (Welch et al. 2008). Coastwide genetic analyses may also be helpful in determining marine ranges of Pacific lamprey. The tribes propose to collaborate with NOAA Fisheries, Center for Coastal Margins and Prediction (CMOP), the Corps and the Lower Columbia Estuary Partnership to address critical uncertainties in marine life history of lamprey. For example, one hypothesis is that coast wide lamprey decline is due to a lack of prey such as Pacific Hake. For this and other hypotheses to be explored, the tribes propose a focused workshop to begin to address the critical issues associated with the lamprey marine life history and habitat.

4.6.1.d Natal origin

Stable isotope and trace elemental ratios in otoliths are a well-established method to identify the natal origin and life history characteristics of teleost fish species. For example, Tzeng and Tsai (1994) clarified the migration history of eels utilizing otoliths. Similarly, the natal origin of Pacific lamprey may be explained by strontium contained within statoliths. Peery and Hobbs (2009) proposed to collect juvenile lamprey mortalities at mainstem dams and use lamprey statoliths to identify and catalogue lamprey natal origins. The migratory history of returning adult Pacific lamprey could also be analyzed to determine migratory history. The tribes recommend that this research be conducted and that exploration of elemental analysis be pursued as important contributions to the lamprey migration and life history knowledge base.

4.6.1.e Climate change

There is considerable scientific evidence to conclude that global surface air temperatures have warmed during the 20th century as a consequence of human activity and that the trend is likely to continue at an increasing rate during the 21st century (Oreskes 2004; IPCC 2007). The results from regional downscaled climate change modeling indicate a significantly altered ecology and economy in the Pacific Northwest during the 21st century (Mote and Salathe 2009; Mote et al. 2003). Some likely impacts include changes to seasonal snowpack and hydrology, reduced peaking and summer stream flows, and an increased frequency of forest fires (Figure 32). These changes could force difficult decisions with regard to resource management, especially when considered in the context of regional population growth (Mote and Salathe 2009; ISAB 2007a; ISAB 2007b; Hamlet and Lettenmaier 2007).

Increases in air temperature from climate change are anticipated to affect changes in precipitation patterns, although these changes are difficult to predict. Rising air temperatures are expected to decrease snowfall and increase rainfall during the winter months, leading to shifts in the timing and quantity of runoff, increased flooding during the winter when water is already in ample supply and decreased flows during the summer when water demands are high (Hamlet 2010; Figure 32). These changes would have significant impacts on water supply for maintaining fisheries, hydropower production, agriculture, and municipal uses (Mote and Salathe 2009; Mote et al. 2003).

Climate change will impact water quality, including increased sediment delivery from winter storms and higher summer water temperatures. Regional projections of temperature increases on the scale of 5–7°F will likely stress already depressed lamprey populations (Brekke et al. 2010; ISAB 2007a; Mantua et al. 2009; Luzier and Schaller 2011). Pacific lamprey are particularly susceptible to changes in water quantity and quality not only because they rely on freshwater rivers and streams as spawning, migration and rearing habitat with an extended freshwater life history, but they also exposed to potential changes in the marine environment, where waters are expected to become more acidic and hypoxic. Lamprey viability is already imperiled by the synergistic effect of other limiting factors (ISAB 2007a; Mantua et al. 2009). For example, reduced summer flows and higher temperatures will likely increase contaminant impacts to lamprey. Climate change may complicate efforts to augment flow rates to improve passage efficiency and survival. It will probably be necessary to modify flood control rule curves and obtain better runoff forecasting to create additional storage for spring and summer flow needs (ISG 1996; ISAB 2001; ISAB 2007a).

Two different pathways to climate change assessment are available for evaluation of future climate change impacts on Pacific lamprey and they both have strengths and weaknesses. The traditional approach, used by the Columbia Basin River Management Joint Operating Committee, utilized multiple downscaled global climate model projections from the University of Washington Climate Impacts Group (CIG) to generate a few water supply scenarios to determine how the hydrosystem is affected by these scenarios (CIG 2010; Low et al. 2011). This approach was used successfully to characterize climate change in the Great Lakes (Brown et al. 2010). The USFWS also recently used this approach with a NatureServe climate vulnerability method to estimate Willamette River temperature increases under several downscaled CIG model projections. They found that by 2050, there was some loss of lamprey viability, but by

2100 there was a high risk to lamprey viability throughout their present coast wide range (Figure 33; Luzier and Schaller 2011). While this approach provides deterministic future scenarios with respect to lamprey viability under climate change, it does not provide a robust, risk assessment of lamprey viability under different climate change assumptions.

The other climate change method is more exploratory, involves active decision maker or stakeholder input and involves decision scaling which requires creation of a vulnerability domain created by stakeholder derived metrics (e.g., system performance indicators). These are linked to a range of future climate conditions to determine the credibility of those climate conditions and the vulnerability of resources to these conditions based upon exceedence of a threshold (Lempert et al. 2003). For example, if stakeholders determined that water temperatures exceed 20°C, which is harmful for fish, climate experts would estimate the probability of exceeding this threshold and together with decision makers would devise adaptive management tools to reduce the risk that the threshold would be exceeded (Figure 34; Willows and Connell 2003). This reduces the need for modeling numerous scenarios and reduces model uncertainties as downscaled models would not need to be generated until the last step in the process. Ultimately, decision makers would have to weigh the risk of exceeding thresholds for identified metrics of concern and devise adaptive management tools to reduce the risk.

The Columbia River Treaty Review is examining these approaches and is seeking ways to improve on climate, temperature, precipitation and flow projections for an informed decision-based analysis for the future Columbia River. We anticipate this work and further research using methods by the USFWS for Willamette Lamprey and others will better inform climate change effects on Columbia basin lamprey populations. Updated climate change projections from the recent International Panel of Climate Change report are available and regional downsizing of these projections needs to be conducted and integrated into hydrosystem regulation, water quality and life cycle models (Mote pers. comm. 2011).

The Center for Coastal Marine, Observation and Prediction group (CMOP) is using CIG climate and historical flow and sea rise modeling data to determine habitat suitability for lamprey in the Columbia River Estuary through the SELFE model (http://www.stccmop.org/CORIE/modeling/selfe/faq.html). Model outputs include salinity, temperature, velocity and elevation. These outputs are filtered to estimate lamprey habitat from Bonneville Dam to the mouth of Columbia River.

Habitat improvement and life cycle work for salmon that addresses climate change impacts should also be considered for lamprey. For example, Crozier et al. (2008), using climate change projections and life cycle modeling of yearling Snake River spring/summer Chinook, established loss of population viability from climate change impacts.

The ISAB (2007a) recommended adaptation and mitigation actions such as establishment of selective temperature withdrawal structures on dams and reopening mainstem riparian areas now closed by development to allow for hyporeic flow and refugia. A patchwork of critical habitat areas offering cool water refugia in mainstem areas that may be set aside from development as conservation easements may be critical to lamprey persistence and should be pursed.

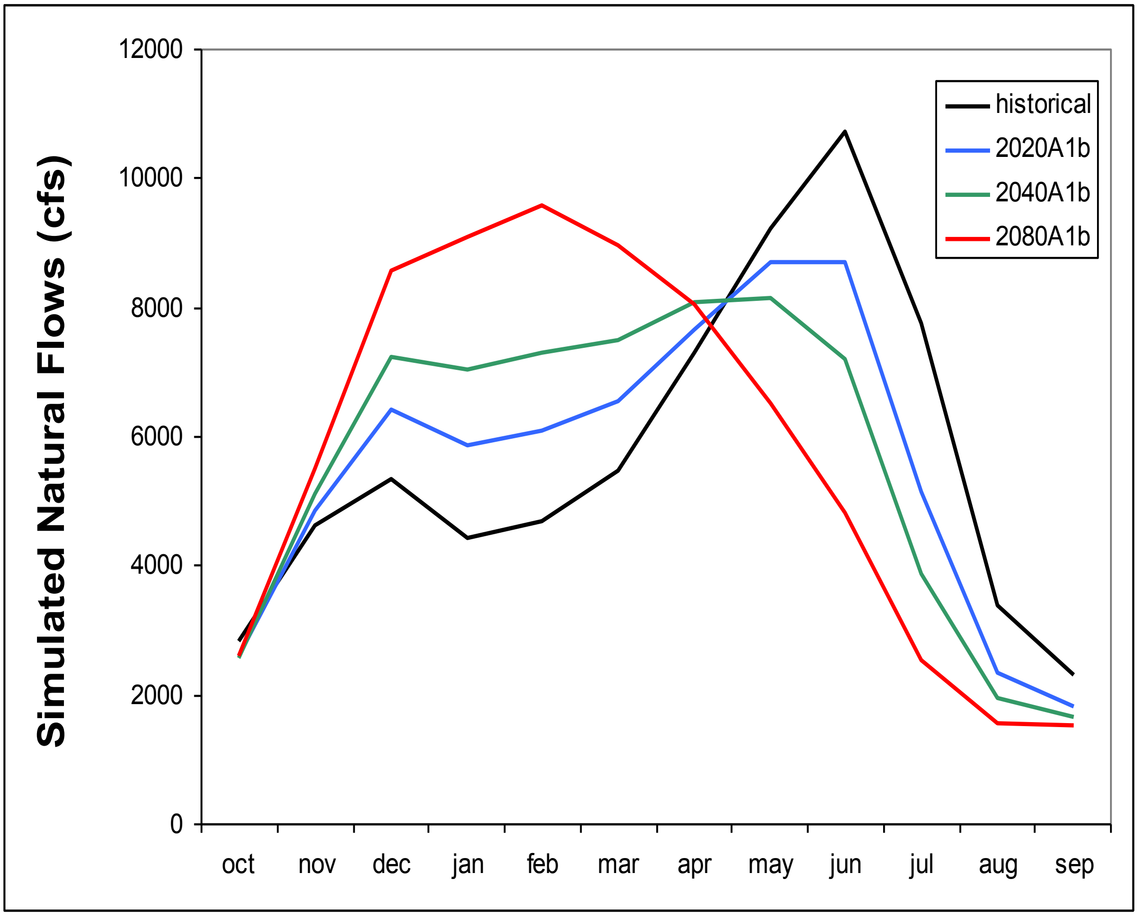

Figure 32. Future hydrographs for the Yakima River for three time periods under one climate model projection (Hamlet 2010).

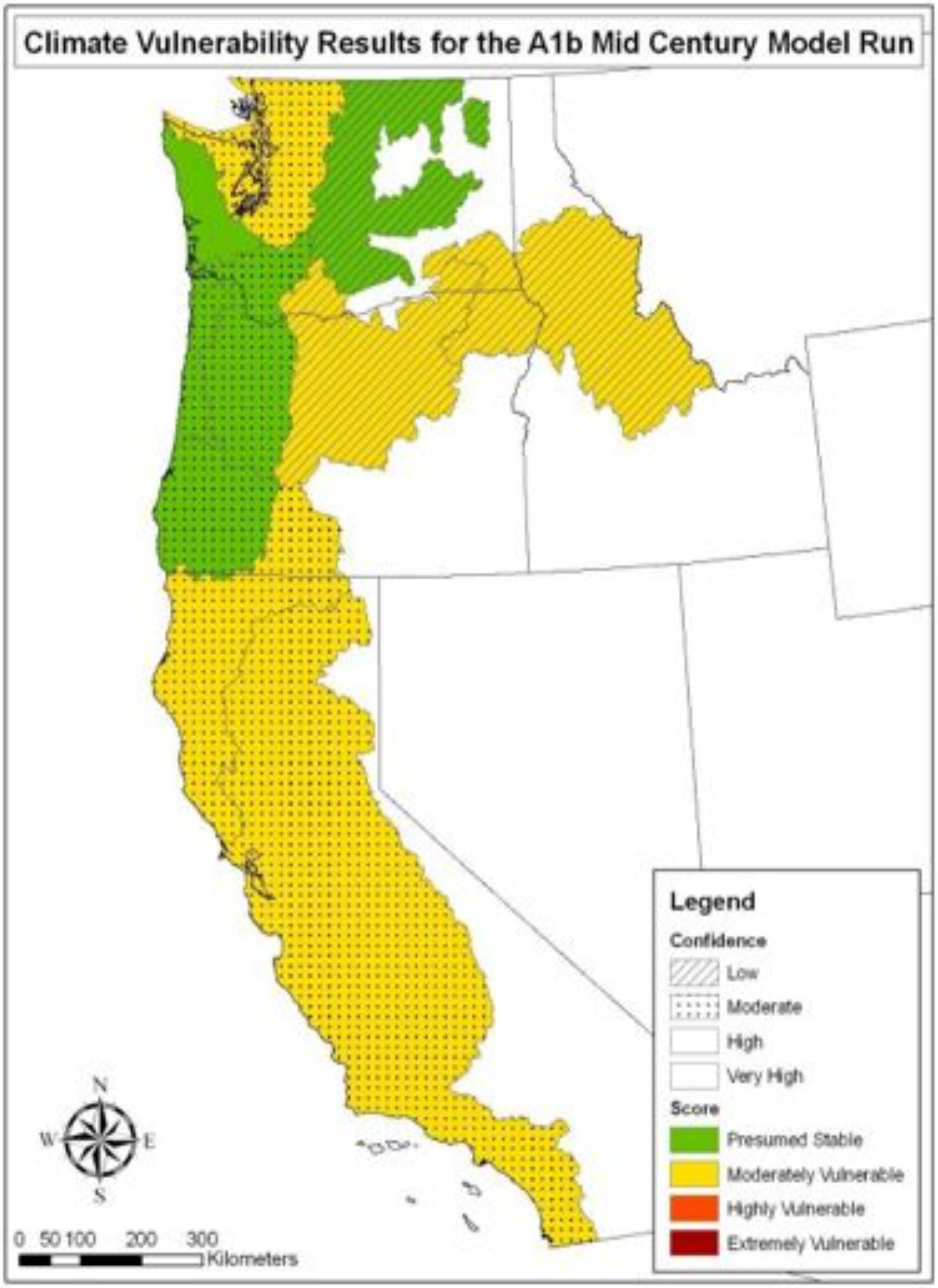

Figure 33. Lamprey coastwide vunerability in 2050 under one climate change scenario (Luzier and Schaller 2011).

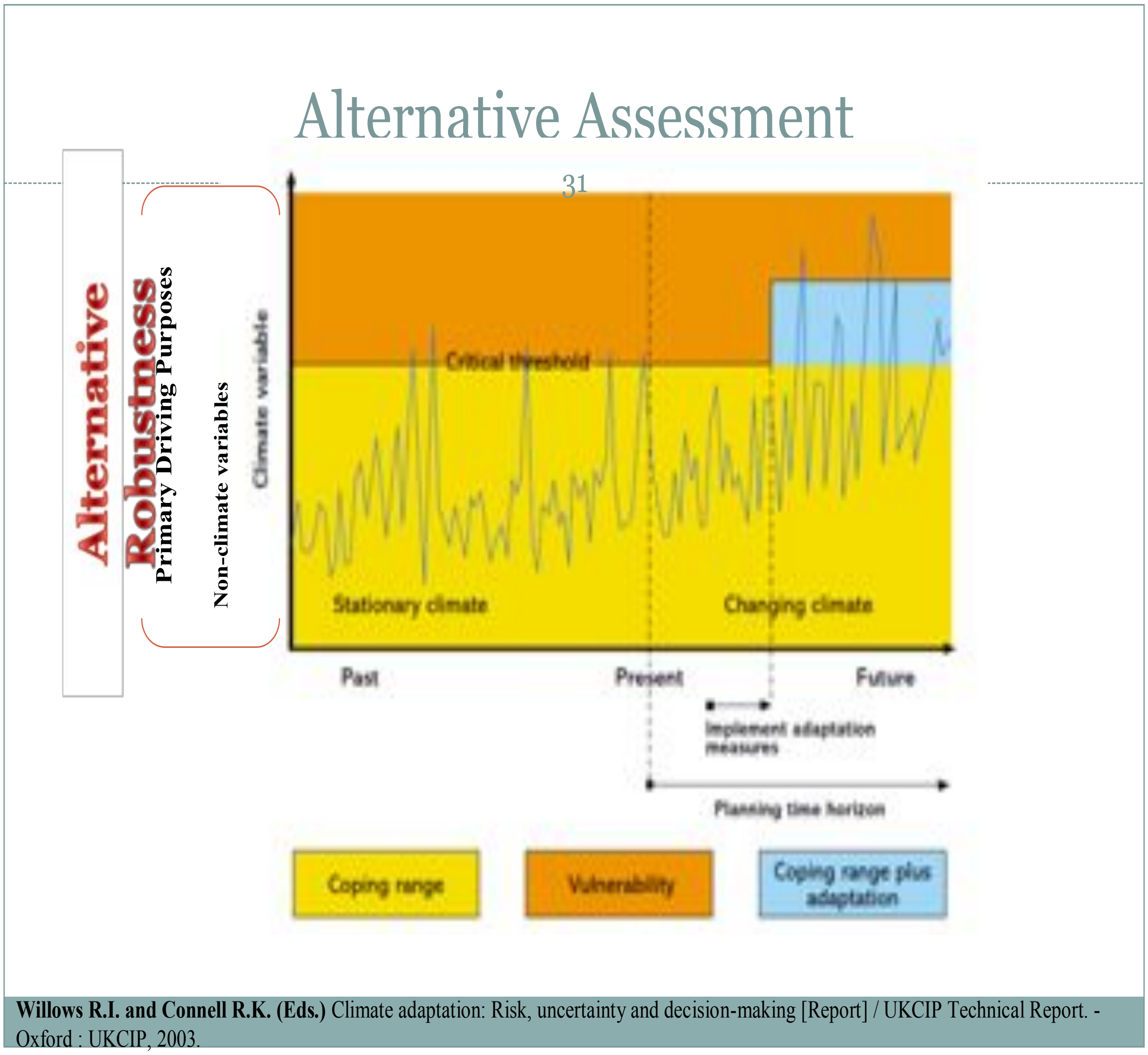

Figure 34. Climate change decision alternative assessment incorporating system vulnerability analysis and adaptive management (from Willows, R.I and Connell R.K., eds. 2003. Climate adaptation: risks, uncertainty and decision-making. UKCIP Technical Report, Oxford, UK).

4.6.1.f Monitoring and evaluation on ongoing actions and research

The tribes recommend using the conceptual foundation expressed in other regional forums and plans previously identified in this Plan to develop lamprey monitoring and evaluation protocols, methods and programs in the Columbia River basin. For example, Bisbal (2001) provided an excellent framework for monitoring and evaluation using a general set of common universal objectives:

- Measure attributes of environmental conditions and biological resources in the system of interest within relevant temporal and spatial scales.

- Conduct ecological research at landscape scales and increase understanding of ecological variables at those scales.
- Improve integration, coordination and sharing of monitoring efforts across organizations, geographic scales and relevant ecosystem elements.
- Ensure management decisions based on the best and most current information.
- Predict future conditions and suggest hypotheses for scientific testing.

In the 2007–2009 NWPCC Fish and Wildlife Program solicitation of new projects, Mesa et al. (2007) submitted a comprehensive proposal to study relative abundance, distribution and population structure of Columbia Basin lamprey. This research directly addresses necessary research, monitoring and evaluation to address critical uncertainties established by the CRBLTWG in their 2005 technical paper and provides a good framework for basin monitoring and evaluation. Other protocols such as EMAP suggested by the ISAB (2009) and Cowx et al. (2009) need regional vetting. We recommend that these monitoring and evaluation designs, plans and protocols be considered by the CRBLTWG and an overarching basin lamprey monitoring and evaluation plan be developed by all regional parties.

As a component of regional monitoring already being implemented, the USFWS and CRITFC are conducting mainstem juvenile abundance, habitat and distribution studies (Schreck and Clemens 2011; Jolley et al. 2010a; Jolley et al. 2010b). As resources allow, CRITFC and its member tribes will collaborate with the USACE, BOR, USFWS, and others in the region to expand these surveys into additional mainstem areas, including the estuary. This work is being supplemented by juvenile distribution, abundance and habitat surveys conducted by CRITFC's member tribes in their ceded tributary watersheds. Further, through the smolt monitoring program (PSMFC 2011; WDFW 2011; ODFW 2011), ammocoetes and macropthalmia are now being sampled and identified using established metrics at mainstem dam bypass facilities (Figure 35; Lampman and Streif 2008). The data produced by this effort will provide passage timing and relative abundance information.

This restoration Plan focuses a significant level of research, monitoring and evaluation effort in the Willamette River basin. The Willamette River basin alone still holds a substantial lamprey population, which provides the opportunity for baseline life history research, monitoring and evaluation. In 2009–2010 CRITFC had the unique opportunity to collaborate and pool resources to investigate adult lamprey migration and habitat preferences with two ongoing studies, one funded by Portland General Electric (PGE) and one funded by the Confederated Tribes of the Grande Ronde (Clemens et al. 2011). In 2011–2012 CRITFC is funding Oregon State University to study larval lamprey distribution and abundance using data gained from the adult migration and habitat study (Clemens and Schreck 2011).

Little is known about adult migration, holding, and spawning habitat in Columbia River basin reservoirs. It is important to determine the extent of these phases of lamprey life history as we develop measures, such as conservation easements, to protect habitat in these areas. Hydroacoustic, PIT-tag, and/or radio tag studies on adult and juvenile lamprey in the Willamette and lower Columbia rivers may provide specific data to address these issues (Clemens et al. 2011).

In addition to other ongoing forums, such as the Corps' Anadromous Fish Evaluation Program and the CRBLTWG, the tribes propose establishment of an annual regional Pacific lamprey conference or workshop to coordinate, exchange and continue to develop lamprey research, monitoring and evaluation efforts.

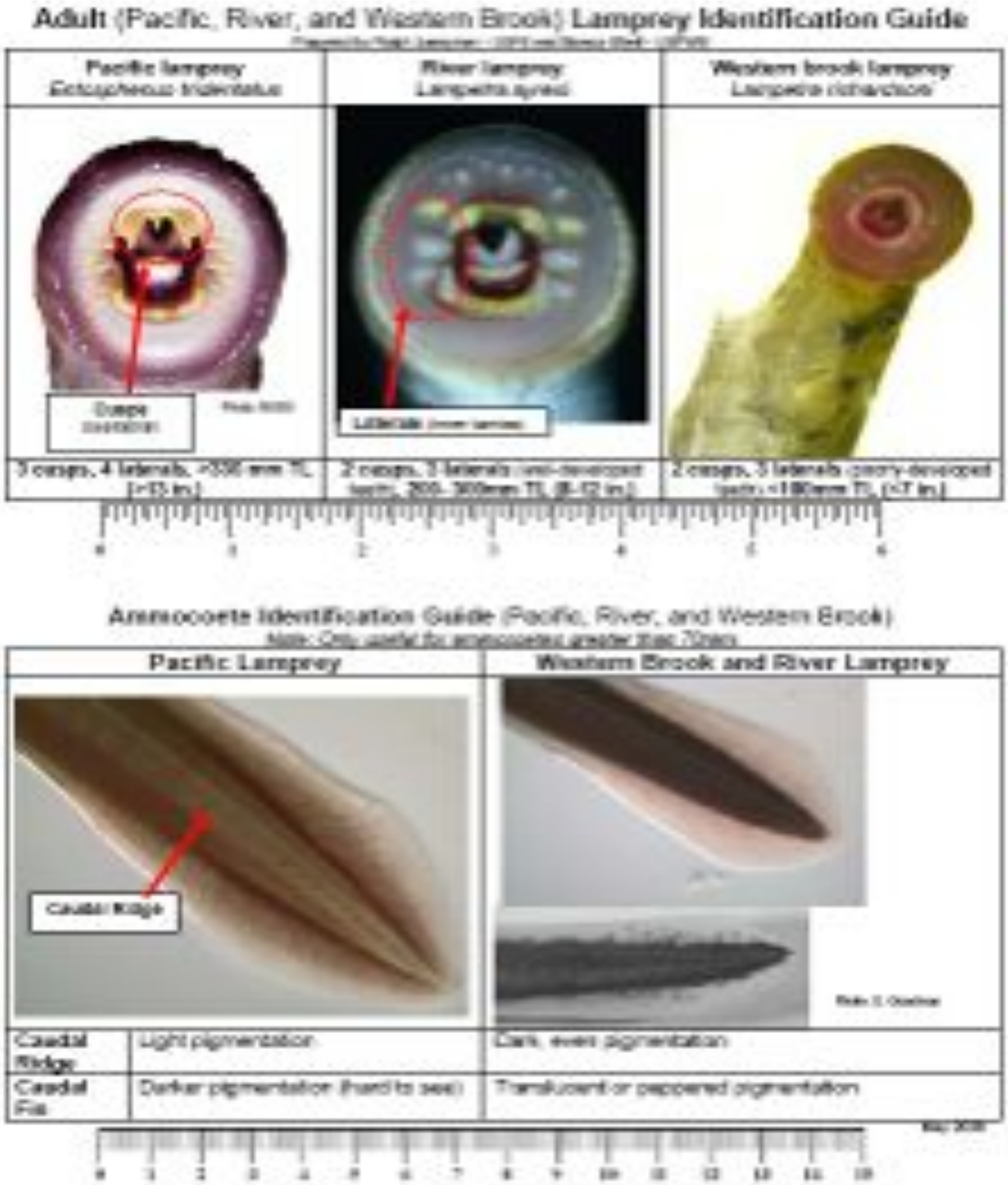

Figure 35. Smolt monitoring program identification guide for lamprey sampling at USACE mainstem dams (Lampman and Streif 2008).

4.6.1.g Effective Population Size

As described in the USFWS Pacific Lamprey Assessment and Template for Conservation Measures, effective population size is a chief concern with respect to management of lamprey to restoration levels. Small lamprey effective population size could contribute to loss of genetic diversity, leading to reduction in demographics, dynamics and population persistence. Determining lamprey population size is a critical need expressed by the CRBLTWG (2005) so that population enhancement is realized.

Basin-wide research, monitoring and evaluation methods should consider this metric prior to implementation.

4.6.2 Tributary and Ceded Lands Research, Monitoring and Evaluation

Nez Perce, Umatilla, Warm Springs, and Yakama tribal lamprey projects are focused on life history studies and lamprey status (adult migration holding, spawning, ammocoete production and early migration) within each tribe's respective ceded areas. These can be found in Appendix A of this Plan.

4.6.3 Data Management

a. Identify agency representatives and processes to develop lamprey regional data structure and data sets
b. Define key management and research questions to be addressed and develop consistent protocols and formats for data collection, evaluation and reporting
c. Define data storage approach and data dissemination protocols
d. Identify key entities expected to collect specific information relative to key questions and describe deficiencies, or "gaps" in long-term data needs

The tribes recognize the need for *regional* coordination to develop a *regional* approach to collect and manage data that will be utilized to assess and monitor the health, abundance and distribution of lamprey populations (Schmidt 2008). This effort is likely to go beyond the Columbia River basin addressing a much larger geographic scope. The data management approach developed under this Plan is intended to serve as a platform for basin-wide work with all lamprey species and to make all key data compatible, uniform and consistent regardless of origin.

4.6.3.a Identify agency representatives and processes to develop lamprey regional data structure and data sets

Progress towards this task is anticipated to begin in year 2012. It will be achieved collaboratively with all cooperating tribes and agencies (including USFWS, Washington Department of Fish and Wildlife, Idaho Department of Fish and Game (IDFG), Oregon Department of Fish and Wildlife (ODFW), FERC license holders and other appropriate parties) should they wish to participate. The tribes recommend that the CRBLTWG coordinate this process and evaluate the group's proposals. Utilizing the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) program may be considered by the CRBLTWG.

4.6.3.b Define key management and research questions to be addressed and develop consistent protocols and formats for data collection, evaluation and reporting

Recognizing that the form in which data will be organized is far from being defined, the tribes recommend the basic data structure, at a minimum, reflect the following:

- Mainstem Columbia River Environments.
- Dam and Reservoir.
    - Adult abundance, condition, migration, habitat and passage success.
    - Juvenile abundance, condition, migration, habitat and passage success.
- Estuary Environments.
    - Adult condition, migration, habitat and passage success.
    - Juvenile condition, migration, habitat and passage success.
- Ocean Environments.
    - (To be developed).
- Tributary Environments.
    - Geographic Information (HUC#, GPS/Location, Elevation, etc.).
    - Habitat Information (Channel Type, Habitat Type, Land Use, etc.).
    - Biologic Information (Number, Length/Weight, Condition, etc.).
    - Adult abundance, condition, movement and passage success.
    - Juvenile abundance, condition, movement and passage success.

4.6.3.c Define data storage approach and data dissemination protocols

A significant amount of work will be required to develop this regional approach. Below, the Plan's authors outline key considerations and steps that will be central to this effort:

- Identify and agree on key research and management questions/uncertainties to be addressed and the specific key metrics needed to be measured.
    - Develop data structure and desired outputs.
    - Identify and agree on the specific sampling methodologies that will be employed by all cooperating tribes and agencies to measure the various key metrics.
    - Develop a common list of data definitions and codes for use in recording and managing the data related to the key metrics.
- Develop a data management plan that outlines the approaches to managing data, including:
    - Where local and regional data will reside.
    - How to consolidate and present data (formats and software) for wide-scale analysis and communication.
    - What data quality assurance procedures will be employed, and by who.
    - How the data will be maintained and updated (process used) and who will be responsible.
    - How the data will be shared and any limitations on data dissemination.
    - Procedures for local and regional summarization and analysis of data.
- Develop metadata (information describing the data) for each data set related to the key metrics.
- Develop standard data recording forms for use by all samplers for each key metric.

- Develop a standard data entry template for data collected in the field, and explore the feasibility of using mobile tools for direct data entry in the field.
- Explore the feasibility of developing a common database system to house the data resulting from these sampling efforts. For example, features to consider may include the ability for data originators to directly enter, review and manage their data). Once completed, the tribes recommend that regional lamprey status and trend data be submitted into CRITFC's Accord Data Base Project (2008-507-00) for regional access and storage.
- Evaluate existing data collection efforts and clearly document key data needs or "gaps" that should be implemented to address key research questions and management considerations.

4.6.3.d Identify key entities expected to collect information specific to management questions and describe deficiencies or "gaps" in long-term data needs

The information presented above is not a complete set of tasks and considerations to develop a systematic and comprehensive data collection and management approach, but it is a sound beginning. The tribes request that the agencies and entities involved with lamprey management engage completely with this effort to obtain cost-efficient and regional data sets to support future management decisions.

The data management approach developed under this Plan is intended to serve as a platform for basin-wide work with all lamprey species, so the program will be developed collaboratively with the direct partners and with input from other interested agencies and parties in the Pacific Northwest, including USFWS, WDFW, IDFG, ODFW, FERC license holders and other appropriate parties, if they wish to participate. Initially we anticipate that regional lamprey status and trend data will be submitted into CRITFC's Accord Data Base Project (2008-507-00) for regional access and storage. However, long term coordination with PNAMP is anticipated.

5 Conclusion

Extinction is not an option.
—Gary Greene, Nez Perce Tribal Executive Committee

The take home message from this Plan is that *action is needed now.* Pacific lampreys are teetering on the brink of extinction. While the Pacific lamprey may lack the charisma of salmon, they remain an important part of the Columbia River basin in their own right. For the tribes, who value lamprey as an essential first food to their culture, losing lamprey is "not an option." Lamprey feed streams with nutrients derived from their decomposing carcasses, clean rivers with filter feeding and act as a predator buffer for fish. The species has played a vital part of ecosystem biodiversity for hundreds of millions of years. In short, all members of the Columbia River basin community, not just tribes, will be hurt if lamprey are lost. If history is a guide, we, along with future generations, will miss them much more than we can anticipate.

The Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin is a unique document that contains a high level of detail describing specific objectives and actions. No plan like this for lamprey has ever been developed before. There are six objectives, of which the first two—improving mainstem and tributary passage and habitat—are of primary and urgent importance (Objectives 1 and 2). Actions aimed at improving juvenile and adult passage must be implemented immediately. While passage improvements are implemented, actions to increase lamprey populations within the Columbia River basin through propagation, reintroduction, translocation, and augmentation should also be implemented (Objective 3). Improving water quality, reducing contaminant levels, and obtaining a better understanding of how toxic and contaminant accumulation, effects lamprey at all life stages is also important especially considering their role as a "first food" in tribal culture (Objective 4). Arguably most critical, effective public education and outreach regarding lamprey, particularly addressing lamprey status and highlighting the potential consequences of failing to implement restoration actions, may be vital to their long-term survival (Objective 5). Finally, research and monitoring directed towards understanding lamprey abundance and distribution, life history, habitat and water quality needs will allow for adaptive management as Pacific lamprey and associated restoration actions are better understood (Objective 6). Special attention must be focused on the impact of contaminants, climate change and human population growth.

Resources and institutional mechanisms within the Columbia basin do not yet exist to fully implement the necessary restoration measures contained in this Plan. Even with increased funding thorough the Tribal Fish Accords and other basin actions, the status quo is not adequate to manifest a reasonable expectation that the Plan's first goal of halting the decline can be accomplished.

The tribes recognize that this Plan is a work in progress, with potential for modification as our knowledge base increases. As the tribes and others actively strive to restore this humble, yet essential species, we welcome and expect support from the entire Columbia River community.

The region must make a significantly greater effort in a very short time frame if Pacific lampreys are to be restored. Thus, implementing this Plan must be an active collaboration—it lives only if the tribes can gain the participation, cooperation, coordination and commitment of federal and state agencies, the public, NGOs and FERC license holders. The test and worth of any community is how it regards and considers all of its members, even those less celebrated such as the lamprey.

It is in this spirit of inclusiveness that the tribes offer this *Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin*.

Figure 36. Young tribal member harvesting eels (lamprey) at Willamette Falls for tribal elders (Begay 2008).

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Appendices

Appendix A-Tribal Ceded Area Tributary Action Plans

Nez Perce Tribe Tributary Action Plan for Pacific Lamprey

The Nez Perce Tribe is gravely concerned about the current plight of the Pacific lamprey. Evidence of the precarious status of Pacific lamprey, which the Nez Perce Tribe commonly refer to as "eels," is striking. Since 1938, the highest day count of adult lamprey at Bonneville Dam was 379,509 in 1969 compared to the lowest day count of 6,234 in 2010. Lower Granite Dam is the last of eight passable mainstem dams on the eels' spawning migration route to Snake River tributaries. The ten-year (2001-2010) average day count at Lower Granite Dam is only 75 adults. Annual adult counts within this period ranged from 282 fish in 2003 to 12 fish in 2009. Adult counts were less than 50 fish for 6 of the 10 years.

Within the Nez Perce 1855 Treaty Area, encompassing vast expanses of stream habitat within the Snake River basin, including the Clearwater, Salmon, Imnaha, Grande Ronde, Tucannon and Asotin subbasins, Pacific lamprey once thrived. Pacific lamprey was and still is a valued cultural resource for subsistence, ceremonial and medicinal purposes. The imperiled status and persistent downward spiral of this valued fishery and cultural resource constitute a painful loss to the Nez Perce Tribe. Harvestable populations of lamprey no longer exist in the extensive Snake River tributary areas where we traditionally sought them within our 1855 Treaty Area. Pacific lamprey appear to be totally absent from certain tributaries where they once were abundant. The persistently low counts of adults passing Lower Granite in recent years signal an urgent need to actively support production of lamprey in the Snake basin or risk local extirpation of this integral cultural resource. Such a loss would be immeasurable to current and future generations of the Nez Perce Tribe.

Immediate, stopgap measures are needed to assist the adult lamprey in getting past the impediments to migration posed by the mainstem dams. The Nez Perce tributary actions contained in this plan focus on continuing urgently needed translocation of adult lamprey from downriver mainstem dams to Snake basin holding facilities for spring release into suitable Snake basin spawning streams. The objective is to thwart extirpation of Pacific lamprey in the Snake River basin and to support ammocoete production that is likely key to attracting adult lamprey to tributary spawning and rearing areas. Docker (2010) indicated that the absence of natal homing indicates that a lampreys need not hatch from a particular site to spawn successfully at that site. This bodes well for translocations. Larval pheromones appear to be the major factor influencing spawning site selection in lampreys. Translocations of ammocoetes to streams where lampreys have been extirpated may be important in establishing a spawning site: not because these ammocoetes will necessarily return to the site to spawn, but because they will produce pheromones that will attract adult lampreys (Docker 2010).

The objective is to annually translocate up to 500 adult Pacific lamprey from the mainstem Columbia River to five or six Snake basin tributaries. Assuming half of the fish are females, and a conservative average fecundity of 50,000 eggs per female, the translocated lamprey would augment production in the Snake River tributaries by 12,500,000 eggs. This constitutes a significant increase in lamprey production in the Snake basin, especially in consideration of the extremely low counts of adult lamprey passing Lower Granite Dam. The resultant production of larval lamprey (ammocoetes) and migrating juveniles (macrophthalmia) is intended to help maintain the species in the Snake Basin until such time as crucial mainstem passage improvements are effectively implemented.

The Nez Perce translocation initiative began in 2006 with the salvage of adult lamprey during fishway dewaterings at The Dalles and John Day dams. Below summarizes the collection, release and tagging of adult lamprey from 2006 through 2011.

Table 1. Adult Pacific lamprey translocation collection, release and tagging information

2006-2007	Winter collections	12/4/2006	JDA	178		
	Spring releases	5/16/2007		50	Lolo	10 RT, 40 NT
		5/17/2007		50	Newsome	10 RT+HD-PIT, 40 NT
		5/18/2007		49	Orofino	9 RT, 40 NT
		6/1/2007		28	Asotin	0 RT, 28 NT
	2006-2007 Collection (Release) Total			178 (177)		29 RT, 148
2007-2008	Winter collections	12/4/2007	JDA	1		
		12/5/2007	TDA	5		
		12/17/2007	TDA	2		
		12/17/2007	TDA	5		
		2/19/2008	JDA	94		
	Spring releases	5/28/2008		28	Lolo	10 RT, 18 NT
		5/28/2008		25	Orofino	0 RT, 25 NT
		5/29/2008		26	Newsome	9 RT, 17 NT
		5/30/2008		27	Asotin	10 RT, 17 NT
	2007-2008 Collection (Release) Total			107 (106)		29 RT, 77 NT
2008-2009	Winter collections	12/1/2008	JDA	15		
		1/6/2009	JDA	126		

	Spring releases	5/27/2009			Asotin	8 RT, 27 NT
		5/28/2009			Orofino	0 RT, 30 NT
		5/28/2009			Lolo	10 RT, 20 NT
		5/29/2009			Newsome	10 RT, 35 NT
	2008-2009 Collection (Release) Total			141 (140)		28 RT, 112 NT
2009-2010	Winter collections	11/16/2009	JDA	4		
		12/3/2009	TDA	0		
		12/8/2009	TDA	20		
		1/12/2010	JDA	0		
		2/8/2010	TDA	4		
		3/3/2010	CTUIR	72		
	Spring releases	5/27/2010			Asotin	8 RT, 14 NT
		5/25/2010			Orofino	0 RT, 22 NT
		5/25/2010			Lolo	10 RT, 14 NT
		5/26/2010			Newsome	8 RT, 15 NT
	2009-2010 Collection (Release) Total			100 (91)		26 RT, 65 NT
2010-2011	Winter collections	11/30/2010	JDA	33		
		12/4/2010	TDA	9		
	Spring releases	5/12/2011			Asotin	7

		5/16/2011			Asotin	22
					Orofino	0
					Lolo	0
					Newsome	0
	2010-2011 Collection (Release) Total			42 (29)		

Post-release monitoring of translocated adult lamprey and follow-up monitoring on ammocoete production have been encouraging. In 2007 and 2008 adult Pacific lamprey were released into four Snake River tributary streams: Asotin, Lolo, Newsome and Orofino creeks, of which 20% and 39% of the translocated population were radio-tagged. Adult spawning activity was observed in both years and in all release streams except Orofino Creek, with behaviors similar to descriptions reported from other systems (McIlraith 2011). A total of 36 lamprey nests were found among all release streams in primarily run and pool-tail out habitat. In 2009 surveys, the U.S. Fish and Wildlife Service (USFWS) detected larval lamprey in portions of Lolo and Newsome creeks where adult lampreys had been released, but did not detect them in nearby streams that had not received translocated adults (McIlraith 2011). Prior to the Nez Perce Tribe translocation efforts, both Lolo and Newsome creeks were declared devoid of lamprey (Cochnauer and Claire 2009). Results from McIlraith (2011) suggest that translocation may be an effective tool in lamprey conservation, as translocated adults remained near release locations and successfully spawned.

Ammocoete presence and densities will continue to be monitored to evaluate translocation and spawning success and to provide benchmark monitoring data needed to track larval distributions and densities through their four-to-six year freshwater rearing cycle. Fixed monitoring sites employed during previous surveys would be employed (Hyatt et al. 2007). This will provide useful data to help evaluate the contribution of migrating juveniles, or macrophalthia, resulting from the translocation effort.

In addition to the translocation initiative, needed tributary actions include presence/absence surveys and larval density trend monitoring at key locations within the major subbasins. Fixed monitoring sites will be identified for long-term trend monitoring.

Incidental observations of larval and metamorphosed (macrophthalmia) juvenile lamprey made by non-project staff within the Department of Fisheries resources management will also be documented. Incidental observations are most likely to occur from screw trap operations monitoring juvenile anadromous salmonids.

The Nez Perce Tribe intends on actively engaging in a well-coordinated Pacific lamprey monitoring and evaluation approach with the CRITFC member tribes and other co-managers as an integral part of lamprey restoration in the Columbia basin.

The Nez Perce Tribe will also pursue the potential to apply micro-elemental analysis of statoliths as a tool for tracking tributary origins of juvenile lamprey (Ludsin et al. 2006). The authors found that laser-ablation, inductively coupled plasma-mass spectrometry analyses of statolith micro-elemental composition could be used to reliably differentiate among individual larval sea lamprey produced in different regions (i.e., geologic zones, watersheds, streams). If this technique could be effectively applied to Pacific lamprey, the origins of larvae and macrophthalmia mortalities collected at mainstem Snake and Columbia River dams could be determined. This would provide valuable information regarding the fate and migration timing of juvenile lamprey produced at target translocation streams and other areas of the Snake basin. Obtaining similar information by tagging juvenile lamprey is likely infeasible due to large sample sizes required.

Table 2. Recommended Pacific lamprey actions for Snake River basin streams targeted for adult translocations. An "H" indicates high priority.

	Objective	Orofino Cr.	Lolo Cr.	Newsome Cr.	Asn Cr.
Status and Monitoring	• Monitor ammocoete densities and length frequencies, focusing on fixed index sites	H	H	H	H
	• Monitor ammocoete/macrophthalmia movements and out-migration	H	H	H	H
	• Monitor adult redd counts	H	H	H	H
Biology/Life History	• Assess spawning periodicity • Track adult post-release/pre-spawning movements • Assess gamete maturation in holding facilities	H	H	H	H
Limiting Factors	• Apply USFWS Best Management Practices for monitoring in-stream activities, such as suction dredge mining and in-water construction activities, to protect spawning and rearing habitat				
	• Monitor exotic species for potential predation threats				
Conservation /Restoration	• Translocate adult Pacific lamprey from mainstem Columbia River dams to target tributary streams (over-winter at tributary holding facility)	H H	H H	H H	H H

	Objective	Orofino Cr.	Lolo Cr.	Newsome Cr.	Asn Cr.
	• Monitor adult over-wintering health				
Research	• Collect lamprey tissue samples for genetic archives/analyses • Investigate the feasibility of using statolith elemental signatures (Hand et al. 2008) to distinguish among lampreys from different tributaries (i.e., to determine if statolith analysis can reliably determine specific stream of origin within the Snake River basin)	H	H	H	H
	• Develop methodology to quantitatively evaluate abundance of young-of-the-year Pacific lamprey	H	H	H	H

Table 3. Recommended Pacific lamprey actions across the general range of the Snake River basin currently accessible for spawning and rearing. An "H" indicates high priority.

	Objective	Clear-water	Salmon	Grande Ronde	Imnaha	Tucannon	Palouse
Status and Monitoring	Assess ammocoete presence/absence	H	H	H	H	H	H
	Monitor ammocoete densities and length frequencies at selected fixed index sites	H	H	H	H	H	H
	Monitor ammocoete/macrophthalmia movements and out-migration at existing salmonid monitoring sites	H	H	H	H	H	H
	Monitor adult redds in streams where ammocoetes are known to be present at higher abundances	H	H	H	H	H	H
Biology/Life History	Assess movement and out-migration periodicity from tributary rearing streams to and through the mainstem Snake/Columbia Rivers as technology becomes available	H	H	H	H	H	H
Limiting Factors	Apply USFWS Best Management Practices for monitoring in-stream activities, such as suction dredge mining and in-water construction activities, to protect spawning and rearing habitat						
	Monitor exotic species for predation threats						

	Objective	**Clear-water**	**Salmon**	**Grande Ronde**	**Imnaha**	**Tucannon**	**Palouse**
	where Pacific lamprey are present						
Conservation/Restoration	Translocate adult Pacific lamprey from mainstem Columbia River dams to selected target tributary streams depending on availability of adults, applicable adult collection criteria and over-winter holding capabilities	H	H	H	H	H	H
Research	Investigate the feasibility of using statolith elemental signatures to distinguish among lampreys from different tributaries (i.e., to determine if statolith analysis can reliably determine specific stream of origin within the Snake River basin)	H	H	H	H	H	H
	Develop methodology to quantitatively evaluate abundance of young-of-the-year Pacific lamprey, focusing on selected fixed index site	H	H	H	H	H	H

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Confederated Tribes of the Umatilla Reservation Tributary Action Plan for Pacific Lamprey

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) occupy tributaries within Northeast Oregon and Southeast Washington. These include the Umatilla, John Day, Grande Ronde, Walla Walla, Tucannon and Powder river basins. Historically, lamprey were abundant and distributed throughout these basins, providing harvest opportunities to the tribes. Currently, Pacific lamprey are still found in the John Day and Umatilla subbasins (due to recent and ongoing restoration actions in the Umatilla). Abundance and distribution of Pacific lamprey have been drastically reduced in the Tucannon, Walla Walla, and Grande Ronde rivers due to poor adult upstream migration conditions in the mainstem Columbia and Snake rivers.

The Confederated Tribes of the Umatilla Indian Reservation understand the importance of recovered lamprey populations within the ceded lands of the tribes' for both ecological and cultural reasons. The CTUIR also recognize the fact that there are limited resources for lamprey research and restoration; therefore, the Umatilla River basin has been chosen for focused lamprey research and restoration actions at this time. This program was the first to reintroduce lamprey into a Columbia River tributary using adult translocation. Instream flow and passage improvements are being implemented as well. Results are showing successful spawning and juvenile production throughout the subbasin. Monitoring trends in juvenile and adult populations will continue.

In a 1995 report for the CTUIR, Close et al. (1995) evaluated the status of Pacific lamprey as directed by the Northwest Power and Conservation Council. The report identified measures that needed immediate implementation for reintroduction of lamprey as well as recommendations for research and data gathering. Among these were recommendations to determine current abundance and distribution and to identify potential applications of translocation. The anticipated results were identification of translocation actions including methodology, source/donor stocks, target locations, and follow-up monitoring and evaluation needs.

In 1998 the CTUIR completed an electrofishing survey for juvenile lamprey in Northeast Oregon and Southeast Washington to document abundance and distribution in the CTUIR ceded lands. The Umatilla, Walla Walla, Tucannon, and Grande Ronde rivers had negligible lamprey presence, suggesting either extremely low abundance or extirpation of Pacific lamprey. The John Day River had the best lamprey production of the rivers sampled, with juvenile lamprey documented throughout the subbasin, except above Izee Falls on the South Fork.

In 1999 the CTUIR developed a peer-reviewed restoration plan for Pacific lamprey in the Umatilla River. The Umatilla River was chosen for reintroduction because it once supported a large number of Pacific lamprey and a traditional lamprey fishery, and because donor stocks for translocation were geographically close. In addition, numerous habitat improvements in the Umatilla River subbasin had been completed for salmonids. The restoration plan called for 1) locating an appropriate donor stock for translocation, 2) identifying suitable and sustainable habitat within the subbasin for spawning and rearing, 3) translocation of 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.

In 1999 and 2000, the CTUIR began implementing the restoration plan. Lamprey used for this program were initially collected during winter lamprey salvage operations at John Day Dam, the first Columbia River hydropower dam downstream from the mouth of the Umatilla River. In following years, collections were augmented with fish collected during summer at Bonneville, The Dalles and John Day dams.

Tasks required to implement the Umatilla translocation plan include:

- Coordinating with U.S. Army Corps of Engineers mainstem dam fishway dewatering activities for the salvage and collection or trap and haul of adult lamprey;
- Utilizing guidelines established by the International Union for Conservation of Nature and the American Fisheries Society (AFS) for fish re-introductions;
- Establishing adult collection facilities at select mainstem projects to facilitate the translocation effort;
- Targeting 500 adult Pacific lamprey to be moved from mainstem dams to the Umatilla River subbasin annually, subject to tribal translocation guidelines;
- Holding transported adults for over-wintering at the South Fork Walla Walla River Adult Lamprey Holding facility and Minthorn Springs Adult Lamprey Holding facility;
- Releasing over-wintered adults in the spring into the Umatilla River subbasin;
- Long-term monitoring of translocation success.

Beginning in 2011, CTUIR will be developing methods to PIT-tag outmigrant juvenile lamprey to evaluate survival past irrigation screens (designed for salmon) in the Umatilla basin and mainstem dams. Research and restoration will continue in the Umatilla River basin from year 2009-2018 and findings from these "pilot" efforts are anticipated to be applied elsewhere. Identification of limiting factors will also be of high priority for all other subbasins within the CTUIR ceded lands. Furthermore, CTUIR will be developing artificial propagation protocols, criteria and facilities with the goal to develop another tool for reintroduction into the tribes ceded lands.

In 2011 the CTUIR began developing an action plan with the Bureau of Reclamation (BOR) for research, monitoring and supplementation within the tribes ceded areas where BOR projects exist. CTUIR has requested adult and juvenile research, passage monitoring at low-elevation diversion dams, and operational and structural changes to improve juvenile and adult migrations.

To address the Independent Scientific Advisory Board (ISAB) comment that "the plan's credibility would be improved if these data were published," (ISAB 2009) CTUIR did publish results of our re-introduction work within the Umatilla River from 1998-2008 in an AFS Symposium publication. The title of the symposium book is *Biology, Management and Conservation of Lampreys in North America*, and our results are published in a chapter of the book.

The use of translocation in the Umatilla subbasin has created a lamprey presence and therefore an opportunity to collect lamprey population data to further our understanding of various life history stages.

10-Year CTUIR Tributary Lamprey Restoration Actions (2009-2018)

Table 1. Recommended Pacific lamprey actions for the Umatilla subbasin

Subbasin: Umatilla				
Actions	**Objective**	**Location**	**Status**	**Schedule**
RM&E				
Monitor Status	**Identify lamprey abundance and distribution within subbasin.** • Document historic adult and juvenile abundance and distribution • Document current adult abundance and distribution • Monitor long-term juvenile index sites • Monitor juvenile outmigration	Sub-Basin Wide	Completed Ongoing Ongoing Ongoing	Through 2018
Monitor Biology/Life History	**Identify biological characteristics** Determine adult and juvenile migration timing, size, age Determine adult and juvenile tributary habitat use: timing, duration and age	Sub-Basin Wide	Ongoing Ongoing	Through 2018
Document Limiting Factors	**Identify in-basin lamprey limiting factors.** • Identify habitat limiting factors for adult migration • Identify habitat limiting factors for adult spawning • Identify habitat limiting factors for juvenile rearing • Identify habitat limiting factors for juvenile outmigration	Sub-Basin Wide	Ongoing Ongoing Ongoing Ongoing	Through 2018

Subbasin: Umatilla				
Actions	**Objective**	**Location**	**Status**	**Schedule**
Conduct Research	**Lamprey research** • Subbasin genetic database development • Investigate long-term juvenile tagging technology, screening criteria • Identify disease concerns • Investigate lamprey attraction to pheromones	Multiple Sub- Basins	Ongoing 2009 start Unfunded Unfunded	2008-ongoing 2008-2013 TBD TBD
Restoration				
Implement Improvements	**Continue to restore lamprey to harvestable, self-sustaining levels within the basin.** • Supplement natural production by outplanting adults • Enhance summer stream flows for adult migration • Develop and implement structural passage aids • Enhance stream/floodplain habitat throughout subbasin	Sub- Basin Wide	Ongoing Ongoing Ongoing Ongoing	Through 2018 Through 2018 2008-2013 Through 2018

Table 2. Recommended Pacific lamprey actions for targeted ceded area tributaries

Subbasin: Walla Walla, John Day, Grande Ronde, Tucannon				
Actions	**Objective**	**Location**	**Status**	**Schedule**
RM&E				
Monitor Status	**Identify lamprey abundance and distribution within subbasin.** • Document historic adult and juvenile abundance and distribution • Document current adult abundance and distribution • Monitor juvenile rearing abundance/distribution & identify species • Monitor juvenile outmigration	Sub- Basin Wide	Unfunded Unfunded Unfunded Unfunded	TBD
Monitor Biology/Life History	**Identify biological characteristics** • Determine adult and juvenile migration timing, size, age • Determine adult and juvenile tributary habitat use: timing, duration and age	Sub- Basin Wide	Unfunded Unfunded	TBD
Document Limiting Factors	**Identify in-basin lamprey limiting factors.** • Identify habitat limiting factors effecting adult migration • Identify habitat limiting factors effecting adult spawning • Identify habitat limiting factors effecting juvenile rearing • Identify habitat limiting factors effecting juvenile outmigration	Sub- Basin Wide	Unfunded Unfunded Unfunded Unfunded	TBD

Subbasin: Walla Walla, John Day, Grande Ronde, Tucannon				
Actions	**Objective**	**Location**	**Status**	**Schedule**
Conduct Research	**Lamprey research** • Subbasin genetic database development • Determine additional research needs	Multiple Sub-Basins	Ongoing Unfunded	2008-ongoing TBD
Restoration				
Implement Improvements	**Restore lamprey to harvestable, self-sustaining levels within the basin.** • Supplement natural production by outplanting adults • Enhance summer stream flows for adult migration • Develop and implement structural passage aids • Enhance stream/floodplain habitat throughout subbasin	Sub-Basin Wide	Unfunded Unfunded Unfunded Ongoing	Through 2018 Through 2018 2008-2013 Through 2018

Confederated Tribes of the Warm Springs Reservation of Oregon Tributary Action Plan for Pacific Lamprey

For the people of the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO), Pacific lamprey are a culturally important subsistence, ceremonial and medicinal resource. The importance of the species to CTWSRO is described through oral history for time immemorial, tribal ordinances, codes and resolutions. Tribal members historically harvested lamprey at many locations including but not limited to Celilo Falls in the Columbia River, Fifteenmile Creek at Seufert Falls, the Deschutes River at Sherar's Falls and Tumwater Falls on the John Day River. It is also believed harvest occurred within the Hood River basin, although information is extremely limited. Due to the construction of The Dalles Dam in the 1950s, Celilo Falls was inundated and a culturally significant collection site for the people of CTWSRO was lost. The loss of fishing sites as well as insufficient numbers of Pacific lamprey at current harvest locations have forced tribal fishers to further supplement their subsistence needs with lamprey collected at Willamette Falls, on the Willamette River.

Once an important cultural food at celebrations, lamprey are now all but absent from the table due to reduced collection opportunities and harvest restrictions at Willamette Falls. The need for restoration of the species cannot be emphasized enough. Although we have chosen to focus on four priority subbasins within CTWSRO ceded lands, the importance of lamprey management, protection, and enhancement in other ceded, aboriginal, or usual and accustomed lands—including but not limited to the Clackamas, McKenzie, and Sandy rivers—should not be overlooked.

The need to improve knowledge of lamprey in the Willamette, Deschutes, John Day and Hood rivers as well as Fifteenmile Creek is supported by:

- Subbasin Plans for all subbasins within CTWSRO ceded lands: focal species, 2005
- Northwest Power and Conservation Council, Fish and Wildlife Program, 1994
- Columbia River Basin Lamprey Technical Workgroup, Critical Uncertainties Document, 2005 (updated 2008, new order found in Columbia Basin Fish and Wildlife Authority NPPC Amendment submission)
- Confederated Tribes of Warm Springs, Integrated Resource Management Plans (I and II), 1992
- Columbia River Inter-Tribal Fish Commission, Wy-Kan-Ush-Mi-Wa-Kish-Wit, Spirit of the Salmon, 1995
- Columbia River Inter-Tribal Fish Commission, Columbia River Basin Lamprey Summit I, 2004
- United States Fish and Wildlife Service, Coastwide Lamprey Initiative, 2008

Willamette River

Prior to the treaties of 1855, Willamette Falls was an important Pacific lamprey gathering and trading location for native peoples across the region. In current years, demand for lamprey from Willamette Falls by the four treaty tribes has increased due to declines in lamprey populations at other traditional harvest locations. The Oregon Department of Fish and Wildlife has regulated tribal harvest at the falls. The CTWSRO believe the following actions need to be taken in the Willamette Basin: 1) monitor adult lamprey escapement at Willamette Falls; 2) analysis of lamprey tissues to determine presence of contaminants, levels of contamination and impacts on native persons; 3) continued collection of historical and current distribution and abundance data, including baseline oral histories and biological data; 4) identification of factors limiting production; 5) implementation of lamprey-specific restoration strategies that address limiting factors; and 6) eventual re-establishment of lamprey populations to historic levels.

Deschutes River

Tribal members have harvested lamprey annually at Sherars Falls in the lower Deschutes River for time in memoriam. Historically, it is believed lamprey had the widest distribution of any anadromous species in the basin. However, today they are confined to the lower Deschutes River and select tributaries downstream of the Pelton Round Butte Dam Complex (PRB) at Rkm 161. Lamprey passage does not currently exist at these facilities, but passage may be feasible in the future. The overall goals for improving Pacific lamprey management and conservation in the Deschutes Basin include: 1) continued monitoring of adult, larval, and outmigrant populations below PRB; 2) annual monitoring of harvest and escapement above Sherars Falls; 3) expansion of knowledge on life history, habitat requirements, population dynamics, and sampling techniques for all life stages; 4) evaluation of both upstream adult and downstream juvenile passage through PRB; 5) restoration of historic lamprey distribution above PRB; and 6) development and implementation of lamprey-specific restoration projects that augment habitat and directly address limiting factors. As knowledge of lamprey in the basin improves, new work elements will be implemented.

John Day

The John Day River Basin has offered harvest opportunities for time immemorial. Pacific lamprey are still harvested by CTWSRO tribal members at Tumwater Falls (Brigette Whipple, CTWSRO Tribal Anthropologist, 2008 pers. com.). Lamprey are distributed throughout the John Day Basin; however, distribution may be limited by Izee Falls on the South Fork. To ensure a properly functioning watershed and return Pacific lamprey to sustainable, harvestable levels we need to improve understanding of population dynamics and habitat requirements. Key objectives include: 1) expand information from previous research to determine larval and spawning distribution and associated habitat within the basin; 2) estimate tribal harvest and adult escapement; 3) document juvenile out-migration timing; and 4) implement lamprey-specific habitat restoration strategies that address limiting factors. As knowledge of life history and habitat preferences improves, management actions will expand and new work elements will be implemented.

Hood River

Pacific lamprey were once thought to be widespread throughout the Hood River Basin. However, very little is known about their current distribution and abundance, and targeted lamprey research or monitoring has not been carried out. Adults have been incidentally detected downstream of Powerdale Dam (river mile 4.5). Ammocoetes were sampled downstream of Powerdale Dam during summer 2009 (CTWSRO, unpublished data). Neither adults nor ammocoetes have been documented above the dam for decades. For this reason, Pacific lamprey are thought to be extirpated upstream of the dam. Powerdale Dam was removed in 2010, creating an opportunity to restore populations within the basin to harvestable levels. Key objectives for managing and conserving lampreys in the basin and establishing a harvestable population include: 1) collection of historical and current distribution and abundance data2) periodic monitoring of all life stages to determine if recolonization and spawning are successful after dam removal; 3) identification of factors limiting production; and 4) implementation of lamprey-specific habitat restoration strategies that address limiting factors. In addition to restoring passage above Powerdale Dam, increasing spawning and rearing habitats by adding large wood and restoring riparian areas, screening of agricultural diversions, and removal of artificial barriers to passage all have potential to substantially increase lamprey production in the basin. Due to the current limited state of knowledge on lamprey biology, research, monitoring, and restoration efforts should be viewed in an adaptive management context, with priorities shifting and objectives added as information is expanded.

Fifteenmile Creek

Fifteenmile Creek is currently and was historically an important harvest location for Pacific lamprey by the CTSRWO tribal members. Anecdotal evidence also suggests that Fifteenmile Creek may play a key role in lamprey production in the lower Columbia River Basin due to its proximity to The Dalles Dam, where passage is limited. Nonetheless, distribution and abundance are not well understood, and there has been minimal work focusing on lamprey in the basin. Primary objectives for improving management and conservation of lamprey in the basin, while maintaining a harvestable population, include: 1) determine larval and spawning distribution and habitat availability within the basin; 2) estimate adult escapement and tribal harvest near the mouth; 3) document juvenile out-migration timing; 4) identify factors limiting production; 5) characterize use of Fifteenmile Creek by adult lamprey that fail to pass The Dalles Dam; 6) implement lamprey-specific habitat restoration strategies that address limiting factors. Due to the current limited state of knowledge on lamprey biology, research, monitoring, and restoration efforts should be viewed in an adaptive management context, with priorities shifting and objectives added as information is expanded.

Table 1. Pacific lamprey actions for the Willamette River basin

Willamette River Basin through 2018				
Action	**Objective**	**Status**	**Location**	**Schedule**
Status	**Describe ammocoete distribution and relative abundance**		Basinwide	2009–2011
	Describe outmigration timing and abundance of macropthalmia		Basinwide	2009-2018
	Describe historic and current use by adult lamprey • Collect anecdotal information • Describe time of adult entrance, over-wintering and spawning time • Estimate tribal harvest and spawning escapement		Basinwide	2009-2018
Biology/ Life History	**Document and describe life history types and/or run times**		Basinwide	2009–2018
	Improve knowledge of lamprey habitats in the basin		Basinwide	2009–2018
	Broaden understanding of population dynamics		Basinwide	2011–2018
Limiting Factors	**Describe and address limiting factors for all lifestages** • Investigate presence of contaminants such as pesticides, herbicides, and fertilizers in lamprey habitats and tissues. • Monitor water temperature, quality, and stream flow. • Locate and evaluate barriers to adult and juvenile passage (e.g., dams, flow, temperature, water withdrawal structures, culverts). • Investigate and quantify screen impingement and entrainment associated with water withdrawal. • Identify and address further limiting factors.		Basinwide	2009-2018
Research	• Collect tissue samples and use molecular techniques to investigate population structure, species composition, and life histories as part of larger study in the CRB. • Pursue additional research questions as needed to restore lamprey populations		Basinwide Basinwide	2009–2018 2009–2018
Restoration	**Develop, employ, and monitor lamprey-specific restoration projects that augment lamprey habitat and directly address limiting factors**		Basinwide	2012–2018

Willamette River Basin through 2018				
Action	**Objective**	**Status**	**Location**	**Schedule**
	Restore historic lamprey distribution and maintain a harvestable population size		Basinwide	2011–2018
Education	**Disseminate information and collaboration** • Coordinate with on-going efforts in the basin (e.g., FERC relicensing, Superfund, ACOE) • Collaborate with tribal, state, and federal government, and non-governmental organizations to achieve objectives. • Guide fisheries managers to make lamprey-friendly improvements as information becomes available. • Make genetic and other relevant data available in a centralized database. • Standardize all data collection methods and determine efficiencies of sampling gears. • Actively participate in multi-agency working groups that aid in lamprey recovery.		Basinwide	2008–2018

Table 2. Recommended Pacific lamprey for targeted ceded area tributaries

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables				
Action	**Objective**	**Location**	**Status**	**Schedule**
Status	**Describe ammocoete distribution and relative abundance.**			
	Implement standardized electrofishing surveys	HR	New	2009; 2012-
		FM	New	2009-2011
		DR	Expanded	Every 3-5
		JD	Expanded	Every 3-5
	Establish and monitor ammocoete index sites to determine changes in distribution and abundance.	HR	New	Every 3-5
		FM	New	Every 3-5
		DR	New	Every 3-5
		JD	New	Every 3-5
	Monitor emigrant abundance			
	Utilize existing technology to monitor annual abundance	HR	New	2014-2018
		FM	New	2009-2018
		DR	Expanded	2011-2018
		JD	New	2009-2018
	Describe historic and current use by adult lampreys.			
	Interview biologists, tribal elders, and landowners with knowledge of lamprey	HR	Ongoing	2008-2018
		FM	Ongoing	2008-2018
		DR	Ongoing	2008-2018
		JD	Expanded	2010-2018
	Estimate tribal harvest and/or spawning escapement	HR	New	2012-2018
		FM	New	2009-2018
		DR	Ongoing	2008-2018
		JD	New	2010-2018

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables				
Action	**Objective**	**Location**	**Status**	**Schedule**
	Characterize use of Fifteenmile Creek by lamprey that fail to pass The Dalles Dam	FM	New	2010-2018
Biology/Life History	**Document and describe life history types and/or times.**			
	Describe adult entrance, over-wintering and spawning timing	HR	New	2011-2018
		FM	New	2009-2018
		DR	Ongoing	2008-2018
		JD	Expanded	2010-2018
	Characterize maturation level of adults entering the basin at various times.	HR	New	2011-2018
		FM	New	2009-2018
		DR	New	2010-2018
		JD	New	2010-2018
	Describe sex ratio and length at times of entry and spawning.	HR	New	2011-2018
		FM	New	2010-2018
		DR	New	2010-2018
		JD	New	2010-2018
	Investigate genetic basis for run time.	HR	New	2011-2018
		FM	New	2009-2018
		DR	Ongoing	2008-2018
		JD	New	2010-2018
Biology/Life History (cont'd)	**Improve knowledge of lamprey habitats in the basin**			
	Identify and map spawning, rearing and overwintering	HR	New	2015-2018
		FM	New	2009-2018
		DR	Expanded	2008-2018
		JD	Expanded	2010-2018

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables

Action	Objective	Location	Status	Schedule
	Describe preferred habitat and environmental conditions throughout the life cycle	HR	New	2015-2018
		FM	New	2009-2018
		DR	Expanded	2008-2019
		JD	Expanded	2010-2018
	Map key ammocoete rearing areas for preservation	HR	New	2015-2018
		FM	New	2009-2018
		DR	New	2010-2018
		JD	New	2012-2018
	Collect outmigrant timing information and determine relationships with habitat parameters (i.e., discharge, water temperature, water quality)			
		FM	New	2009-2018
		DR	Expanded	2008-2018
		JD	New	2010-2018
Limiting Factors	**Document and describe life history types and/or times**			
	Monitor water temperature, quality, and stream flow	HR	New	2009-2018
		FM	New	2009-2018
		DR	Expanded	2008-2018
		JD	Expanded	2010-2018
	Locate and evaluate barriers to migration for all lifestages (i.e., flow, temperature, water withdrawal structures, culverts)	HR	New	2010-2018
		FM	New	2010-2018
		DR	New	2009-2018
		JD	New	2010-2018
	Identify and quantify screen impingement and entrainment associated with water withdrawal	HR	New	2013-2018
		FM	New	2010-2018
		DR	New	2009-2018
		JD	New	2010-2018

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables				
Action	**Objective**	**Location**	**Status**	**Schedule**
	Describe predation, parasites, and disease and their prevalence by location for all life stages	HR	New	2012-2018
		FM	New	2010-2018
		DR	New	2010-2018
		JD	New	2010-2018
	Assess habitat limitations associated with sedimentation of spawning areas, channelization and scouring of rearing areas, lack of shade and riparian cover, and large wood removal	HR	New	2012-2018
		FM	New	2010-2018
		DR	New	2010-2018
		JD	New	2010-2018
	Determine presence of contaminants such as pesticides, herbicides, and fertilizers in lamprey habitats and tissues	HR	New	2012-2018
		FM	New	2012-2018
		DR	New	2010-2018
		JD	New	2010-2018
	Continue to identify and address limiting factors	HR	New	2009-2018
		FM	New	2009-2018
		DR	Ongoing	2009-2018
		JD	New	2010-2018
Research	**Broaden understanding of populations dynamics**			
	Analyze ammocoete length data to describe age-structure, investigate year-class success, and detect years with failed spawning/larval recruitment	HR	New	2015-2018
		FM	New	2009-2018
		DR	New	2010-2018
		JD	New	2010-2018
	Describe relationships between various life stages (e.g., stock-recruitment indices) to help understand which are most important for determining year-class success	HR	New	2015-2018
		FM	New	2011-2018
		DR	New	2012-2018

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables				
Action	**Objective**	**Location**	**Status**	**Schedule**
		JD	New	2012-2018
	Develop tributary spawner escapement estimates			
		DR	New	2010-2018
		JD	New	2012-2018
	Miscellaneous Needs			
	Develop and maintain a genetic library/database	HR	New	2010-2018
		FM	New	2009-2018
		DR	Ongoing	2008-2018
		JD	New	2010-2018
	Collect tissue samples and use molecular techniques to investigate population structure, species composition, and life histories as part of larger study in the Columbia River Basin	HR	New	2010-2018
		FM	New	2009-2018
		DR	Ongoing	2008-2018
		JD	New	2010-2018
	Investigate use of pheromones emitted by ammocoetes (or synthetic derivatives) as means for attracting spawning adults	HR	New	2011-2018
	Develop new capture methodologies for all life phases			
		FM	New	2012-2018
		DR	Ongoing	2008-2018
		JD	New	2012-2018
	Develop or improve methods for estimating annual abundance for all lifestages			
		DR	Ongoing	2008-2018
		JD	New	2012-2018

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables				
Action	**Objective**	**Location**	**Status**	**Schedule**
	Estimate fecundity, larval production and early life survivorship			
		DR	New	2001-2018
		JD	New	2010-2018
	Pursue additional research questions as knowledge of lampreys progress	HR	New	2009-2018
		FM	New	2009-2018
		DR	Ongoing	2008-2018
		JD	Ongoing	2008-2018
Restoration	**Develop, employ, and monitor lamprey-specific restoration projects that augment lamprey habitat and directly address limiting factors**			
	Evaluate ongoing restoration projects aimed at salmonids in terms of effects on lamprey	HR	New	2012-2018
		FM	New	2012-2018
		DR	Expanded	2008-2018
		JD	New	2011-2018
	Construct or enhance aids to passage	HR	New	2012-2018
		FM	New	2012-2018
		DR	New	2009-2018
		JD	New	2011-2018
	Increase instream flows using water conservation measures	HR	New	2012-2018
		FM	New	2012-2018
		DR	New	2009-2018
		JD	New	2011-2018
	Plant native vegetation in and/or fence riparian areas to stabilize banks, contribute leaves and woody debris, and add shade	HR	New	2012-2018
		FM	New	2012-2018
		DR	Ongoing	2008-2018
		JD	New	2011-2018
	Promote responsible grazing practices through	HR	New	2012-2018

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables				
Action	**Objective**	**Location**	**Status**	**Schedule**
	collaborative efforts	FM	New	2012-2018
		DR	New	2009-2018
		JD	New	2011-2018
	Restore historic lamprey distribution above Powerdale Dam removal and maintain a harvestable population size			
	Develop, evaluate, implement methods for introducing adults and/or ammocoetes into areas where suitable habitat exists, but populations have been extirpated or are low	HR	New	2011-2018
	Restore historic lamprey distribution and maintain a harvestable population.			
	Develop, evaluate, implement methods for introducing adults and/or ammocoetes into areas where suitable habitat exists, but populations have been extirpated or are low	FM	New	2011-2018
		JD	New	2014-2018
	Restore historic lamprey distribution above Pelton-Round Butte Hydroelectric Complex (PRB).			
	Assess habitat availability above PRB	DR	New	2010-2018
	Assess upstream and downstream lamprey passage after completion of the Selective Water Withdrawal Structure in Lake Billy Chinook	DR	New	2010-2018
	If passage is feasible, implement reintroduction of Pacific lamprey	DR	New	2010-2018
Education	**Disseminate information and collaboration.**			

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables				
Action	**Objective**	**Location**	**Status**	**Schedule**
	Coordinate with entities within the basin to include lamprey in their data collection activities such as rotary screw trap operations and steelhead redd counting	HR	New	2009-2018
		FM	New	2009-2018
		DR	Expanded	2008-2018
		JD	New	2009-2018
	Collaborate with tribal, state, and federal government, and non-governmental organization to achieve objectives	HR	New	2009-2018
		FM	New	2009-2018
		DR	Ongoing	2008-2018
		JD	Expanded	2008-2018
	Guide fisheries managers to make lamprey-friendly improvements as information becomes available	HR	New	2009-2018
		FM	New	2009-2018
		DR	Expanded	2008-2018
		JD	New	2008-2018
	Work with landowners and public to improve knowledge and importance of lamprey to a healthy ecosystem	HR	New	2009-2018
		FM	New	2009-2018
		DR	Ongoing	2008-2018
		JD	New	2009-2018
	Actively participate in multi-agency working groups which aid in lamprey recovery	HR	New	2009-2018
		FM	Ongoing	2008-2018
		DR	Ongoing	2008-2018
		JD	Ongoing	2008-2018
	Make genetic and other relevant data available in centralized database	HR	New	2009-2018
		FM	New	2009-2018
		DR	New	2009-2018
		JD	New	2009-2018
	Collaborate in the development of standardized data collection methods and determine efficiencies of	HR	New	2009-2018
		FM	New	2009-2018

Hood River (HR), Fifteenmile Creek (FM), Deschutes River (DR), and John Day River (JD) Action Tables				
Action	**Objective**	**Location**	**Status**	**Schedule**
	sampling gear	DR	Expanded	2008-2018
		JD	New	2009-2018

Yakama Nation Tributary Action Plan for Pacific Lamprey

The ceded lands of the Yakama Nation (YN) comprise many tributaries of the lower Columbia River including the Wind River, the Little and Big White Salmon rivers, the Klickitat River and Rock Creek. To the north along the mid-Columbia River the larger tributaries include the Methow, Entiat, Wenatchee and Yakima rivers and the lower reaches of Crab Creek.

Historically, Pacific lamprey are believed to have been distributed throughout all of these subbasins. Comprehensive surveys to document distribution, abundance or life history attributes throughout most of the YN ceded lands have not yet been completed, thus relatively little is known about these fish. Recent surveys (presence/absence) by the Yakama Nation Pacific Lamprey Project (YNPLP) have identified lamprey juveniles throughout much of the Klickitat River (2009) and very few in the Yakima River (2010-2011). Surveys by the U.S. Fish and Wildlife Service (USFWS) note Pacific lamprey juveniles in the lower reaches of the Wenatchee River (below Tumwater Dam) and in several locations of the Entiat River. These (USFWS) surveys were performed primarily as "spot checks" with additional and more systematic surveys planned in the next couple years. Additionally, in 2008 the Wild Fish Conservancy surveyed the Methow River subbasin and found lamprey throughout much of the mainstem Methow (below Winthrop) and Chewuch rivers.

By year 2013, the YNPLP intends to have completed presence/absence surveys for the Klickitat, Yakima, White Salmon and Wenatchee river basins. Similar surveys for the Wind, Crab Creek, Little White Salmon, Entiat and Methow are anticipated to occur in 2013 through 2015. Associated with each of these surveys will be the development of restoration strategies and "Action Plans" as well as the establishment of long-term index sites for status and trend measurements.

Restoration of lamprey populations throughout the ceded lands is of high importance for the Yakama Nation for both cultural and ecological reasons. The highest priority is the Yakima River subbasin. These are our reservation lands, and it is fundamental for the peoples of the Yakama to once again harvest eels in these waters. We believe the mid-Columbia, and more specifically the Yakima River, is an anchor point for Columbia River basin populations. This understanding is based on the 1) centralized location of the Yakima within the Columbia River basin and relatively close proximity to the Pacific Ocean, 2) extraordinary geographic breadth and capacity of highly productive spawning and rearing habitats and 3) proximity to the Umatilla and Walla Walla subbasins which, similarly, also have tremendous spawning and rearing habitat capacity and great potential for high productivity. Lamprey populations in these areas must quickly be restored to a high level if we are to realize robust populations in the Columbia River basin within the foreseeable future.

One of the key issues within tributary systems, and specifically for the Yakima subbasin, is the presence of many irrigation diversion dams that can block adult passage to spawning areas and entrain juveniles into irrigation ditches. The USFWS, in coordination with the Yakama Nation, the U.S. Army Corps of Engineers (Seattle

District) and the U.S. Bureau of Reclamation are currently evaluating potential adult passage issues with a radio telemetry study at several Yakima irrigation facilities. In addition, the Yakama Nation will be working closely with the Bureau of Reclamation in order to evaluate the extent of juvenile entrainment into irrigation ditches and cost effective ways to correct this issue.

The Yakama Nation recognizes that in spite of our best attempts, it will take considerable time, maybe decades, before adult passage at Columbia River dams is "fixed." Additionally, there are countless irrigation dams and diversions within the Columbia River basin. Fixing these problems, along with other persistent issues such as warmer water temperatures, excessive native and non-native fish and bird predation, and potential issues concerning toxicants and habitat degradation, will require much time to correct. Unfortunately, the lamprey are quickly running out of time.

YNPLP staffs believe we have already experienced extirpation from key areas, such as the upper Yakima and Wenatchee systems. We expect that annual returns of Pacific lamprey to our upper watersheds will continue to remain very low for many years to come. The continuation of this trend makes it entirely possible that lamprey will become extirpated from even more watersheds within our ceded lands. We have come to a point where we no longer have enough fish to harvest, to contribute ecologically to the basin, or to study and learn from. We cannot simply wait for passage over dams and many other issues to be resolved before we begin restoration of populations back to these watersheds. This is why the Yakama Nation will actively pursue a translocation program (similar to current programs of the Umatilla and Nez Perce tribes) within the ceded lands and will soon begin research and application of artificial propagation.

Over the next several years, our work in translocation and propagation will focus on critical research questions. With respect to translocation, we will focus our efforts in understanding 1) how adult passage over irrigation facilities can be improved, 2) migration behaviors and 3) preference in migration holding and spawning locations. With regards to artificial propagation, our research activities will focus on 1) successful propagation techniques, 2) attainment of rearing relatively high numbers and densities of lamprey over longer time periods, 3) addressing issues associated with larval/juvenile entrainment and interactions with irrigation screens, 4) preferred habitat characteristics, 5) potential use of natural riverine environments as a propagation tool, 6) species and ecological interactions, and the 7) effects of agricultural and industrial toxicants on juveniles. Over the next couple years, if adult counts over Columbia River dams continue to remain at very low levels, we intend to significantly expand both translocation and propagation programs towards supplementation and re-establishment of local populations within the ceded lands.

These and other general objectives are indicated in Table 1 and Table 2 below. To accomplish this work will require a strong level of commitment and coordination extending well beyond the Yakama Nation. It will require an adjustment in the way all natural resource agencies interact and will require closer and stronger ties in collaboration and creativity in the way we use our existing resources and capacities.

Table 1. Five Year Research and Monitoring Strategy for Pacific lamprey in the Yakama Nation ceded lands. Subbasins listed as "High" are priority areas for these activities. These subbasins have facilities or ongoing activities that could facilitate preliminary investigations. Subbasins listed in Table 1 are considered as primary index sites for long-term status and trend monitoring.

	Objective	Klickitat	Yakima	Wenatchee	White Salmon
Status and Monitoring	**Identify lamprey abundance and distribution within subbasin.**				
	• Document historic adult and juvenile abundance and distribution	High	High	High	High
	• Document adult abundance and distribution	High	High		High
	• Monitor juvenile rearing abundance and distribution & identify species	High	High	High	High
	• Monitor juvenile outmigration	High	High	High	
Biology/Life History	**Identify biological characteristics.**				
	• Identify environmental/physiological conditions that trigger spawning and migration to occur	High	High		
	• Describe key predators and conditions where lamprey are most vulnerable		High		
	• Identify extent lamprey are subject to disease		High		
	Describe key habitat characteristics.				
	• Identify and describe adult and juvenile tributary habitat use	High	High	High	High

	Objective	Klickitat	Yakima	Wenatchee	White Salmon
	• Identify current strongholds and relative densities in ammocoete rearing areas	High	High	High	High
	• Identify key areas where adults hold and/or spawn. Provide description of the amount of suitable adult holding and	High	High	High	High
Limiting Factors	**Identify in-basin lamprey limiting factors.**				
	• Identify habitat limiting factors affecting adult migration	High	High	High	High
	• Identify habitat limiting factors affecting adult spawning	High	High	High	High
	• Identify habitat limiting factors affecting juvenile rearing	High	High	High	High
	• Identify habitat limiting factors affecting juvenile outmigration		High	High	
Restoration	**Identify actions that can be taken to restore or enhance adult holding, spawning and/or juvenile rearing habitats.**				
	• Develop subbasin restoration strategies	High	High	High	High
	• Implement and evaluate restoration projects with respect to changes in habitat characteristics, habitat use, and productivity		High	High	High

	Objective	Klickitat	Yakima	Wenatchee	White Salmon
	• Describe if eggs/ammocoetes distributed in degraded habitat may be at significantly greater risk relative to those in healthy or properly functioning environmental conditions. Provide strategy for habitat restoration		High	High	
	Reintroduce/translocate lamprey where severely depressed or extirpated				
	• Implement translocation of adults from mainstem dams to upstream watersheds		High	High	High
	• Monitor spawning at target translocation streams		High	High	High
	• Monitor ammocoete production at target supplementation streams		High	High	High
	• Monitor macrophthalmia emigration at selected target supplementation streams		High	High	High
	• Monitor adult abundance at target supplementation streams		High	High	High
Research	**Identify population structure relative to Interior Columbia River basin.**				
	• Supplement existing genetic libraries of genetic markers	High	High	High	High
	• Build and maintain lamprey tissue collections		High	High	High
	Identify body weight of adults entering subbasin and compare with time of spawning. Identify factors contributing to inadequate energy		High	High	High

	Objective	Klickitat	Yakima	Wenatchee	White Salmon
	reserves to successfully spawn.				
	Evaluate if artificial production can be used to "jump-start" ammocoete production in appropriate watersheds where productivity is lacking.		High	High	High
	Identify existing facilities potentially available or needed facilities to successfully rear ammocoetes to desired age classes	High	High	High	High
	Evaluate areas and ammocoetes where toxins potentially accumulate.		High	High	High
	Continue evaluating physical and/or biologic cues that may influence and/or guide adult migration and spawning.		High	High	High
	Assess trophic relationships of both juvenile and adult lamprey.		High	High	High

Table 2. Five Year Research and Monitoring Strategy for Pacific lamprey in the Yakama Nation ceded lands. Subbasins listed as "High" are priority areas for these activities. These subbasins have facilities or ongoing activities that could facilitate preliminary investigations.

	Objective	Entiat	Little White Salmon	Wind	Methow	Crab Creek
Status and Monitoring	**Identify lamprey abundance and distribution within subbasin.**					
	• Document historic adult and juvenile abundance and distribution	High	High	High	High	High
	• Document adult abundance and distribution					
	• Monitor juvenile rearing abundance and distribution & identify species	High				
	• Monitor juvenile outmigration	High			High	
Biology/ Life History	**Identify biological characteristics.**					
	• Identify environmental/physiological conditions that trigger spawning and migration to occur					
	• Describe key predators and conditions where lamprey are most vulnerable					
	• Identify extent lamprey are subject to					
	Describe key habitat characteristics.					
	• Identify and describe adult and juvenile tributary habitat use	High	High	High	High	
	• Identify current strongholds and relative densities in ammocoete rearing areas	High	High	High	High	

	Objective	Entiat	Little White Salmon	Wind	Methow	Crab Creek
	• Identify key areas where adults hold and/or spawn. Provide description of the amount of suitable adult holding and spawning habitat	High				
Limiting Factors	**Identify in-basin lamprey limiting factors.**					
	• Identify habitat limiting factors affecting adult migration	High	High	High	High	High
	• Identify habitat limiting factors affecting adult spawning	High				
	• Identify habitat limiting factors affecting juvenile rearing	High				
	• Identify habitat limiting factors affecting juvenile outmigration					
Restoration	**Identify actions that can be taken to restore or enhance adult holding, spawning and/or juvenile rearing habitats.**					
	• Develop subbasin restoration strategies	High	High	High	High	High
	• Implement and evaluate restoration projects with respect to changes in habitat characteristics, habitat use, and productivity					
	• Describe if eggs/ammocoetes distributed in degraded habitat may be at significantly greater risk relative to those in healthy or properly functioning environmental conditions. Provide strategy for habitat restoration					
	Reintroduce/translocate lamprey where severely					

	Objective	Entiat	Little White Salmon	Wind	Methow	Crab Creek
	depressed or extirpated.					
	• Implement translocation of adults from mainstem dams to upstream watersheds				High	
	• Monitor spawning at target translocation streams				High	
	• Monitor ammocoete production at target supplementation streams				High	
	• Monitor macrophthalmia emigration at selected target supplementation streams				High	
	• Monitor adult abundance at target supplementation streams				High	
Research	**Identify population structure relative to Interior Columbia River basin.**					
	• Supplement existing genetic libraries of genetic markers				High	
	• Build and maintain lamprey tissue collections				High	
	Identify body weight of adults entering subbasin and compare with time of spawning. Identify factors contributing to inadequate energy reserves to successfully spawn.					
	Evaluate if artificial production can be used to "jump-start" ammocoete production in appropriate watersheds where productivity is lacking.				High	
	Identify existing facilities potentially available or needed facilities to successfully rear ammocoetes	High			High	

	Objective	Entiat	Little White Salmon	Wind	Methow	Crab Creek
	to desired age classes.					
	Evaluate areas and ammocoetes where toxins potentially accumulate.					
	Continue evaluating physical and/or biologic cues that may influence and/or guide adult migration and spawning.					
	Assess trophic relationships of both juvenile and adult lamprey.					

Appendix B-Response to Regional Comments on Draft Tribal Lamprey Restoration Plan

Battelle Pacific Northwest Laboratories

Document well written and informative.

Comment appreciated.

Add information on the egg-ammocoete-macrophthalmia survival estimates or need for such information.

Table 2, Linkage of Pacific Lamprey Threats/Limiting Factors, Uncertainties contains the need for this information.

It is not clear that passage metrics are any more important than reservoir survival for juvenile lamprey. It would be good to segregate these issues…

Table 2 and Plan Sections 4.1.2 Juvenile Mainstem Passage and 4.2.1 Mainstem and Estuary Habitat segregate these issues.

We often forget that species complex has changed coincident with dam construction. The topic of non-native species is not well addressed.

See Section 4.1.3.b Evaluate and reduce avian, piscivorous and mammalian predation.

Any tag discussion would benefit from thoughts on the use of acoustic tag technology to gain insight into the over winter behavior and survival of adult lamprey.

See Section 4.1.3.a Identify lamprey life histories and impacts through temporal and spatial assessments of mainstem and estuary habitats for this issue.

Body cavity space and fish reaction to tag shape and material compatibility are additional consideration (for juvenile tags).

See Section 4.1.2.c Utilize juvenile tag technology and other methods to obtain route-specific passage and survival at mainstem dams.

It would be useful to state how far upriver historical production of the Pacific lamprey occurred.

CRITFC is working with its member tribes to collect traditional ecological knowledge with respect to historical distribution of lamprey. This is an ongoing task that was not able to be completed to be added to this final Plan.

Have "suitable spawning streams" been identified for the Snake Basin?

See the Nez Perce Ceded Area plan in the Appendix section.

While augmentation of depressed runs may require translocation it would be helpful to discuss benefits (perhaps this has worked in other basins) and risks (mortality factors may be high).

This is addressed in Section 4.3 Objective 3: Supplement/Augment interior lamprey populations by reintroduction and translocation.

Public Utility District No. 1 of Grant County, Washington

We concur with most of the draft Plan contents.

Comment appreciated.

Grant PUD will work with the tribes to assure that Grant's lamprey obligations are fulfilled.

We appreciate the commitment. We encourage Grant PUD to expedite passage studies for adult and juvenile lamprey through the Wanapum Dam deep slot passage structure as we believe this facility may hold a future paradigm for a safer lamprey passage route that may be emulated at other mainstem dams.

Independent Scientific Advisory Board

The ISAB shares the sense of urgency to complete and implement the plan but it seems overly ambitious. It would be improved by explicit separation and elucidation of its goals as well as further prioritization of objectives and proposed research.

The final Plan has gone through extensive changes from the draft version based upon these and other regional comments. There are detailed tables and priority lists for the main objectives that are linked to specific actions.

CRITFC should explicitly coordinate overall objectives of the Plan to avoid work being duplicated by the various entities and to foster useful comparisons between subbasins. The ISAB recommend that the Plan include more interagency planning among co-managers and stake holders. The Plan should include a clearly defined vision for lampreys at the basin, province and subbasin levels.

The final Plan calls for extensive regional networking to accomplish the Plan objectives. In particular, the Plan references and integrates the 2011 USFWS Assessment and Conservation Template wherever possible. The individual tribal ceded area plans in the Appendix link provincial lamprey goals into the regional goals. The final Plan calls for the establishment of regional lamprey working groups. The emerging Yakima and Willamette basin groups are providing visionary paradigms.

The decline of lamprey is widespread and is difficult to document because of incomplete data on trends in abundance at monitoring locations. The Plan would be improved by showing any available data on trends in harvest and counts at dams.

The final Plan includes additional data on dam count indexes and harvest rates, including those for Willamette Falls. See Section 3.3 Tribal Harvest and Section 3.6 Historical Abundance and Status and Section 4.1.1.a Obtain accurate counts of adult lamprey passing mainstem dams.

Tagging studies are needed to address most issue of adult and juvenile passage and habitat use. Development of tags suitable for use in juvenile lamprey remains a challenge that should be highlighted in the Plan.

This issue is addressed in detail in Section 4.1.2.c Utilize juvenile tag technology and other methods to obtain route-specific passage and survival at mainstem dams.

We agree with the Plan's strong emphasis to improve knowledge of limiting factors and to refine methods for monitoring and evaluating status and distributions. Without this information, it will be difficult to design restoration efforts that will benefit lamprey.

Comment appreciated. The final Plan has expanded sections on limiting factors, monitoring and evaluation.

The Plan identifies estuary and ocean life histories for Pacific lamprey as a critical uncertainty. The ISAB agrees that development of tagging systems to track juvenile lamprey in the estuary and near-ocean environment is an essential first step.

The difficulties in developing an active juvenile tag and possible alternatives are discussed in Section 4.1.2.c. The Plan recommends establishment of a marine lamprey workshop with appropriate experts as a starting point to address ocean and estuary limiting factors.

The ISAB believes the scale of necessary retrofitting of existing screens at dams and tributary barriers is so large that effort should probably be focused on some pilot projects to test a variety of alternatives.

The Plan discusses screen design work conducted by the USGS for tributary barriers and that prioritization of placement of these newly designed screens is aligned with ongoing inventories at irrigation facilities through tribal and Reclamation planning. Screen replacement at mainstem dams is so expensive it probably will not occur, however, turbine screen deployment is being delayed to improve juvenile lamprey passage conditions at McNary Dam.

Supplementation (including translocation and other aquaculture or hatchery – supported introductions) should be regarded as experimental and should proceed only with a clear experimental design and evaluation protocol. Experiments must be accompanied by adaptive management on the basis of information from aggressive monitoring and evaluation.

Section 4.3 Supplementation/Augmentation provides the rationale for translocation as a restoration strategy. Careful monitoring and adaptive management of ongoing tribal translocation programs indicates that adult lamprey returns to translocated areas are increasing. Translocation programs have provided additional benefits with respect to gaining increased knowledge about lamprey life histories and critical uncertainties (See Close et al. 2009). Under the Plan, the tribes will engage the region, including the ISAB, with respect to input on a regional artificial production/supplementation plan.

Contaminant studies must remain within the scope of this Plan, perhaps even figuring prominently, as lamprey are subjected to considerable exposure and have a high lipid content which makes them particularly susceptible to contaminant uptake.

We agree. Section 4.4 Contaminants and Water Quality contains expanded and updated information on ongoing studies of lamprey and contaminant loading. Assessing the role of contaminants on lamprey life histories and productivity is a full-fledged Plan objective.

The Plan would be improved by further prioritization of objectives and proposed research. It is generally best to first present the objectives before describing the actions needed to achieve the objectives. It is often effective to present the hierarchy of vision, goals, objectives and sub-objectives.

The final Plan has been extensively reorganized to address these comments. The hierarchy described in the comment has been adopted in the final Plan.

A major shortcoming is the lack of clear quantitative evidence for the decline in lamprey abundance, as this is the core problem to be resolved. The ISAB agrees with CRITFC's prioritization of mainstem passage as an important issue but also recognizes that current understanding of the life history and population dynamics of Pacific lamprey is so incomplete that severe mortality during other phases of the life cycle may turn out to be as important as passage related mortality.

The declines in lamprey abundance appears clear to us from the historical data at hand. We agree that there may be other important lamprey mortality factors other than passage and the Plan has objectives and actions to address them. However, the documented, qualitative and quantitative lamprey mortality from dam passage and operations is significant and must be immediately addressed.

Attention to correct the broad, negative societal bias against lamprey should be given greater emphasis in the Plan.

We have expanded this emphasis in several Plan sections but most notably in Section 4.5 Public Outreach and Education.

The life history synopsis could be improved with additional references. Recent information on the marine and estuarine life history phase in the North Pacific Ocean could be added.

Comment noted. Additional references and information have been added in the final Plan.

Information could be gleaned from fisheries researchers working in the Columbia River Basin. Biologists working in Intensively Monitored Watersheds might be a source of detailed information on freshwater phases of lamprey.

Comment noted. We anticipate that as provincial/sub basin lamprey working groups are established, additional information on lamprey will be forthcoming from participants who have not yet engaged in dissemination of lamprey information.

Based on historic spawning abundances, nutrient contents and spawning locations one could make rough evaluations of the potential nutrient contributions and compare them to other sources.

While such information is available for salmon, it is not available for lamprey. It is likely that the large lamprey abundance in the basin from general tribal historical accounts and more recent dam counts contributed to providing important nutrients throughout the basin ecosystem similar to salmon.

Dams may be preventing adults from reaching spawning grounds or the spawner-recruit relationship maybe impaired by habitat conditions. These hypotheses need testing.

That dams are preventing adults from reaching spawning grounds is evident from the dam count and tagging data. The lack of spawners in tributaries and the lack of quantifying recruits from those spawners challenge quantitative analyses in models such as spawner-recruit evaluations. Lamprey research and monitoring in the Umatilla River may provide conditions to evaluate these parameters.

The Plan could be more compelling if CRITFC thoroughly addressed the extent and possible causes of declines up front.

Comment noted. We have revised and expanded the Plan to address this comment.

It would be prudent to begin detailed monitoring of Pacific lamprey abundance at strategic locations as soon as practicable. Abundance data from the Willamette River would be particularly informative as the Willamette is below major dams.

We agree. Adult abundance estimates are being prioritized at key index sites including Willamette Falls. Collaborative research on adult life histories in the Willamette River is nearly complete. Juvenile abundance estimates are available from the Willamette below Willamette Falls and research is ongoing to procure juvenile abundance estimates for other key portions of the Willamette River.

Improving the accuracy and precision of counting procedures for upstream migrants at each dam is identified as a critical objective. The ISAB agrees with this conclusion.

Comment appreciated.

The effects of radio-tags on lamprey behavior, physiology, and survival have not been extensively studied. Such studies, not mentioned in the Plan, are important as radio tag impacts could invalidate conclusions based upon earlier research and could be damaging to lamprey recovery.

We concur that existing information concludes that radio-tags may impact lamprey behavior and physiology. Radio-tags have been useful to gather broad migration, habitat and life history information but they are already being supplanted by PIT-Tags and acoustic JSATS tags which are smaller and likely have less detrimental impacts on lamprey. These technologies are still under development and it is anticipated that as salmon tag detection systems become proven they will provide a monitoring basis for tagged lamprey.

In the absence of information on what can practically be achieved, setting generic performance standards are a bit premature at this time. One approach to setting goals for lamprey passage is to base them initially on performance level already shown to be achievable.

We concur. For adult lamprey the Plan adopted an 80% successful passage rate at mainstem dams by 2020 based upon the current achievement of that target at The Dalles Dam (Section 4.1.1.d). For juvenile lamprey the Plan notes that as juvenile passage estimates improve with emerging tag and other technology it will be possible to establish passage and survival targets similar to those established for juvenile salmon (Section 4.1.2.d).

Critically important questions about passage of juvenile lamprey through hydroelectric projects on the Snake and Columbia Rivers cannot be addressed without tagging studies.

We concur and address this issue in Section 4.1.2.c.

Because of this limitation (e.g. lack of suitable internal tag) natural tags (genetic markers, otolith, and statolith), microstructure and microchemistry are the only feasible methods available at present for long term marking of juvenile lamprey.

We agree that these should be pursued and they are addressed in Section 4.6.1.a and Section 4.6.1.d.

Development of a suitable for juvenile lamprey should be given a high priority.

We concur. See Section 4.1.2.c.

The effectiveness of surface bypass devices for passage of juvenile lamprey should be investigated.

We concur. See Section 4.1.2.d.

It would be difficult at this time to argue for flow augmentation specifically for the benefit of migrating lamprey.

We do not agree with this statement. There is empirical evidence that larval lamprey, that are poor swimmers, are mobilized in large numbers to migrate past dams with corresponding increases in the hydrograph that may occur any time in the year. Based upon dam monitoring at bypass systems, transformers or macrophthalmia, similar to salmon smolts, migrate to sea during the spring freshet. Their travel time and avoidance of predators through faster velocities and increases in river turbidity coincides with this event. We agree that more research is needed in this area.

The method used to estimate avian predation pressure on juvenile salmonids (recovery of PIT-tags from bird colonies) is not presently applicable to similar studies with juvenile lamprey.

While PIT-tag methods are not presently used to calculate avian predation rates for juvenile lamprey, Section 4.1.3.b discusses use of a bioenergentics approach developed by Roby et al. (2003) to estimate avian consumptive rates for lamprey ammocoetes. The Plan also recommends conducting a literature review of lamprey predation in the basin.

Unfortunately, no assessment of water quality, stream flow and temperature problems in tributaries used by lamprey for spawning and rearing (other than in the context of translocation) is currently included in the Plan.

Section 4.2.2.a Restore and protect migratory, spawning and rearing habitat discusses stream flow effects on lamprey migrations and also contains the Umatilla River Vision framework which considers tributary water quality, food webs and conductivity of habitats, among other things. Individual tribal ceded area plans in the Plan Appendix also address these issues.

The Plan indicates that an inventory of potential problems (e.g. tributary barriers) was implemented in 2008 but does not refer to any results of that work.

See Section 4.2.1.b Implement structural and operational changes within tributaries to improve juvenile passage for an expanded discussion of this topic.

We encourage a focus on screen development and demonstration of both salmon and lamprey passage effectiveness before a wide ranging program of retrofitting existing screens is undertaken.

We concur. See Section 4.2.1.b *Tributary Screens*.

A broad synthesis of tributary sampling results from various studies and a critical evaluation of the common or suspected limitations of ongoing sampling are not yet available. A project to summarize existing data available across the basin and to develop standardized sampling methods is needed.

We concur. Mesa et al. (2007b), cited Section 4.6.1.f in the Plan, proposed to summarize existing data across the basin and develop standardized sampling protocols. Through the CBLTWG, the tribes will encourage the region to adopt these as a important part of a monitoring and evaluation framework.

Although some juvenile lamprey have been produced by translocation of spawning adults to a stream in the Umatilla Basin, the results are preliminary and not published.

See Close et al. (2009) cited in the Plan.

It would be useful to compare translocation guidelines in George et al. (2009) to those in the Plan.

We have compared the two guidelines and have updated the tribal translocation guidelines in the Plan.

If upriver fish from different sub basins are genetically homogeneous then selected translocation efforts using known sources of migrant could be timely.

We concur. Additional genetic analyses that have come available since the time of the Draft Plan further support lamprey as a pandemic species. As stated in the Plan, translocation reduces passage mortality as dam passage improvements are ongoing.

It would be useful if the two proposed translocation programs outlined (Nez Perce and Umatilla) indicated how pheromone work might be used in translocation and reintroduction decisions.

It does appear that as for sea lamprey, pheromones may play a role in guiding adult lamprey to upriver spawning areas, in which case translocation becomes even more important. The tribes will pursue additional pheromone research in conjunction with translocation in the next few years.

Lamprey groups in the Basin need to coordinate their research and monitoring more effectively, much as have been done for salmonids and sturgeon.

We agree. See Section 4.6.1.f and Section 4.6.3.d.

Protocols for sampling juvenile lampreys in streams should consider the use of EMAP protocols for stream surveys as well as the sampling efficiencies and potential for bias across methods and environmental gradients.

See Section 4.6.1.f.

The Plan proposes to build a data management system to make all key monitoring data on the health, abundance and distribution of lamprey populations compatible. Collaboration with all cooperating tribes and agencies is envisioned, but no details are provided to suggest how this will be accomplished. The ISAB suggests that lamprey data management systems take advantage of current data management systems in the region, wherever possible, to make the lamprey system as effective and efficient as possible.

See Section 4.6.3.c. Details have been added to the Plan. Also see response to Bureau of Reclamation comment on the same issue.

The Plan does not provide enough details concerning methods to be used, sample sizes and spatial distributions to allow and effective evaluation of lamprey genetics.

We have added a lot of detail to the genetics section. See Section 4.6.1.a.

The Plan lacks sufficient indication of specific actions to achieve the objective to establish a coordinated public education and other outreach programs.

See Section 4.4 Public Outreach and Education. The final Plan has expanded this objective considerably.

The ISAB wishes to emphasize the potential implications of contaminants for both lamprey restoration and human health.

We concur. See Section 4.4 Contaminants and Water Quality. CRITFC and its member tribes are engaged multi-year studies in both adult and juvenile studies for contaminants and their effects on fish and tribal health. In addition, exploratory work at Oregon State University is focused on larval lamprey habitat preference by testing lamprey affinity to toxic Portland Harbor sediments.

<u>Oregon Department of Fish and Wildlife</u>

Plan is consistent with other regionally based plans and follows CBFWA's recommendations to the NWPCC for amendments to the Fish and Wildlife Program and CBFWA Lamprey Technical Workgroup products.

We appreciate the comment.

Document needs to be more concise and structure revised to better identify important actions and priorities.

We have made significant structural revisions to better define important actions and priorities.

Add a table of contents.

A table of contents has been added.

Provide list or tables of limiting factors/threats and necessary actions to address these, monitoring needs, critical uncertainties, research priorities, outreach and do these in a geographic framework.

We have included tables addressing limiting factors, threats and actions. We have listed monitoring needs, critical uncertainties, research priorities and outreach. We have separated the Willamette basin from the rest of the Columbia basin. As the USFWS Assessment and Template for Conservation Measures contains an excellent geographical structure to address these issues, we refer to it in the final Tribal Lamprey Plan.

Separate science information from policy statements, appeals for action and recommend

We have reorganized Plan sections to address this comment.

More emphasis needed on marine factors and getting more information on juveniles that pass below Bonneville Dam.

We have included additional information on ocean life history and juvenile lamprey estuary surveys by the USFWS. The Plan identifies pursuance of marine investigations as a priority research need.

Translocation is a reasonable strategy for lamprey reintroduction in areas with reduced numbers.

Appreciate the comment.

Plan should call for more in-depth genetic analyses before conducting large scale translocation programs.

The Plan refers to several ongoing genetic studies in Section 4.6.1.a Genetics and Population Structure. The Plan promotes increasing translocation actions in parallel with these genetic investigations in a precautionary manner.

It is critical to differentiate Pacific and brook lamprey in monitoring actions- verify with appropriate field methods- could be done with genetic analyses.

We agree. Section 4.6.1.f Monitoring and evaluation on ongoing actions and research contains methods developed to facilitate field identification of different lamprey ammocoetes. This work is being conducted by smolt monitoring personnel at the mainstem dams and in juvenile lamprey field surveys.

Plan should clarify that the State take of marine mammals does not include stellar sea lions.

Comment incorporated into the Plan. See Section 4.1.3.b Evaluate and reduce avian, piscivorous, and mammalian predation.

Not sure what term "ecological health" means in context to Pacific lamprey abundance.

Lampreys are a good indicator species of ecosystem health. Abundant groups of lamprey indicate that the ecological functions of the Columbia basin, including water quality, are working well.

ODFW cannot commit to a full time lamprey scientist/manager because of limited funding.

We acknowledge there are serious funding constraints, especially from state agencies. We request that state agencies place a higher priority on coordinating lamprey restoration actions throughout their agencies and with the tribes and others in the basin.

Suggest that juvenile to adult returns be added as another passage metric.

We concur with this concept and when appropriate tagging methods are developed and tested this metric can be better developed.

List potential operations for salmon that may be helpful or harmful for lamprey.

These are addressed in detail in Sections 4.1.1 Adult Mainstem Passage and 4.2.1 Juvenile Mainstem Passage.

Include Bureau of Reclamation dams along with Corps and FERC license holders with respect to lamprey impacts.

Bureau of Reclamation mainstem dams are outside the current anadromy of Pacific lamprey. The Plan focuses on Corps and FERC dams as lamprey passage is still possible and can be vastly improved. Should anadromy be expanded in the future, Reclamation dams will be examined as to factors limiting lamprey. For Reclamation impacts, the Plan focuses on the significant number of lamprey barriers in tributaries as a key limiting factor to lamprey productivity.

Identify modifications to dams for passage that may be interim and not full scale for implementation.

These are addressed in detail in Sections 4.1.1 Adult Mainstem Passage and 4.2.1 Juvenile Mainstem Passage.

In addition to supply fish for research, the plan should point out that an aquaculture facility would help begin development of techniques to propagate lamprey if hatchery supplementation is necessary.

See Section 4.3.1.c Develop and implement lamprey artificial propagation as a component of a regional supplementation/augmentation plan.

The Appendix is well organized and concise. If necessary the authors meet with local and regional biologists from the state and federal agencies to review MOA and other projects.

Comment appreciated. The tribal and CRITFC technical staffs held regional meetings throughout the basin on the draft Plan to provide more extensive outreach and to gain more input on the final Plan. Currently, ODFW, Warm Springs, CRITFC, USFWS and the Grande Ronde Tribe are collaborating on a lamprey workgroup for the Willamette Basin and the Yakama Nation is collaboration with USFWS, WDFW and

Reclamation in the Yakima Basin. We support expanding these examples into other sub basins in the region.

Plan should clarify that the Pelton water withdrawal structure in itself will not change lamprey passage conditions, but habitat and other passage improvements may improve lamprey passage.

Section 4.2.1.b indicates that the Pelton water withdrawal structure has proven successful in passing juvenile salmon. We believe that passage of juvenile lamprey through the structure may also be possible, but acknowledge specific research is needed.

<u>U.S. Bureau of Reclamation</u>

The final draft of the Plan is a relatively comprehensive approach for restoration of Pacific lamprey in the Columbia River basin. The authors did a thorough job of describing the current situation of Pacific lamprey in the Columbia River basin and describing measures that they feel are necessary to restore Pacific lamprey to sustainable levels.

Comments appreciated.

The paragraph regarding the size of the extended length turbine screens that cause juvenile lamprey impingement should be clarified.

This issue is clarified in Section 4.1.2.d Identify and implement longer term structural and operational improvements to mainstem dams to improve juvenile passage through dams and reservoirs.

The existing PNAMP (Pacific Northwest Aquatic Monitoring Partnership) process may be an option for managing data related to the Pacific lamprey restoration plan, rather than setting up a parallel and likely redundant database.

Good comment. Under the Fish Accords, CRITFC has a data base project funded and underway where tribal salmon research information is being collected and archived. We have suggested that we use this project for lamprey data. However, we will examine the future potential of PNAMP and regional data sharing through the CBFWA Lamprey Technical Workgroup. See Section 4.6.3 Data Management.

<u>U.S. Corps of Engineers</u>

Consider further discussion of nighttime passage data using count window videotaping.

See Section 4.1.1.c Continue to identify and implement long-term structural and operational improvements at mainstem dams to improve adult passage for more detail on this effort.

The premise that increased flow augmentation and thus spill will aid adults in upstream migration is unfounded. Increasing spill at dams is likely to increase fallback in lamprey as it does in salmon reducing passage success.

We agree that more specific research investigating spill and fallback on adult lamprey needs to be conducted. Currently, adult lamprey fallback rates appear to range from 10-18 % during salmon spill conditions where some data is available, however, since lamprey hold overwinter we would expect some traversing upstream and downstream and thus safe downstream passage routes through dams is likely a critical need. We do believe that managing river flows toward a more natural or normative hydrograph is desirable for lamprey passage and river habitat including attraction into the river from an enlarged Columbia River near ocean plume (See Section 4.1.1.c).

Dan Roby's preliminary data from East Sand Island has some information about juvenile lamprey consumption rates by terns and cormorants based upon expansions and energy budgets.

Good point. See Section 4.1.3.b for inclusion of this information.

The question of prioritization and passage goals needs to be as technically and scientifically based as possible.

We agree. Table 3 contains general categories and timelines of adult improvements and Table 4 addresses juvenile improvement needs. We expect that these priorities will be adjusted on a real time basis according to available resources but we believe that all of the improvements listed are important and will seek new resources beyond current regional capacities.

Fyke net studies enumerating juvenile lamprey have occurred at various dams with data indicating that over 70% of run of river juvenile lamprey approach powerhouses deep enough to be below the juvenile screens….still when screens are encountered (25-30% is not insignificant) juvenile lamprey are at risk for impingement and mortality.

See Section 4.1.2.d Continue to identify and implement long-term structural and operational improvements at mainstem dams to improve adult passage. We have updated this section and concur that juvenile impingement on current turbine intake screens is a known and serious problem.

Researchers do not think using Hi-Z balloon tag studies is feasible because of their small size and behavior differences between salmon and lamprey. We appreciate the need to get information from active tagged lamprey and are working toward miniaturization of acoustic tags to allow such evaluations as fast as possible.

See Section 4.1.2.c Utilize juvenile tag technology and other methods to obtain route-specific passage and survival at mainstem dams. Given the uncertain timeline when miniature acoustic tags may be available for lamprey, the Plan continues to promote other methods, such as balloon tags, synthesizing existing migration data and dam passage data, and developing improved PIT-Tag detection rates to resolve route specific dam information.

It is suggested that the goal and standard for juvenile lamprey downstream passage should be 98 % as for salmon fry at some projects. This is not an appropriate surrogate considering the vast differences between the species.

See Section 4.1.2.d Identify and implement long-term structural and operational improvements at mainstem dams to improve juvenile passage and survival through dams and reservoirs. We note that as information for juvenile passage improves it will be easier to establish survival targets for juvenile lamprey similar to those of juvenile salmon-not that these are already the same but perhaps may be in the future.

U.S. Fish and Wildlife Service

We are encouraged that the plan developed in spirit of cooperation and regional collaboration.

Comment appreciated.

The plan correctly identifies the main impacts impacting lamprey and actions needed for recovery.

Comment appreciated.

The plan goal- to immediately halt population declines and reestablish lamprey as a fundamental component of the ecosystem by 2018 is commendable.

Comment appreciated.

Public education and outreach is also important.

We agree. The final Plan has expanded this topic. See Section 4.5 Public Outreach and Education.

Translocation should be an emergency, interim measure only- current tribal plan for 500 adults for two tribes appears risky.

The tribes and others including the CBFWA Lamprey Technical Work Group have assembled much information to address translocation benefits and risks over the last three years. The tribes have established very conservative guidelines for translocation. Among other things, translocation increases passage success while dam passage improvements are being researched and implemented. See Section 4.3 Supplementation/Augmentation for more details.

USFWS recommends small scale translocation as a measure to identify success of completion of life histories (ie: spawning to emergence, ammocoete to macropthalmia).

Comment noted. See Section 4.3 Supplementation/Augmentation.

Adult entrances to fishways and juvenile migration through dams appear significant problems.

Agree. See Section 4.1.1.c Continue to identify and implement long-term structural and operational improvements at mainstem dams to improve adult passage and Section 4.1.2.d Identify and implement longer term structural and operational improvements to mainstem dams to improve juvenile passage and survival through dams and reservoirs.

Additional water quality issues (i.e. toxics, heavy metals, ect.) need to be addressed.

See Section 4.4.1 Contaminant Accumulation.

Additional research recommended for some areas that were not included in the plan.

See Section 4.6.1 Research, Monitoring and Evaluation.

Include limiting factors prioritized by the CBLTWG such as habitat preference and availability, response to environmental stressors and trophic relationships.

See Table 5. Linkage of Pacific Lamprey Threats/Limiting Factors, Uncertainties, and Recommended Plan Objectives/Actions by Life History Phase.

USFWS would like to work with the tribes on future research: gender identification, aging techniques, ecological functions and increasing understanding of population dynamics through the USFWS Rangewide Conservation Initiative.

Tribes have supported this important USFWS work on the Conservation Initiative and the final report from the Initiative is noted in several places in the Plan.

Tribes should classify lamprey from their fish and game codes.

This work is underway.

USFWS is not inconsistent when prescribing passage conditions for lamprey at various FERC project- the tribes should focus on obtaining additional information at dams so that USFWS can make better passage prescriptions.

We wish the USFWS promoted lamprey passage for the Enloe and Hells Canyon FERC licensing proceedings as they have done for other FERC proceedings. In this regard the burden of proof that lamprey need passage and/or improved passage at FERC licensed dams should not fall on the lamprey or tribes who do not have mandatory authority to prescribe passage or passage improvements.

If passage is not improved, translocation could result in reducing existing lamprey groups.

Translocation will improve adult passage to upstream areas and the tribes' conservative take of lamprey for translocation should not impact downstream groups.

Expand plan and USFWS conservation initiative nexus.

The final Plan contains many areas that join the USFWS conservation initiative and tribal recommended actions.

Expand Umatilla translocation success description.

Section 4.3.2.1. a Continue translocation in accordance with tribal guidelines provides additional details on the Umatilla River translocation success. More information is available in Close et al. (2009; see citation in reference section).

The plan should describe who and how data management is conducted.

See Section 4.6.3 Data Management which addresses these issues.

Need pilot aquaculture effort before full fledged facility.

See Section 4.3.1.c Develop and implement lamprey artificial propagation as a component of a regional supplementation/augmentation plan. The Plan calls for creation of a regional lamprey supplementation plan and guidelines and that pilot propagation efforts need to be consolidated and further developed.

U.S. Environmental Protection Agency

Language should be included to recognize toxics as part of water quality impacts on lamprey-because of their high fat content and extended freshwater residence, lamprey may be more susceptible to toxic impacts.

See Section 4.4 Contaminants and Water Quality. We have incorporated language that expresses these comments.

Additional research on lamprey and toxics is needed.

This comment is thoroughly addressed in Section 4.1.1.b

Washington Department of Fish and Wildlife

Consider a ramp down period in irrigation canals to keep lamprey from dessication in the fall.

Good comment. This recommendation was added in Section 4.2.1.b Implement structural and operational changes within tributaries to improve juvenile passage.

Some irrigation diversion structures barriers to salmon but not yet evaluated for lamprey.

The Plan calls for assessing all tributary screens for lamprey passage through prioritized inventories whether the screens work for salmon or not.

At remote sites, power is not available to implement spray systems to keep lamprey from sticking to screens and ending up in irrigation canals.

Good comment. This recommendation was added in Section 4.2.1.b Implement structural and operational changes within tributaries to improve juvenile passage.

Appendix C-Glossary

acoustic telemetry-Remote measurement and reporting of information using sound waves.

aggregation-A group of organisms of the same or different species living closely together but less integrated than a society.

allele frequency-The percentage of all alleles for a particular genetic marker in the gene pool of a population (or other group of individuals of interest) represented by a given allele.

allele-An alternative form of a genetic marker; markers can be proteins (enzymes) or DNA segments specific to a location (locus) within coding or non-coding regions of the genome.

allozyme (or, alloenzyme)- Any of the variants of an enzyme that are determined by alleles at a single genetic locus.

ammocoetes-The larval stage of a lamprey.

anguilliform-Having the shape or form of an eel.

anthropogenic-Caused or produced by humans.

benthic-Of or pertaining to the bottom of a body of water and to near shore or splash zones in the marine environment or to the organisms that live there.

bioaccumulation-Referring to substances, especially toxins that build up within the tissues of organisms.

biodiversity-Diversity among and within plant and animal species in an environment for a given set of characters – morphological, physiological behavioral, genetic, etc.

bioengineering-The use of engineering applications, such as physics, mathematics, and computer science to understand or solve problems associated with biological organisms or processes.

biogeographic-Species and organisms in regions or particular environments.

bioinformatics-The retrieval and analysis of biochemical and biological data using mathematics and computer science.

biota-The animals, plants, fungi, etc., of a region or period.

BOR-U.S. Bureau of Reclamation.

cavitation-The formation of empty cavities, or bubble-like spaces, in a liquid by high forces and the immediate implosion of them.

CBFWA-Columbia Basin Fish and Wildlife Authority.

CE-QUAL-2-A two-dimensional water quality model.

climate change-A long-term change in the earth's climate, especially due to an increase in the average atmospheric temperature.

CMOP-Center for Coastal Marine Observation & Prediction.

Corps or **USACE**-U. S. Army Corps of Engineers.

CRBLTWG-Columbia River Basin Lamprey Technical Workgroup.

CRITFC-Columbia River Inter-Tribal Fish Commission.

CTUIR-Confederated Tribes of the Umatilla Indian Reservation

CTWSRO-Confederated Tribes of the Warm Springs Reservation of Oregon

diatoms-Any of numerous microscopic, single-celled, marine or freshwater algae having cell walls containing silica, commonly used in water quality studies.

DIDSON-Dual Frequency Identification Sonar. A multi-beam underwater acoustic camera; a DIDSON repetitively emits sets of sound beams and uses a unique patented lens to resolve the reflections of objects passing in the water column within its field of view into two-dimensional images.

dioxin-A general name for a family of chlorinated hydrocarbons ($C_{12}H_4Cl_4O_2$) typically used to refer to a by-product of pesticide manufacture: a toxic compound that is carcinogenic and teratogenic (a cause of birth defects) in certain animals.

DNA-Deoxyribonucleic Acid. A double-stranded nucleic acid, portions of which (genes) contain the genetic information for cell growth, division, and function, and can be faithfully replicated so as to transmit this information in the process of cell division.

electroreception-The biological ability to perceive natural electrical stimuli.

endocrine disruption-Interference with endocrine (or hormone system) in animals, including humans via exposure or ingestion of certain chemicals.

ESA-Endangered Species Act.

extirpation-Complete elimination or extermination.

fecundity-The measure of an organism's ability to produce offspring; among fishes, typically refers to the total number, or number per unit weight, of eggs within a female.

FERC-U. S. Federal Energy Regulatory Commission.

fyke-A bag-shaped fish trap.

hydroacoustic-The study of sound traveling through water.

hydrograph-A graph of the water level (or rate of flow) of a body of water over time that shows the seasonal change.

hydrophilic-Having a strong liking for water.

IDFG-Idaho Department of Fish and Game.

impinged-To strike, dash, or collide.

ingestion-To take, as food, into the body.

invertebrate-Of or pertaining to creatures without a backbone.

ISAB-Independent Scientific Advisory Board.

isolate-To set or place apart; detach or separate so as to be alone.

ISRP-Independent Scientific Review Panel.

JSATS-Juvenile Salmonid Acoustic Telemetry System. This system utilizes acoustic telemetry to track fish using sound and vibration.

larva-A distinct juvenile or immature form of many animals.

lipid-Any of a group of organic compounds that are greasy to the touch, incapable of dissolving in water, but capable of dissolving in alcohol and ether: lipids comprise the fats and other compounds with similar properties.

lipophilic-Having a strong liking for lipids.

LPS-Lamprey Passage Structure. This structure consists of a series of ramps and metal boxes, connected to a consistent flow of water, which allows lamprey to efficiently ascend vertical barriers.

macropthalmia-The juvenile stage of a lamprey; characterized by large eyes.

metabolized- Change brought about by the physical and chemical processes of living organisms.

metamorphosis-A profound change in form from one stage to the next in the life history of an organism, as from caterpillar to pupa and from pupa to adult butterfly.

metrics-Parameters of quantitative assessment used for measurement.

microsatellite DNA marker-Short repeats of nucleotide (units of RNA and DNA) sequences present throughout a complete set of genes in an organism (or genome), which exhibit variations within a population a tandem array of a short (typically, 2 to 6 basepairs).

model-A standard or example for imitation or comparison.

molecular-Of or pertaining to or caused by molecules; a molecule is the smallest particle of a substance that retains all the properties of that substance and is composed of at least two atoms.

monomorphic-Having only one form.

morphological-Branch of biology dealing with the form and structure of organisms.

NOAA-United States National Oceanic and Atmospheric Administration.

ODFW-Oregon Department of Fish and Wildlife.

olfactory-Of or pertaining to the sense of smell.

oligotrophic (of a lake)-Characterized by a low accumulation of dissolved nutrient salts, supporting only a sparse growth of algae and other organisms, and having a high oxygen content due to the low organic content.

osmoregulation-The process by which cells and simple organisms maintain fluid and electrolyte balance with their surroundings.

otolith-Part of the internal ear of vertebrates and composed in part of calcium carbonate.

pelagic-Of or pertaining to the open seas or oceans.

PGE-Portland General Electric

pheromones-Secreted or excreted chemicals that trigger a social response in members of the same species.

philopatric-The tendency of a migrating animal to return to a specific location in order to breed or feed.

physiological-Of or pertaining to the study of functioning of living things.

PIT-Passive Integrated Transponder. PIT tags are implanted into fish for the purpose of identifying and tracking individual fish using radio waves.

planktonic-The collection of passively floating, drifting, or somewhat motile organisms occurring in a body of water, primarily comprising microscopic algae and protozoa.

plasticity-The capability of being molded, receiving shape, or being made to assume a desired form.

population dynamics-The branch of life sciences that studies short- and long-term changes in the size and age composition of populations and the biological and environmental processes influencing those changes.

primers- Strand of nucleic acid that serves as a starting point for DNA synthesis.

PUD-Public Utility District.

QAPP-Quality Assurance Project Plan.

ratios-The relation between two similar magnitudes with respect to the number of times the first contains the second.

refugia-An area where special environmental circumstances have enabled a species or a community of species to survive after extinction in surrounding areas.

salinity-The saltiness or dissolved salt content of a body of water.

semelparous (of an animal)-Producing offspring only once during its lifetime.

statolith-Small, movable pieces of calcium carbonate found in balance sensory receptors or statocysts. See otolith.

subcellular-Contained within a cell.

sublethal-Almost lethal or fatal.

synergistic-Pertaining to, characteristic of, or resembling synergism, which may be described as an instance where an outcome may be greater than the sum of individual component changes.

teleost-Belonging or pertaining to the Teleostei, a group of bony fishes including most living species.

total suspended solids/organics-Matter suspended or dissolved in water or wastewater.

toxicology-The science dealing with the effects, antidotes, detection, etc. of poisons.

translocation-Movement from one position or place to another.

trophic-Of or pertaining to nutrition; concerned with nutritive processes.

USEPA-U.S. Environmental Protection Agency.

USACE or **Corps**-U.S. Army Corps of Engineers.

USFWS-United States Fish and Wildlife Service.

USGS-United States Geological Survey.

viability-The ability of living, developing, or reproducing under a given set of conditions.

WDFW-Washington Department of Fish and Wildlife.