SYNOPSIS OF LAMPREY-RELATED PROJECTS FUNDED THROUGH THE COLUMBIA RIVER BASIN FISH AND WILDLIFE PROGRAM

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Columbia Basin Fish and Wildlife Authority

Report for

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INTRODUCTION

The Biological Objectives section of the Northwest Power and Conservation Council's (Council) 2009 Fish and Wildlife Program (Program) includes language specific to lamprey: "Restore lamprey passage and habitat in the mainstem and tributaries that historically supported spawning lamprey populations. Attain self-sustaining and harvestable populations of lamprey throughout their historical range. Mitigate for lost lamprey production in areas where restoration of habitat or passage is not feasible" (Council 2009). Despite the existence of lamprey-related biological objectives in the current and past Programs, funding for lamprey work has been slow to develop. The number of lamprey projects has increased with the signing of the "Fish Accords" between the Bonneville Power Administration and various tribes.

Our understanding of lamprey biology, physiology, behavior, and habitat requirements is far from complete; therefore, most lamprey projects have emphasized increasing this understanding. Exceptions include projects to implement and assess management actions such as translocation. Monitoring and evaluation for lamprey in the Columbia River Basin is an ongoing need, and almost all work has targeted Pacific lamprey *Entosphenus tridentatus*, with little effort put towards river lamprey *Lampetra ayresi* or brook lamprey *Lampetra richardsoni*.

Work has been conducted or is currently underway to assess the status of Pacific lamprey in Snake River subbasins, and in the Yakima River, Umatilla River, Deschutes River, Klickitat River, Fifteenmile Creek, Hood River, Willamette River, and Lewis River subbasins. Status in many subbasins remains unknown. A number of projects have increased our knowledge of Pacific lamprey behavior and requirements, but further investigations are needed. Long-term results from translocation projects are just now becoming available. Additionally, a long term monitoring and evaluation program of lamprey research and conservation actions is needed for the purpose of understanding lamprey status and its response to management actions.

In addition to the Program projects summarized in this report, the U.S. Army Corps of Engineers has funded projects to improve passage at mainstem dams. The U.S. Fish and Wildlife Service has funded a larval lamprey distribution study in the mainstem Columbia and Willamette rivers as well as tributary passage projects (Umatilla and North Umpqua Rivers). In addition, the Nez Perce Tribe has implemented a translocation program. Although not funded as part of the Program, this project is summarized because of its similarity to Program projects that address issues other than passage at mainstem dams. Although much remains to be learned and many improvements remain to be implemented, these projects combined will hopefully be a start towards reversing the decline in numbers of Pacific lamprey in the Columbia River Basin.

In its review of lamprey projects funded through the Council's Program, the Independent Scientific Review Panel (ISRP) included a series of questions regarding the status of lamprey in the Columbia River Basin and the degree of coordination among lamprey projects. The ISRP noted that it might be appropriate to have the Columbia River Basin Lamprey Technical Workgroup (CRBLTWG) develop a synthesis report to summarize lamprey projects and answer these questions. The Council agreed, and called for the development of a synthesis report on the lamprey efforts under the Program. This report therefore includes two primary sections: (1) a synopsis of ongoing and past lamprey-related projects funded through the Program, and (2) answers to specific lamprey questions asked by the ISRP.

SUMMARY OF FISH AND WILDLIFE PROGRAM PROJECTS

Pacific Lamprey Research and Restoration Project
Project Number 1994-026-00
Umatilla River Subbasin, Oregon

The overall purpose of this study is to provide the critical information to restore Pacific lamprey in the Umatilla River Subbasin, to provide harvest opportunities and to recover ecosystem functions that lamprey provide. Efforts to date have shown that outplanting adult lamprey can result in successful adult reproduction and increased larval production. The next step in this project is to insure that outplanted lamprey will result in a self-sustaining population in the Umatilla Subbasin. In addition to increasing the abundance of larval lamprey in the subbasin, key components are to establish that more adult lamprey are now returning to the Umatilla Subbasin, and that they are able to reach historical spawning areas. The comprehensive lamprey restoration program using translocation allows the following project objectives: (1) estimate the numbers of adult lampreys entering the Umatilla River, (2) monitor passage success to spawning areas using radio telemetry, (3) develop structures to improve passage success, (4) increase larval abundance in the Umatilla River by continuing to collect, hold and outplant adult lamprey , 5) conduct redd surveys, 6) monitor larval population trends in the Umatilla River by conducting electrofishing surveys, and 7) estimate the numbers of juvenile lampreys migrating out of the Umatilla River.

To initiate the restoration of Pacific lamprey in the Umatilla River, in 2000 the Confederated Tribes of the Umatilla Indian Reservation began a multi-year project to outplant sexually mature adults in the upper watershed to increase larval densities. Results to date have been summarized in the report "Translocating Adult Pacific Lamprey within the Columbia River Basin: State of the Science".
http://www.cbfwa.org/Committees/LTWG/meetings/2011_0331/TranslocatingAdultPacificLamprey31March2011.pdf
A revised version of the report has been accepted by the journal *Fisheries*, and should be published in 2012.

Translocated lamprey spawned, producing viable eggs in the Umatilla River and Meacham Creek. Larval abundance in index plots sharply increased one year after translocation of adult lamprey to the Umatilla River. Mean densities remained elevated. Larval distribution also increased through time. Abundance of out-migrating lamprey began increasing in the years after translocation began. The number of adults has increased over time, but the total number of individuals entering the Umatilla River is still low. However, 129 adult lamprey did return in 2011 to the Umatilla River Basin which represents a large increase from previous years returns.

A pilot study was initiated in 2005 to determine whether radio telemetry could be used to assess the effects of low elevation structures on adult lamprey passage in the Umatilla River. Results of this study provide evidence that low elevation structures combined with low flows impact the ability of adult Pacific lamprey to migrate upstream. These results were also used to prioritize which diversion dam projects should be the first to receive adult lamprey passage structures (LPS), and where the LPS should be placed at each project.

This project was the first to install adult lamprey specific passage structures within a Columbia River tributary. Beginning in 2009, Threemile Falls Dam, Feed Diversion Dam, Maxwell Diversion Dam, and Dillon Diversion Dam were outfitted with LPS to aid adult upmigration. Monitoring and evaluation studies will continue to assess effectiveness of these structures. Initial results of these structures will provide valuable knowledge that is expected to be applied in other Columbia River basin tributaries.

An additional component of the project was to determine if transmitter weight affects lamprey vertical climbing ability. Results provided evidence that vertical climbing ability of adult Pacific lamprey is not significantly compromised by transmitter weight.

This project was also the first to document genetic differences among Pacific lamprey across much of their range. Collections of migrating adult Pacific lamprey from Japan, Alaska, and six locations in the Pacific Northwest were examined. Based on variation at 180 polymorphic loci of the 556 AFLP loci generated by seven primer combinations, the different collections were characterized by a high proportion of shared bands, which indicated significant levels of historical gene flow across the range of the species. No differences observed corresponded to any obvious geographical patterns.

Future work will include continuing to conduct long-term monitoring and evaluation tied to recovery efforts, implementation of juvenile lamprey PIT tagging studies, and development of artificial propagation methods.

Determining Adult Pacific Lamprey Abundance and Spawning Habitat in the Lower Deschutes River Subbasin, Oregon
Project Number 2002-016-00

This project was initiated to assess the status of lampreys in the Deschutes River Subbasin because information about lamprey species composition, distribution, life history, abundance, habitat requirements, and exploitation in the subbasin were extremely limited. Initial project objectives were to determine larval lamprey distribution and associated habitats, lamprey species composition, numbers of larval emigrants, and adult escapement and harvest rates at Sherars Falls. An additional objective added later was to determine lamprey focal spawning areas, spawn timing, and habitat through radio telemetry.

Pacific lamprey is the only species identified to date. Surveys throughout the lower subbasin found larval Pacific lamprey in four streams: Warm Springs River, Badger Creek, Beaver Creek, and Shitike Creek. Lamprey were present in the downstream portions of the streams. Larvae were also found in the mainstem Deschutes River between river kilometers (Rkm) 24 and 156. Positive relationships were identified linking ammocoete presence and average water depth, presence of wood, depositional area, velocity, and fine substrate.

Peak movements of Pacific lamprey macropthalmia and ammocoetes varied among year and stream. Macropthalmia generally out-migrated from Shitike Creek and the Warm Springs River in November or December. Ammocoete movements often peaked in spring, but in some years peaked in November or December. Abundances of ammocoetes and macropthalmia were not estimated.

Abundance and harvest of adult Pacific lamprey have been estimated yearly since 2004 (Table 1). Estimates have not followed a discernible pattern; however abundance was lowest in 2010.

Adult Pacific lamprey migration rates were loosely correlated with water temperature and change in discharge; migration rates increased with rising daily average water temperatures and declining river discharge. Although the size of the Deschutes River prohibited pinpointing exact locations for each individual, lamprey appeared to hold in fast water or tailout areas. Lamprey in tributaries appeared to over-winter in riffles and glides.

At the onset of the study, it was thought that spawning would be observed primarily in tributaries, particularly in Shitike Creek and the Warm Springs River. An unexpectedly high percentage (60%) actually appeared to have spawned in the Deschutes River; however, no redds were documented or measured. Redds were observed in multiple years in Shitike and Beaver creeks, where Pacific lamprey spawned in water about one-third meter deep, with flows near zero at the substrate and about one-half meter per second 60% in the upper water column.

Determine the Status and Limiting Factors of Pacific Lamprey in the Fifteenmile Creek and Hood River Sub-basins, Oregon
Project Number 2007-007-00

Fifteenmile Creek is an important harvest location for members of the Confederated Tribes of Warm Springs Reservation, Oregon, but little information is available about the status of Pacific lamprey in the Fifteenmile Creek Subbasin. Determining Pacific lamprey status in Fifteenmile Creek has been identified in the Fifteenmile Subbasin Plan as a key objective. The goal of this project is to determine the status and limiting factors of Pacific lamprey in the Fifteenmile Creek Subbasin by:

1. Determining larval and spawning distribution of Pacific lamprey within the Fifteenmile Subbasin;
2. Estimating adult escapement and tribal harvest near the mouth of Fifteenmile Creek;
3. Documenting larval out-migration timing; and
4. Identifying factors that may limit lamprey production within the Fifteenmile Creek Subbasin.

Surveys began in Fifteenmile Creek in 2010, but have not yet started in the Hood River. Eighty seven stream kilometers were surveyed for ammocoetes, with presence confirmed in Fifteenmile and Eightmile creeks. No redds were identified during surveys from late June through early July. Approximately 20,000 ammocoetes and macropthalmia were counted in a downstream migrant trap in Fifteenmile Creek. Outmigration coincided with high flow events.

Table 1. Abundance and harvest estimates for Pacific lamprey in the Deschutes River Subbasin.

Year	Abundance in Deschutes Subbasin: Population Estimate	Abundance in Deschutes Subbasin: Confidence Limits	Escapement over Sherars Falls	Tribal Harvest
2004	6,412	--	4,854	1,558
2005	3,895	--	2,881	1,015
2006	3,783	--	3,299	485
2007	8,083	6,352-10,279	5,780	2,303
2008	3,471	2,384-5,041	2,669	806
2009	3,707	2,699-5,082	3,332	375
2010	1,711	1,240-2,355	1,366	345

Willamette Falls Lamprey Escapement Estimate
Project Number 2008-308-00
Willamette River Subbasin, Oregon

Objectives of this project include conducting a mark-recapture experiment to estimate lamprey escapement at Willamette Falls and developing a long-term monitoring index of abundance of adult lamprey at Willamette Falls. While populations of Pacific lamprey in the Columbia River have declined and fishing opportunities have diminished, the Pacific lamprey fishery at Willamette Falls has continued to provide a harvest opportunity for tribal subsistence fisherman. Despite the importance of Willamette River Pacific lamprey, abundance estimates at the falls have not previously been attempted.

In 2010, the first year of the project, 2,156 lamprey were captured in the fish ladder at Willamette Falls between May and September, tagged, and released approximately 1.6 kilometers downstream. Through inspection of lamprey captured in the fish ladder and during creel surveys, 89 tagged lamprey were recaptured. Based strictly on the number of lamprey marked, recaptured and inspected at Willamette Falls, the estimated escapement during summer 2010 was 89,658. However, fish that do not return to the fish ladder (considered strays for this analysis) are not subject to recapture. Previous radio-telemetry data for lamprey released downstream of Willamette Falls suggested that, while over 90% of tagged lamprey returned to the falls, passage through the fish ladder ranged between 23% and 42%. Applying the inverse of the passage rates (77% to 58% stray rates), adult lamprey escapement at Willamette Falls in 2010 was estimated to be in the range of 22,000 to 36,000. Given an estimated escapement of Pacific lamprey at Willamette Falls in 2010 with stray rates applied, lamprey harvest rate in 2010 (1,606) was approximately 4.4 % to 7.3%.

In 2011, a new mark-detection effort utilizing PIT tags allowed the stray rate to be estimated with more confidence. In addition, a new video surveillance effort increased the potential number of fish inspected for tags. The straying rate of PIT-tagged fish was estimated to be about 57%, based on a passage rate through the fish ladder of about 43% for PIT-tagged fish. All information needed to estimate escapement at Willamette Falls in 2011 is not yet available; however, applying the new, year-specific straying rate will greatly increase the confidence in escapement estimates. In 2011, 2,490 lamprey were marked, and 117 were physically inspected or recaptured. Information for PIT-tagged fish will greatly increase the number of recaptures. At least 8,127 fish were inspected for marks, a number that will increase when all video information is reviewed.

Implement Tribal Pacific Lamprey Restoration Plan
Project Number 2008-524-00
Columbia River Basin, Washington, Oregon, and Idaho

This project is directed toward implementation of the objectives within the Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin (TPLRP). Objectives include improving mainstem and tributary passage, evaluating supplementation and augmentation strategies for lamprey recovery, evaluating contaminant and water quality issues for lamprey, implementing a regional outreach and education program, and conducting research, monitoring, and evaluation of lamprey at all life history stages. Below is a list of completed and ongoing projects related to the TPLRP.

- First international forum on the recovery and propagation of Lamprey (completed)
- Radio telemetry studies in the Willamette River: Migration characteristics and habitat use of the imperiled Pacific lamprey (completed)
- Microsatellite analysis of Pacific lamprey from the Willamette River basin (ongoing)
- Monitoring the relative abundance of ammocoetes in the Willamette River basin (ongoing)
- Assess emerging and legacy contaminants in juvenile and adult Pacific lamprey in the Columbia River basin (ongoing)
- Tribal elder outreach and lamprey education (ongoing)
- Assess the impact of irrigation diversion screens on juvenile lamprey in the Columbia River basin (ongoing)
- Assessment of gene flow in Pacific lamprey using microsatellite markers (ongoing)

Willamette River Subbasin, Oregon

In 2009, this project was initiated with the goal of providing information that would improve understanding of the migration biology and habitat use of adult Pacific lamprey in the Willamette River Subbasin for the purposes of conservation, restoration, and education. Very little is known about pre-spawning migration characteristics, including habitat use by adults in the Willamette River Subbasin.

From May through July of 2009 and 2010, a total of 294 and 219 adult Pacific lamprey were collected and surgically implanted with radio tags and released above Willamette Falls. Tagged lamprey expressed a variety of behaviors, ranging from immediate movement into tributaries to limited movement within the main stem in both years. During active migration, tagged lamprey traveled approximately 8–10 km/day, typically during night and early morning hours. Tagged lamprey tended to migrate upstream until early July through August, when mean daily temperatures in the lower river were > 20 ^{o}C. Some fish began moving again in October and November when mean daily river temperatures dropped by 5–10 ^{o}C. Main channel, main channel off rock revetments (> 6 m away from a rock revetment shore), and rock revetments were the three most common habitats in which lamprey held in 2010, compared with 2009, when more fish held on rock revetments, main channel, and logs. Tracking data indicated that most fish were detected in the mainstem Willamette River, the Santiam River system, and the Molalla River. Results indicate that Pacific lamprey use and effectively reproduce in many of the streams in the Willamette Subbasin.

Yakama Nation Pacific Lamprey Restoration Project
Project Number 2008-470-00
Various Subbasins

The Yakama Nation Pacific Lamprey Program (YNPLP) was developed with a three phase approach with Phase I occurring in 2009 – 2010. Phase I work centered on building the program, regional survey and data input coordination, developing relationships with local and regional entities and refining YNPLP objectives. The eight objectives are:

(1) Document historic distribution of adult lamprey from historical records, literature reviews and oral interviews and compare with known current distribution.
(2) Participate in and contribute to regional consistency in data collection, data management, analysis and reporting.
(3) Document status of larval Pacific lamprey with presence/absence surveys to determine distribution of recruitment.
(4) Document biologic condition, migration behaviors and environmental cues that trigger migration for both adult and juvenile Pacific lamprey.
(5) Identify habitat characteristics that are preferred at various life stages and determine the extent these habitats are available and are being utilized (habitat mapping).
(6) Identify and inventory all known and potential limiting factors, and current threats existing in tributary habitats. Develop and implement a Pacific Lamprey Action Plan for the Methow, Entiat, Wenatchee, Crab Creek, Yakama, Rock Creek, Klickitat, White Salmon, Wind, and Little White Salmon subbasins.
(7) To increase larval abundance in tributary streams, implement a pilot adult Pacific lamprey translocation program from main-stem Columbia River hydro-electric projects into various subbasins and evaluate methodology and potential biological benefits and risks of expanding this program as appropriate.
(8) Evaluate the potential for and participate in the development of supplementation / artificial propagation techniques of Pacific lamprey.

Tribal elders, fishermen and tribal families were interviewed for traditional ecological knowledge (TEK). This knowledge was very useful in gaining baseline life history information. TEK helped more accurately identify eras when Pacific lampreys were abundant, where harvest took place, and run timing at traditional fishing areas near rapids, crevices, and falls of rivers and streams.

Surveys for larval lampreys were conducted in the Klickitat River Subbasin in 2009-10 up to Rkm 145. External morphological characteristics were used to identify ammocoetes to genus.

No Lamprey were found above Castille Falls on the Klickitat River. Pacific lamprey were identified in the Klickitat mainstem from Rkm 2 through 69.5, and in the Little Klickitat from Rkm 2 through 6. Western brook lamprey were identified only in the Little Klickitat River. No river lamprey were identified. Length frequency distributions indicated the presence of several year classes of Pacific lamprey.

Nez Perce Tribe Adult Pacific Lamprey Translocation Initiative
No Project Number
Clearwater Subbasin, Idaho and Asotin Subbasin, Washington

The objective is to annually translocate up to 500 adult Pacific lamprey from the mainstem Columbia River to five or six Snake River Basin tributaries. Assuming half of the fish are females, and an 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 River Basin, especially in consideration of the extremely low counts adult lamprey passing Lower Granite Dam. Results to date have been summarized in the report "Translocating Adult Pacific Lamprey within the Columbia River Basin: State of the Science".
http://www.cbfwa.org/Committees/LTWG/meetings/2011_0331/TranslocatingAdultPacificLamprey31March2011.pdf
A revised version of the report has been accepted by the journal *Fisheries*, and should be published in 2012.

From 2007 through 2010 a total of 480 adult lamprey were released into four study streams. Of these, 115 were radio-tagged and available for tracking. Over the four years, a total of 48 redds were observed in the four streams. It is likely that all redds observed were from translocated lamprey but this could not be confirmed. Juvenile lamprey were observed in all study streams but in only one of six control streams surveyed.

Evaluate Habitat Use and Population Dynamics of Lampreys in Cedar Creek
Project Number 2000-014-00 (Ended June 30, 2008)
Lewis River Subbasin

This was a multi-year study to examine lamprey in Cedar Creek, Washington, a third-order tributary to the Lewis River. Objectives were to (1) estimate abundance, measure biological characteristics, and determine migration timing of adult Pacific lamprey; (2) evaluate spawning habitat requirements of adult lamprey; (3) determine outmigration timing and estimate the abundance of recently metamorphosed lamprey (macrophthalmia) and ammocoetes; and (4) determine larval lamprey distribution, habitat use, and biological characteristics.

Annual population estimates of adult Pacific lamprey based on mark-recapture efforts ranged from 493 to 1,765. A small peak in migration usually occurred in early summer and another in the fall. Pacific lamprey spawning occurred throughout Cedar Creek. Ammocoete movement generally occurred during periods of peak flows, indicating passive migration. Migration of macrophthalmia did not always coincide with high flows. Peak movements were observed in both spring and summer.

Evaluate Status of Pacific Lamprey in Idaho
Project Number 2000-028-00 (Ended June 30, 2008)
Clearwater and Salmon River Subbasins, Idaho

This project addressed status, relative abundance, and habitat utilization in Idaho. Current (at the time) distribution was determined in most of the Clearwater River drainage, approximately 50% of the Salmon River drainage, and 10% of the mainstem Snake River between Lewiston, ID and Hells Canyon Dam. The project also documented required and desired habitat for larval and juvenile rearing and determined relative abundance throughout a major portion of the Idaho range. The project focused on ammocoetes and macropthalmia to describe status, distribution, and habitat utilization.

Identification of Larval Pacific Lampreys, River Lampreys and Western Brook Lampreys and Thermal Requirements of Early Life History Stages of Lampreys
Project Number 2000-029-00 (Ended December 31, 2003)
Systemwide

This project characterized aspects of the thermal ecology of embryonic and larval stage Pacific and western brook lamprey, and also provided information on the fine-scale morphology of embryonic and larval Pacific and western brook lampreys. This work also provided rationale for development of molecular techniques suitable for discrimination of closely related species of lampreys. Discrimination of larval lampreys based on morphology is tedious and requires special equipment not readily applicable to field situations. Therefore, molecular techniques, specifically those that are field applicable, may provide a more accurate and less technical method for species identification.

Color patterns of larval Pacific and western brook lampreys did not appear to vary temporally. Although species identification was confirmed for two Pacific lampreys consistently identified as Pacific lamprey based on color patterns of the caudal region, this sample size was too small to provide validation for this technique within the Columbia River Basin.

Pacific lamprey larvae had significantly more trunk myomeres than western brook lampreys; however, trunk myomere numbers were highly variable within species and deviated from previously published data. Principal components analysis indicated allometric relationships among the morphometric characteristics examined. Changes in body shape were indicated by groupings of morphometric characteristics associated with body regions (e.g., oral hood, branchial region, trunk region, and tail region). Discriminant function analysis using morphometric characteristics was successful in classifying a large proportion (> 90%) of the lampreys sampled.

The estimated temperature for zero development was 4.85° C for Pacific lampreys and 4.97° C for western brook lampreys. Survival was greatest at 18° C followed by 14° C, 10° C, and 22° C, with significant differences observed between 22° C and other temperatures.

Upstream Migration of Pacific Lampreys in the John Day River, Timing and Habitat Use
Project Number 2000-052-00 (Ended April 17, 2003)

This was an “innovative” pilot study with objectives to (1) assess the logistics associated with conducting a radio telemetry study of Pacific lamprey in the John Day River including developing capturing, tagging, holding, and tracking (i.e., fixed station and mobile tracking) protocols, (2) collect preliminary information on the migration behavior in the John Day River, and (3) collect preliminary information on the over-wintering and spawning habitats used by Pacific lamprey in the John Day River. Unfortunately, given the timing and one-year duration of the “innovative project” funding contract, only preliminary information on the migration behavior and over-wintering habitats was collected.

Forty two adult Pacific lamprey were surgically implanted with radio transmitters. Movement past fixed receivers was exclusively between sunset and sunrise. Most over-winter holding was initiated by mid-September and continued until mid-March. Lampreys over-wintered under boulders in riffle/glide type habitats.

ANSWERS TO SPECIFIC QUESTIONS ASKED BY THE ISRP

1. *What are the general conclusions of the studies to date? Are lamprey recovering in the Basin?*

Results from the USFWS Pacific Lamprey Assessment and Template for Conservation Measures (Assessment) indicate Pacific lamprey do not seem to be recovering in the Columbia Basin. A risk assessment conducted at the 4th code HUC level show that Pacific Lamprey distribution and abundance have decreased compared to historic levels and that many threats are impacting Pacific Lamprey throughout their range (Luzier et al. 2011). In addition no areas are recovered or recovering enough to restore extirpated or high risk areas.

It should be noted that because funding for lamprey-related work has only recently been considered a priority by funding entities, most projects in the Columbia River Basin are still in early stages, and are collecting information on status, habitat requirements, etc., rather than focusing on specific restoration actions. These projects have helped managers gain a better understanding of limiting factors. In addition, a number of critical recovery tools such as passage structures and translocation techniques have been developed and implemented. In the Umatilla River Subbasin, where a translocation program has been implemented for over 10 years, and where a lamprey passage structure was installed (at Threemile Falls Dam), numbers of adult Pacific lamprey have increased from virtually none in the late 1990’s to 129 in 2011.

2. *What have emerged as primary limiting factors for lamprey basinwide? The ISRP noted that lamprey are declining coast wide, suggesting that ocean factors may be affecting survival, but no studies are being conducted in the marine environment. Lampreys are also likely very susceptible to toxic contaminant effects but very limited work is being done on this issue. Most proponents are focusing on key limiting factors in tributary habitat but the ISRP, as*

well as ISAB (2009-3) has pointed out this approach is too restrictive for anadromous lamprey. A comparison of lamprey stocks in various rivers might be useful, including those outside the Columbia River Basin.

A number of documents have been produced that identify and prioritize key factors limiting Pacific lamprey in the Columbia River Basin and range-wide. Pertinent documents developed by the CRBLTWG include:

- Passage considerations for lamprey (CRBLTWG 2004)
- Critical Uncertainties for Lamprey in the Columbia River Basin: Results from a strategic planning retreat of the Columbia River Lamprey Technical Workgroup (CRBLTWG 2005)
- Translocating adult Pacific lamprey within the Columbia River basin: State of the science (CRBLTWG 2011)

Other collaboratively-developed documents important to the Columbia River Basin include:

- Pacific Lamprey passage improvements final implementation plan 2008 – 2018 (USACE 2009).
- Pacific Lamprey Assessment and Template for Conservation Measures (Luzier et al. 2011)
- Tribal Pacific lamprey restoration plan for the Columbia River (CRITFC 2011)

The following information on limiting factors has been compiled from these and other documents as noted.

Pacific Lamprey face a variety of threats to various life history stages, and no single threat can be pinpointed as the primary reason for the apparent decline. Threats include artificial barriers to migration, poor water quality, predation by native and nonnative species, stream and floodplain degradation, loss of estuarine habitat, decline in prey, ocean conditions, dredging, and dewatering (Jackson et al. 1996; Close et al. 1999; BioAnalysts, Inc. 2000; Close 2000; Nawa et al. 2003).

A comparison of lamprey geographic populations throughout the U.S. range has been conducted and the results can be found in the USFWS Assessment document (Luzier et al. 2011). It shows that these threats in varying combinations and severities are impacting Pacific Lampreys throughout the U.S. range. Though some geographic populations may be at relatively lower risk when taking into account population demographics and local threats, all geographic populations are at risk of decline and extirpation.

***Passage (dams, culverts, water diversions, tide gates, other barriers).*—**Artificial barriers impact distribution and abundance of Pacific Lamprey by impeding upstream migrations by adults and downstream movement of ammocoetes and macropthalmia (Close et al. 1995; Vella et al. 1999; Ocker et al. 2001; Lucas et al. 2009). Upstream adult migrations are blocked by dams without suitable passage alternatives or attraction to fish ladder entrances (Moser et al. 2002). Fish ladders and culverts designed to pass salmonids can block lamprey passage, particularly if they have sharp angles to which lamprey cannot attach (Keefer et al. 2010), and high water velocities (Moser et al. 2002; Mesa et al. 2003). Culverts and other low-head structures that have a drop at the outlet are impassable for a variety of reasons including high velocities or distance, insufficient resting areas, and lack of suitable attachment substrate (CRBLTWG 2004). Pacific Lamprey populations persist for only a few years above impassable barriers before becoming locally extirpated (Beamish and Northcote 1989).

Downstream migrating macrophthalmia and drifting ammocoetes are often entrained in water diversions or turbine intakes (Moursund et al. 2001; Dauble et al. 2006). Juvenile lampreys have shown high survival through the juvenile salmonid bypass systems at Columbia River mainstem dams (Moursund et al. 2002), but are often inadvertently collected and transported downstream in barges or trucks with salmonid smolts. Due to their size and weak swimming ability (Sutphin and Hueth 2010), ammocoetes and macrophthalmia can be impinged on turbine screens (Moursund et al. 2002) and irrigation screens (Ostrand 2004), resulting in injury or death.

Dewatering and Stream Flow Management (reservoirs, water diversions, instream projects).—Rapid fluctuations in reservoir and stream water levels from irrigation diversions, power hydropeaking and instream channel activities strand ammocoetes in the substrate and isolate them from flowing water (J. Brostrom, USFWS; J. Crandall, Wild Fish Conservancy; E. Egbers, WDFW; personal communication; Douglas County PUD 2006 http://relicensing.douglaspud.org/documents/pud_relicensing_documents/downloads/SR/EffectofWaterLevelFluctuations.pdf). Suitable habitats for juvenile lamprey are often the first areas dewatered when stream flow drops.

Low flows during summer and fall can impede adult lamprey migration by restricting flow into an exposed, shallow river channel or by creating a thermal block. Lamprey movement at all life stages is predominantly nocturnal (Beamish and Levings 1991; Moursund et al. 2000; Chase 2001; White and Harvey 2003); consequently, flow reductions during daylight will inhibit lamprey from moving into more suitable habitat as they will be reluctant to leave a dark, secure area.

Stream and Floodplain Degradation (channelization, loss of side channel habitat, scouring).—Lamprey spawn (Mattson 1949; Pletcher 1963; Kan 1975), and rear (Pletcher 1963; Potter 1980; Richards 1980; Torgeson and Close 2004; Graham and Brun 2005) in low gradient stream reaches with complex channel structure, pools, and riffles, and adjacent stream margins and side channels with finer sediment and detritus. These features are frequently found in low gradient areas with wide floodplains, which are popular for development. The loss of these habitats reduces areas for spawning and rearing.

Riparian vegetation is an important component of ammocoete rearing areas. Pirtle et al. (2003) found that ammocoetes were collected where canopy cover was 71.8% on average; however, they were observed over a wide range of cover from 7.5% to 100%. In Idaho, the amount of riparian vegetation and shading was positively correlated with ammocoete abundance (Claire 2003) and loss of these features would likely negatively impact lamprey.
Eggs and ammocoetes from many lamprey species that rear in stream substrates have been impacted by activities that remove silt and fine substrate from the stream such as excavation, mining, or dredging activities (Beamish and Yousan 1987; King et al. 2008).

Water Quality (water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source).—Water temperatures of 22°C have been documented to result in mortality or deformation of eggs and early stage ammocoetes under laboratory conditions (Meeuwig et al. 2005). Water temperature of 22°C or higher is often a common occurrence in degraded streams during the early-to-mid-summer period of lamprey spawning and ammocoete development.

Ammocoetes are relatively immobile in the stream substrates and can concentrate in areas of suitable habitat that include many age classes (King et al. 2008), making them susceptible to chemical spills or chemical treatment (e.g. rotenone) targeting other species. Bettaso and Goodman (2010) investigated mercury concentrations of larval lampreys (ammocoetes; *Entosphenus* spp.) and western pearlshell mussels *Margaritifera falcata* in the Trinity River, California to determine whether these two long-lived and sedentary filter feeders show site-specific differences in uptake of this contaminant. Ammocoetes contained levels of mercury 12 to 25 times those of mussels from the same site in Trinity River. The Pacific Lamprey ammocoetes were also found to have 70% higher mercury levels in a historically mined area when compared to a non-mined reference reach (Bettaso and Goodman 2008). Their data indicate that ammocoetes may be a preferred organism to sample for mercury contamination and ecological effects compared with mussels in the Trinity River. Other chemicals of concern include PCBs, pesticides and other heavy metals, but the threat of these is not well assessed. Pacific Lamprey adults sampled in the Willamette River had levels of dieldrin, total PCBs and arsenic that were above acceptable tissue concentrations, and as a result consumption guidelines were recommended to Siletz Tribal members (ODHS 2005). More study is needed to determine potential impacts of elevated toxins on Pacific Lamprey.

Harvest/Overutilization.—Pacific lamprey harvest for food or commercial purposes may present a threat if these activities are concentrated in rivers with low population numbers. Harvest of lamprey can change population structure and alter distribution, thus reducing population numbers. Legal harvest of adults and ammocoetes occurs in California and Alaska.

Predation.—Native and non-native fish, marine mammals, and birds prey upon Pacific lamprey (Close et al. 1995; Moyle 2002) and may pose a threat to lamprey abundance, particularly in altered habitat. As Pacific lamprey migrate through reservoirs and associated dams, they may be more susceptible to predation. American mink, birds, raccoons, various fish, and other species feed upon ammocoetes (Semakula and Larkin 1968; Galbreath 1979; Beamish 1980; Wolf and Jones 1989). Adult lamprey are eaten by otters, sea lions, seals, and sturgeon (Roffe and Mate 1984), and northern pike in Alaska (Betsy McCracken, USFWS, personal communication). Concentrations of Stellar sea lions in recent years below Bonneville Dam in the Columbia River have been observed consuming large quantities of salmon, white sturgeon, and Pacific Lamprey, although the impact of predation has not been quantified.

Disease.—Information pertaining to Pacific lamprey disease is limited; however, some adults have been collected and the samples analyzed for a spectrum of potential pathogens by the USFWS Lower Columbia River Fish Health Laboratory in the 1990−2003 period (Cochnauer et al. 2006). The pathogen that causes furunculosis, *Aeromonas salmonicida*, has been detected in lamprey in the Columbia River Basin (Cummings et al. 2008) and in western Oregon. The causative agent for bacterial kidney disease (BKD), *Renibacterium salmoninarum*, was also found in Pacific lamprey sampled in the ponds at Entiat National Fish Hatchery in Washington (J. Evered, USFWS, personal communication). The impact of these diseases in lamprey is currently unknown; however, in general, disease may influence lamprey health and reduce their ability to reproduce and survive. Finally, a basic understanding of the pathology of lampreys is lacking. *Aeromonas salmonicida* and *A. hydrophila* are known to infect adult Pacific Lamprey (Cummings et al. 2008; Clemens et al. 2009; CRBLTWG 2011), and *Renibacterium salmoninarum* has been shown to reside in Sea Lamprey (Faisal et al. 2006) but no infection was found in directly challenged Pacific Lamprey adults (Bell and Traxler 1986). Direct disease challenge of Pacific lamprey ammocoetes with infectious hematopoietic necrosis virus [IHNV] and a west coast variant of viral hemorrhagic septicemia [VHS] were conducted and in both cases the virus was shed completely within days of exposure. More disease challenge work is needed to determine lampreys' potential role as a vector of disesase.

Small Effective Population Size.— As Pacific lamprey adults are attracted to ammocoete pheromones (Fine et al. 2004) as seen in other lamprey species (Li et al. 1995; Bjerselius et al. 2000; Vrieze and Sorensen 2001; Fine et al. 2004), low numbers or a lack of ammocoetes in spawning tributaries may result in reduced attraction of adults and therefore increase the chances of inbreeding.

Lack of Awareness.—A lack of awareness on the distribution of Pacific lamprey and their preferred habitat use can have negative and unintended impacts when in-channel activities restoring habitat or passage for other species are implemented. For example, dewatering a stream to replace a culvert may strand ammocoetes, and use of heavy equipment to dig out channels can remove ammocoetes from the channel (Streif 2009; USFWS 2010).

Ocean Conditions.—Given that Pacific lamprey spend up to several years at sea to increase in weight and length prior to returning to freshwater to reproduce, it follows that direct and indirect actions to this environment may have significantly impacts. Actions that greatly effect lamprey, their prey species, or that alter the pelagic or substrate habitats to depths up to 500 meters may alter demographics (Orlov et al. 2008). Direct research on Pacific lamprey during their ocean phase is needed. This effort has been impeded by the difficulty in sampling lamprey in the ocean and a lack of an active tag for juveniles.

3. *What are the major impediments to implementation of recovery plans? Will mainstem passage problems be resolved to enable sufficient numbers of adults to migrate into tributaries to initiate recovery in synchrony with translocation and habitat improvements such as ramps on low head dams and irrigation screens?*

The major impediments to implementation of restoration plans for lamprey are lack of both funding and legal requirements to perform restoration actions. A variety of federal agencies, states, tribes, NGO's, universities, and public utility districts have interest in conserving lamprey, and many actions are currently being planned and implemented, but lack of resources impedes the progress of implementation.

Both upstream passage for adults and downstream passage for larvae and juveniles is affected by mainstem and tributary dams. Adult lampreys have difficulty negotiating fish ladders designed for salmonids and studies have indicated that lamprey have difficulty at fishway entrances (Moser et al. 2005). Sharp corners, diffuser gratings, dead ends, high velocities, tailrace conditions, increased mortality from delays, count stations and fallback, orifices, lack of attachment points, trapping areas, transition zones, excessive energy use, temperature changes, lighting, unplanned maintenance and sound all have an impact on adult lamprey passage. Pacific lamprey are less capable swimmers in high velocity flows than salmon (Moser and Mesa 2009; Keefer et al. 2010). Nearly all salmon-based velocity criteria in fish ladders may be too high for lamprey to navigate without repeated burst swimming, reattaching, and resting.

Pacific lamprey macrophthalmia have been observed to be routinely impinged on screens located in front of turbine intakes for Columbia River dams (Morsund and Bleich 2006). More than 20% of juvenile lampreys that approach powerhouses and encounter turbine intake screens are vulnerable to impingement (USACE 2009). Impingement on the screens can result in mortalities under certain conditions, but a gap reduction from 0.32 to 0.18 cm virtually eliminated impingement (Moursund et al. 2003; Moursund and Bleich 2006). The USAOE has changed screen spacing criteria to address lampreys; however, due to the expense of approximately $1 million dollars for replacement per screen it will be many years before the passage screens are replaced to meet lamprey criteria at most of the facilities (USACE 2009). Screen impingement, passage through turbines, pressure changes, the salmonid juvenile bypass system, transportation around the dams, passage through spillways, dead ends, tailrace conditions, bright lighting, loud sound, forebay hydraulic conditions, maintenance and cooling water screens were the potential threats identified for downstream migrants.

Modifications such as rounding of corners in ladders and screen gap reductions at mainstem hydroelectric facilities are underway (see USFWS Assessment Luzier et al. 2011 Chapter 7 and Appendix C) though they are limited by requirements for ESA-listed salmonid passage and by expense. The slow progress of these modifications is such that it is unknown if the passage problems will be resolved to enable sufficient numbers of adults to migrate into tributaries to initiate recovery in synchrony with translocation and habitat improvements such as ramps on low head dams and irrigation screens.

4. *Is the draft lamprey master plan for Tribal Pacific Lamprey Restoration that will guide recovery efforts completed? (Project #2008-524-00)*

The Tribal Pacific Lamprey Restoration Plan was finalized in December 2011 (CRITFC 2011) and is available on the Columbia River Inter-Tribal Fish Commission website (http://www.critfc.org/wana/lamprey.html). A summary of the Tribal Restoration Plan's objectives are listed below:

Mainstem Passage and Habitat
Objective 1: Improve lamprey mainstem passage, survival and habitat

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

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

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

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

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

It should be noted that this project is not actually a "master plan" in the sense of a master plan being all-encompassing. The Tribal Pacific Lamprey Restoration Plan is a tribally focused action plan; however, it incorporates much of the information available in, and is consistent with, other regional lamprey planning documents. In turn, these other documents include information from, and are consistent with, the Tribal Pacific Lamprey Restoration Plan. These other documents include the USFWS Assessment (Luzier at al. 2011), and subsequent Regional Implementation Plans, which is a collaborative conservation effort that integrates other lamprey planning documents such as the Tribal Restoration Plan, the U.S. Corps of Engineers 10 year Lamprey Plan (USACE 2009), several plans developed by public utility districts, and the Council's Fish Wildlife Program (Council 2009). The USFWS Assessment was just finalized in October 2011 and development of the Regional Implementation Plans is commencing.

5. *Are study designs and sampling methods coordinated among projects? Some proponents noted that key technical issues, such as sampling efficiency for juvenile lamprey during instream trapping, as well as our inability to tag juvenile life stage lamprey to obtain travel time and survival information, have yet to be resolved. Others did not, suggesting increased communication among groups is needed. The ISRP is therefore concerned that data may not be comparable between projects, or that critical information is lacking, e.g., juvenile travel time and survival.*

Coordinating research and conservation actions for lamprey has improved. Key technical issues such as sampling efficiencies, tag development, migration timing and survival estimation are being worked on as current resources (funding, fish, and researchers) allow. Advances have been made in all of these areas but they are not yet resolved. Additionally, a monitoring and evaluation framework which would provide metrics such as juvenile travel times, survival and adult passage metrics is needed. Personnel from each project are members of the CRBLTWG, and as such, meet and share ideas with each other. Conservation planning activities such as the Tribal Pacific Lamprey Restoration Plan, the U.S. Corps of Engineers 10 year Lamprey Passage Plan and the USFWS Pacific Lamprey Conservation Initiative regularly convene forums for communication and coordination.

6. *What are the escapement goals for lamprey, recognizing that development of these metrics is difficult because of lack of historical information?*

It should be recognized that the life history of anadromous Pacific lamprey is much different than that of anadromous Pacific salmon; therefore, the setting of escapement goals for lamprey should not follow the same logic as setting goals for salmonids. Pacific lamprey do not necessarily return to natal streams and do not appear to exhibit the well-defined and geographically-related population structure found in anadromous salmonids. The concept of "returning adults" is therefore a misnomer when applied to Pacific lamprey.

Subbasin-specific escapement goals are difficult to justify at this time for Pacific lamprey. Actions taken to enhance productivity and survival will likely have benefits, but may not result in increased numbers of adults within the subbasin taken. However, it is likely that actions taken to increase survival and abundance of ammocoetes may eventually result in increases in adults due to the attraction of adults to ammocoete-released pheromones. Because of this somewhat indirect relationship between actions and numbers of adults, and because of the time required to observe any response (e.g., response to the Umatilla River translocation program described previously), it is premature to set goals at this time.

It is however, reasonable to set and work towards goals based on basin-wide numbers, especially when those goals are based on numbers of adult Pacific lamprey observed in the recent past. The Tribal Pacific Lamprey Restoration Plan (CRITFC 2011) has therefore developed goals for 2012 (halt the decline), 2020 (200,000 adults – based on counts at Bonneville Dam in 2002-03), 2035 (1,000,000 adults – based on counts at Bonneville Dam in the 1950s and 1960s), and 2050 (restore lamprey to sustainable, harvestable levels throughout their historic range).

7. *What is the status of lamprey in various subbasins and can a comparison of their status inform an analysis of limiting factors?*

The USFWS Assessment (Luzier et al. 2011) provides a series of tables with relative risk rankings by 4th code HUC in the Columbia River Basin. A detailed threat analysis, which was used in the determination of the relative risk rankings, is also available by watershed. These can be used to compare subbasin status and inform an analysis of limiting factors and threats. The NatureServe Risk Assessment was conducted for geographic populations of Pacific lamprey throughout the U.S. range. In the lower Columbia Region, all watersheds were ranked high risk, except for the Lower Columbia-Clatskanie, Coast Fork Willamette, McKenzie, and Clackamas, which were rated moderate. All watersheds in the Middle Columbia, Upper Columbia, and Snake River regions were ranked high risk. In addition, an assessment of climate change impacts and vulnerability has been overlaid upon the risk assessment for Pacific Lamprey watersheds and most watersheds are predicted to be extremely vulnerable to climate change by the end of the century.

8. *Comparative data on the non-anadromous brook lamprey might help determine if limiting factors in the ocean are important for the Pacific lamprey.*

In stark contrast to genetic analyses for Pacfic lamprey, western brook lamprey exhibit fine scale genetic differentiation. This could impact comparing species to determine the oceanic effect on Pacific lamprey. More funding for non-anadromous lamprey research is needed.

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