Proceedings of the Pacific Lamprey Conservation Initiative Work Session

October 28-29, 2008
Portland, Oregon

Sponsored by:
Western Lampreys Conservation Team
U.S. Fish and Wildlife Service
Regions 1 and 8

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Available at
http://www.fws.gov/pacific/Fisheries/sp_habcon/lamprey/index.html

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Preface

The U.S. Fish and Wildlife Service (USFWS) hosted the Pacific Lamprey Conservation Initiative Work Session on October 28-29, 2008 in Portland, Oregon. The purpose of the Work Session was to bring managers and scientists with various skills and expertise together to facilitate communication on the current status and ongoing efforts to conserve Pacific lamprey (*Lampetra tridentata*) and to begin development of a collaborative, range-wide Conservation Plan.

The general objectives of the Work Session were: 1) to develop an outline of existing knowledge, data, and information about Pacific lamprey; and 2) to identify uncertainties or knowledge gaps related to these topics. The Work Session was organized around four questions: 1) Pacific lamprey biology; 2) conservation units and Pacific lamprey population structure; 3) Pacific lamprey habitat preferences; and 4) threats to Pacific lamprey. A presentation outlining the information that is currently known about each topic was given to the whole group and participants were given a chance to ask clarifying questions. The large group then broke into smaller sections at which time they were asked to answer specific questions about these topics and provide data and references. Each small group was led by a facilitator who was responsible for recording the information shared in the break-out sessions. This information was then compiled, checked for accuracy, and sent to the USFWS lamprey team to develop draft proceedings. The lamprey team produced a draft of the proceedings and sent it to the Work Session participants for review. Comments were received and incorporated and this final proceedings document was produced.

The contents of this proceedings document include a list of Work Session participants; a list of those people who did not attend the Work Session but contributed information for the proceedings; the members of the facilitation team; the final agenda for the Work Session; and the summarized information obtained for each question and list of references.

Work Session Participants

Les Bill - Columbia River Inter-Tribal Fish Commission (CRITFC)
Jody Brostrom, U.S. Fish and Wildlife Service (USFWS)
Abel Brumo - Stillwater Sciences, Arcata
Fabian Carr - Oregon Department of Fish and Wildlife (ODFW)
Mike Clement - Grant County Public Utility District
David Clugston - U.S. Army Corps of Engineers (ACOE)
Carrie Cook-Tabor - U.S. Fish and Wildlife Service
Charlie Corrarino - Oregon Department of Fish and Wildlife
John Crandall - Wild Fish Conservancy
Elmer Crow - Nez Perce Tribe
Dan Diggs - U.S. Fish and Wildlife Service
Dan Domina - Normandeau Associates, Inc.
Tim Dykstra - U.S. Army Corps of Engineers
Ron Eggers - Bureau of Reclamation (BOR)
Vicki Finn - U.S. Fish and Wildlife Service
Derek Fryer - U.S. Army Corps of Engineers
Damon Goodman - U.S. Fish and Wildlife Service
Stephen Grabowski - Bureau of Reclamation
Ritchie Graves - NOAA Fisheries
Phil Groves - Idaho Power Company
Stephanie Gunckel - Oregon Department of Fish and Wildlife
Molly Hallock - Washington Department of Fish and Wildlife (WDFW)
Kirk Haskett - Oregon Department of Fish Wildlife
Keith Hatch - Bureau of Indian Affairs (BIA)
Russ Holder - U.S. Fish and Wildlife Service
Aaron Jackson - Confederated Tribes of the Umatilla Indian Reservation (CTUIR)
Steve Jacobs - Oregon Department of Fish and Wildlife
John Johnson - U.S. Fish and Wildlife Service
Kim Johnson - Environmental Protection Agency (EPA)
Daniel Jordan - Hoopa Tribe, CA
Chris Karchesky - Normandeau Associates, Inc.
Mike Karnosh - Confederated Tribes of Grand Ronde (CTGR)
Ray Kinney - Casco
Bernard Klatte - U.S. Army Corps of Engineers
Deborah Konnoff - U.S. Forest Service (USFS)
Kathryn Kostow - Oregon Department of Fish and Wildlife
Ralph Lampman - U.S. Forest Service
Gena Lasko - California Department of Fish and Game (CDFG)
Peter Lickwar - U.S. Fish and Wildlife Service
Patrick Luke - Yakama Nation Fisheries
Christina Luzier - U.S. Fish and Wildlife Service
Matt Mesa - U.S. Geological Survey (USGS)
Joseph Moreau - Bureau of Land Management (BLM)
Mary Moser - NOAA Fisheries
Samuel Moyers - Oregon Department of Fish and Wildlife

R.D. Nelle - U.S. Fish and Wildlife Service
Ken Ostrand - U.S. Fish and Wildlife Service
Richard Pastor - Bureau of Reclamation
Natalie Richards - U.S. Army Corps of Engineers
Steven Rondeau - Cow Creek Band of Umpqua Tribe of Indians (CCBUTI)
Howard Schaller - U.S. Fish and Wildlife Service
Bruce Schmidt - Pacific States Marine Fish Commission, Streamnet (PSMFC)
Tim Shibahara - Portland General Electric
Gregory Silver - U.S. Fish and Wildlife Service
Jennifer Smith - Bureau of Land Management
David Statler - Nez Perce Tribe Department of Fisheries Resources Management
Bianca Streif - U.S. Fish and Wildlife Service
Cindy Studebaker - City of Portland (COP)
Katherine Thompson - U.S. Forest Service
Linda Ulmer - U.S. Forest Service/Bureau of Land Management
Stan Van de Wetering - Confederated Tribes of the Siletz Indians of Oregon (CTSIO)
Dave Ward - Columbia Basin Fish and Wildlife Authority (CBFWA)
Larry Ward - Lower Elwha Klallam Tribe
Steve Waste - U.S. Geological Survey
Tim Whitesel - U.S. Fish and Wildlife Service
Robert Willis - U.S. Army Corps of Engineers

Contributed to Work Session Proceedings
Ian Chane – U.S. Army Corps of Engineers
Shawn Chase - Sonoma County Water Agency
Debbie Docherty – Bonneville Power Administration (BPA)
Demian Ebert - PBS&J
Matt Fox – Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO)
Scott Grunder – Idaho Department of Fish and Game (IDFG)
Debbie Hollen – U.S. Forest Service
Craig Johnson – Bureau of Land Management, Idaho
Robert Lea – Retired Researcher
Christine Mallette – Oregon Department of Fish and Game
Doug Markle – Oregon State University (OSU)
Betsy McCracken – Alaska Department of Fish and Game (ADFG)
Robert Mueller - Pacific Northwest National Laboratory (PNNL)
Carl Page - Aquatic Resources Specialists Environmental Consulting
Claude B. Renaud - Canadian Museum of Nature
Dan Shively – U.S. Forest Service
Deborah Virgovic – U.S. Department of Agriculture – NRCS (USDA)

Work Session Facilitation Team
Turner Odell – Oregon Consensus Group (OCG)
Gail McEwen – Oregon Consensus Group
Vicky Ridge-Cooney – Oregon Consensus Group
Steve Morey – U.S. Fish and Wildlife Service

PACIFIC LAMPREY RANGE-WIDE CONSERVATION PLAN
Work Session
October 28-29, 2008
Ambridge Event Center
300 N.E. Multnomah Street, Portland, Oregon

Agenda

Work Session Goal:

- ***To facilitate an increased knowledge regarding Pacific lamprey biology, distribution, abundance, population structure and threats in support of the U.S. Fish and Wildlife Service's effort to develop a Pacific Lamprey Conservation Plan.***

Work Session Objectives:

- ***For each of the four organizing questions set forth below:***
  - ***Develop an outline of existing knowledge, data, and information that helps to answer each question;***
  - ***Organize information according to the various life history stages of the Pacific Lamprey and identify differences by regions where appropriate; and***
  - ***Identify uncertainties or knowledge gaps related to each questions and research, monitoring, and evaluation approaches to narrow gaps.***

DAY 1 – OCTOBER 28, 2008

8:30 AM *Arrive, register, receive materials*

9:00 – 10:00 Introductions, Meeting Objectives, and Ground Rules

- Welcome and overview of USFWS Pacific Lamprey Conservation Initiative – *Dan Diggs, Assistant Regional Director Fisheries Resources, USFWS*
- Introduce meeting participants
- Review work session agenda and objectives – *Turner Odell, Oregon Consensus*
  - Review and confirm Organizing Questions
- Meeting ground rules – *Turner Odell, Oregon Consensus*
  - Note: Participants are requested to provide references, documentation, or personal communication to assist USFWS in recording the data, information, and analyses used at the work session.

Organizing Question 1:
What is known about Pacific lamprey biology for the several life history stages?

- ***Can we describe the Pacific Lamprey life cycle (stage by stage)***
- ***Do regional difference exist among Pacific lamprey life history stages and life cycle***

10:00 – 10:30 Introduction to Life History Discussion

- Overview of lamprey life cycle and life history stages biology – *Christina Luzier, USFWS*

10:30 – 10:45 **BREAK**

10:45 – 12:00 Breakout Session – Life Cycle and Life History Stages

- Working from Overview:
    - Identify additional information or data, corrections, and uncertainties or knowledge gaps
    - Identify any regional differences
- Organize discussion according to each life history phase:
    - Deposition/incubation/ emergence
    - Ammocoetes
    - Macropthalmia
    - Adults

12:00 – 12:30 Reports from Breakout Sessions

- Breakout reports and discussion – *breakout facilitators and group*

12:30 – 1:30 **LUNCH (on your own …)**

Organizing Question 2:
How should a Pacific lamprey conservation unit (or units) be defined?

- ***What is a conservation unit?***
- ***What is known or may be hypothesized about Pacific lamprey population structure and what may influence reproductive isolation as it relates to defining conservation units?***
    - ***What is known about the historic and current distribution of Pacific lamprey?***
    - ***What may be some behavioral, oceanographic, and geologic factors that have influenced reproductive isolation and population structure? Is there genetic evidence for this reproductive isolation? Does this information lead to identification of conservation units for Pacific lamprey?***
- ***What approach should be taken to identify Pacific lamprey conservation units? What are the research, monitoring, and evaluation needs for determining and refining conservation units?***

1:30 – 2:00 Introduction to Conservation Unit Discussion

- Overview of thinking on Pacific lamprey population structure and potential conservation units – *Tim Whitesel and Damon Goodman, USFWS*
    - I.e., how the conservation unit concept could apply to Pacific lamprey.

2:00 – 3:30 Breakout Session – Population Structure

- Working from Overview:
    - Identify additional information or data, corrections, and uncertainties or knowledge gaps
    - Discuss potential options for conservation units, and research, monitoring, and evaluation approaches

3:30 – 3:45 **BREAK**

3:45 – 4:30 Reports from Breakout Sessions

- Breakout reports and discussion – *breakout facilitators and group*

4:30 **ADJOURN**

DAY 2 – OCTOBER 29, 2008

8:00 – 8:30 *Arrive*

8:30 – 8:45 Overview of Day 2 Agenda, Objectives and Ground Rules

- Review work session agenda, objectives, ground rules – *Oregon Consensus*
- Debrief Day 1 process as needed – *Oregon Consensus*

Organizing Question 3:
What is known or may be hypothesized about Pacific lamprey habitat preferences by life-stage?

- ***Are there regional differences in habitat preferences***
- ***What approaches should be taken to determine habitat preferences by life-stage?***

8:45 – 9:15 Introduction to Habitat Preferences by Life History Stage

- Overview of habitat preferences by life history stages biology – *Jody Brostrom, USFWS*

9:15 – 10:45 Breakout Session – Habitat Preferences (Includes **BREAK**)

- Working from Overview:
  - Identify additional information or data, corrections, and uncertainties or knowledge gaps
- Organize discussion according to each life history phase:
  - Deposition/incubation/ emergence
  - Ammocoetes
  - Macropthalmia
  - Adults
- Discuss potential approaches for determining habitat preferences

10:45 – 11:30 Reports from Breakout Sessions

- Breakout reports and discussion – *breakout facilitators and group*

11:30 – 12:30 **LUNCH (on your own ...)**

Organizing Question 4:
What is known about the range wide threats to Pacific lamprey?

- ***What life stages do we believe these threats effect?***
- ***What do we know about the region specific threats to Pacific lamprey?***
- ***Develop a matrix of threats by life-stage for the work session (e.g. eggs, ammocoetes rearing and migrating, macropthalmia rearing and migrating stage, adults migrating and spawning stage).***

12:30 – 1:00 Introduction to Range-wide Threats to Pacific Lamprey

- Overview of identified threats by life history stage – including proposed matrix of threats by life stage – *Bianca Streif, USFWS*

1:00 – 2:30 Breakout Session – Range-wide Threats (Includes **BREAK**)

- Working from Overview/Matrix:
    - Identify additional information or data, corrections, and uncertainties or knowledge gaps

2:30 – 3:15 Reports from Breakout Sessions

- Breakout reports and discussion – *breakout facilitators and group*

3:15 – 4:30 Wrap-Up Discussions and Next Steps

- Outline next steps for Conservation Initiative – *USFWS staff*
- Discuss potential topics/activities for regional step-down process – *USFWS staff and group*
    - Identify regional actions for addressing threats?
- Discuss overall goal for the Pacific Lamprey Conservation Initiative – *USFWS staff and group*
- Closing questions and comments

4:30 **ADJOURN**

Question 1. What is known about Pacific lamprey biology for the several life history stages?

- **Can we describe the Pacific Lamprey life cycle (stage by stage)**
- **Do regional difference exist among Pacific lamprey life history stages and life cycle**

There is a lot of uncertainty related to the deposition, incubation, emergence life stage and it is hard to extrapolate from single observations, or from other species. It is unknown whether or not females are laying eggs in multiple nests. Fecundity is estimated at 30,000 – 130,000 (Kan 1975). Regional differences in fecundity were found in British Columbia and were related to the distance of upstream migration (Beamish 1980). Does adult life history affect fecundity? What effect if any does genetic population structure have on fecundity?

Many factors affect survival of egg to emergence. Close et al. (2002) reported that survival to hatching (stage 12) was between 50-60%. In a two year preliminary study on the South Fork Coquille, survival until emergence was significantly correlated with spawning stock size, discharge during spawning, and their interaction though these factors were not determined to be causal. Survival generally declined with increasing spawning stock and decreasing discharge. These relationships could be due to constriction of spawning habitat associated with falling river levels (Brumo 2006). Egg predation by speckled dace (*Rhinichthys osculus*) was observed only above 14°C and appeared to increase in intensity with increasing water temperature (Brumo 2006). Despite the apparent insignificance of dace predation on larval cohort survival, it may be influential under certain conditions (Brumo 2006). Brumo (2006) observed that the period of incubation ranged from 18 to 49 days and was dependent on water temperature. In laboratory studies the effects of temperature on the development of larvae showed zero development at 4.85°C and greatest survival at 18.0°C (Meeuwig et al. 2005). Survival of larvae is optimal over a range of 10-18°C with a sharp decline at 22°C (Meeuwig et al. 2005). Additionally, larvae exhibiting abnormalities increased sharply at 22°C (Meeuwig et al. 2005). Regional differences in egg/embryo viability and survival were not identified at the work session.

Ammocoete diets consist of detritus, diatoms and algae (Hammond 1979; Potter 1980). Ammocoetes have been observed in salmon and steelhead carcasses (R. Lampman, T. Whitesel, A. Brumo, personal communication) which could be part of their diet but more likely the ammocoetes are eating microorganisms growing on the carcasses (A. Brumo, personal communication). Downstream movement happens year round. Due to poor swimming ability movement is probably driven by flow conditions and velocities (Moursund 2002). Movement is mostly nocturnal (Beamish and Levings 1991, White and Harvey 2003, Moursund et al. 2000) and correlated with discharge but not temperature (Hammond 1979; Potter 1980; Beamish and Levings 1991; Close et al. 1995). Coastal ammocoetes move during the new moon (R. Lampman, personal communication). Ammocoetes are being collected in smolt traps and at dams throughout the Columbia basin and on the coast including main stem habitats.

Ammocoete distribution has been determined by directed studies in a few areas (e.g., Cochnauer et al. 2006 [Clearwater River, ID; Torgerson and Close 2004 [Middle Fork John Day River, OR]) and incidentally in many others. Sampling techniques are still inefficient for ammocoetes and thus distribution and densities are largely unknown. Smolt trapping, dam dewatering, backpack and deep water electrofishing are used but may only be effective for determining presence and not abundance or distribution. Standardized sampling techniques and specifically efficacy of sampling techniques are needed for ammocoete sampling. The Columbia River Fisheries Program Office of the USFWS has conducted ammocoete specific electrofishing efficiency work with the AbP-2 electrofisher (Engineering Technical Services, Madison, WI) They found that when distributed at low densities (1/m^2) the probability of detecting ammocoetes, especially large ones (110-130mm), is low (20%) (Luzier et al., USFWS unpublished data). Similarly, capture efficiency is lower for larger ammocoetes at low densities (Luzier et al., USFWS unpublished data). Average capture efficiency is low (7%) for all sizes of ammocoetes (Luzier et al., USFWS unpublished data). The capture efficiency between electrofishing passes is not constant rendering the use of electrofishing for abundance estimation less effective (Luzier et al., USFWS unpublished data).

The stages of metamorphosis have been described for Pacific lamprey (McGree et al. 2008). There may be regional differences in the duration of metamorphosis. McGree et al. (2008) followed ammocoetes through transformation from July to December. Triggers for metamorphosis and the ability to predict it remain unknown. Ammocoetes destined for transformation may be >150 mm (J. Graham, CTWSRO, personal communication). Studies with captive ammocoetes describe smaller ammocoetes transforming (C. Luzier, USFWS, personal communication). Migrating macropthalmia are collected in smolt traps and dams year round though more are thought to migrate from late fall to late spring (Close et al. 1995 [Umatilla River, OR]; Kostow 2002). Regional differences in migration timing are probably affected by rain or snow melt, distance from ocean, and elevation. When migration occurs during storm flow, altering the natural hydrograph, are environmental cues being distorted? Macropthalmia are thought to migrate lower in the water column (Close et al. 1995; Moursund et al. 2000; White and Harvey 2003). Onset of parasitic feeding is unknown although C. Luzier and G. Silver have observed macropthalmia attached to salmonids in both fresh and varying concentrations of salt water (USFWS, personal communication).

Very little is known about ocean distribution, vertical or geographic; methods of distribution in the ocean; and homing. They have been caught in depths ranging from 90 to 800 m and as far as 100 km offshore in ocean haul nets (Close et al. 2002; USFWS 2004). Adults are preyed upon by sharks, sea lions, and other marine animals (USFWS 2004), and they parasitize a wide variety of ocean fishes, including Pacific salmon (Oncorhynchus spp.), flatfish (such as Pleuronectes spp. and Platichthys spp.), rockfish (Sebastes spp.), and walleye pollock (*Theragra chalcogramma*) (USFWS 2004). It is unknown how hosts are chosen, if there is a preferred host, when they attach, how long they are attached, what stimulates release from a host, or when and where do lampreys initiate free-swimming migration.

Much of what is known about lamprey migratory behavior originates from studies of sea lampreys (*Petromyzon marinus*). Bergstedt and Seelye (1995) investigated spawning site fidelity in a non-anadromous sea lamprey population by mark-recaptures studies in Lake Huron. Of the 555 tagged juvenile lampreys, 41 tags were recovered, but none within the stream of origin. This study is presented as evidence for a lack of homing in sea lamprey populations. Rather than natal homing, it is hypothesized that sea lampreys migrate in response to pheromones produced by conspecific larvae. Migrating adult sea lampreys are sensitive to a unique combination of bile acids that are produced and released by ammocoetes (Li et al. 1995). Furthermore, sea lampreys are thought to use presence of pheromones (including the bile acids) as a cue during their migration to spawning grounds (Bjerselius et al. 2000; Vrieze and Sorensen 2001). The sea lamprey studies have been used as a starting point for investigating the role of biochemical cues in stream localization by Pacific lampreys. The pheromones used by migrating sea lampreys have been identified in Pacific lampreys (Yun et al. 2003; Fine et al. 2004). Research is currently underway to determine the role of the bile acids in the migratory behavior of Pacific lampreys (Moser et al. 2009).

Adults are thought to migrate upstream nocturnally (e.g., Potter 1980; Beamish and Levings 1991; Chase 2001 [Santa Clara River, CA]; R. Peterson, personal communication [Klamath]) from late spring to fall (e.g., Luzier et al. 2006 [Cedar Creek, WA]). Regional differences may be present in adult migration timing. Size differences have been observed in adults (Kostow 2002; Pletcher 1963; Kan 1975; Beamish 1980; Chase 2001; Moyle et al. 1995) as have coloration differences (M. Fox, CTWSRO, [Sherar's Falls, Deschutes River, OR], personal communication). Multiple color morphs have been observed spawning simultaneously (D. Goodman, USFWS; C. Luzier, USFWS, [Cedar Creek, WA] personal communication). Whether these differences are regionally based or due to run type, time of observation and/or maturity is unknown. Bayer and Seelye (1999) found that some adults spawned the same year they entered fresh water. Others have been radio tracked for one year in freshwater before spawning (S. Gunckel, ODFW, unpublished data). Morphometric differences observed by C. Schreck and B. Clemens are being researched further to determine if different runs exist for adult Pacific lamprey. Standardized sampling methods are needed for adults. In particular the development of a tag to aid in researching the ocean phase is needed. Death has been observed 3-36 days after spawning (Pletcher 1963; Kan 1975; Beamish 1980) but incidences of adults surviving after spawning have been recorded as well (Michael 1980 [Snow and Salmon Creeks, WA]).

Regional differences in the timing of spawning have been observed, with spawning possibly occurring later in inland areas. Generally, spawning occurs between April-June (e.g., Luzier et al. 2006 [Cedar Creek, WA]; Gunckel et al. 2006 [Smith River, OR]). Differences noted by Work Session attendees include March-June ([Coastal streams]), April-August ([Klamath, CA]; L. Ward, Lower Elwha Klallam Tribe, personal communication [Elwha, WA]) and May into July for translocated adults in the Clearwater and Snake rivers (Nez Perce Tribe, personal communication). Biologists have observed lamprey nest-building activity when doing winter steelhead surveys on the coast (K. Kostow, ODFW, personal communication). Timing of spawning is believed to be related to temperature, which influences sexual maturation (Close et al. 2002; A. Jackson, CTUIR, personal communication [Umatilla River, OR]; Brumo 2006 [S. Fork Coquille, OR]). There is a physiological need to be in freshwater for maturation (Wydoski and Whitney 2003).

Question 2. How should Pacific lamprey conservation units be defined?

What is a conservation unit?

A conservation unit can be defined as a distinct segment of biological diversity that shares an evolutionary lineage and contains the potential of a unique evolutionary future (Whitesel et al. 2004). This definition includes populations that have shared an evolutionary past or have the potential to share an evolutionary future. Many variables can be considered to evaluate the level and extent of reproductive isolation associated with conservation units. These variables include genotype, phenotype, location, temporal isolation, behavior, reproductive characteristics, historic range changes, causes for historic range changes, ecological distinctiveness and importance, and others (Utter 1981; Ryder 1986; Waples 1991, 1995; Moritz 1994, 1999; Moritz et al. 1995; NRC 1995; Allendorf et al. 1997; Fraser and Bernatchez 2001). The distinction of a conservation unit is strengthened by integrated lines of evidence from multiple variables (Grady and Quattro 1999). Conservation units can range from a single to multiple groupings depending on the available biological evidence and can provide a framework for conservation of intraspecific biodiversity.

What is known or may be hypothesized about Pacific lamprey population structure and what may influence reproductive isolation as it relates to defining conservation units?

What is known about the historic and current distribution of Pacific lamprey?

Currently, Pacific lampreys are distributed from Eastern Asia to Western North America. Within Eastern Asia they occur in coastal rivers from Hokkaido, Shikoku and Honshu Islands of Japan (Yamazaki et al. 2005), north to the Bering Sea (Vogt 1988). In North America, Pacific lampreys occur in coastal rivers from the Ventura and Santa Clara rivers in Southern California (Swift et al. 1993, Chase 2001), inland to the Clearwater and Salmon rivers of Idaho and north into Alaska (Mecklenburg et al. 2002).

Little is known about the historical distribution of Pacific lampreys, but some records do exist. Historical collections of lampreys occurred as far south as Clarion Island, approximately 386 km south of the southern tip of Baja California, Mexico (Renaud 2008). Additionally, records exist of Pacific lampreys occurring in Baja California, Mexico (Ruiz-Campos and Gonzalez-Guzman 1996; Ruiz-Campos et al. 2000) and at various locations south of their current distribution (Swift et al. 1993). Within their historic range, Pacific lampreys have been extirpated in specific drainages above impassible barriers such as dams (Beamish and Northcote 1989; Moyle et al. 1996; USFWS 2004; Hamilton et al. 2005). Changes in the range of Pacific lampreys, localized extirpations and the associated causes need to be further investigated and documented.

What may be some behavioral, oceanographic, and geologic factors that have influenced reproductive isolation and population structure? Is there genetic evidence for this reproductive isolation? Does this information lead to identification of conservation units for Pacific lamprey?

There are many variables used to delineate conservation units, but genetic evidence can be one of the primary drivers. To date, there are two genetic studies evaluating broad scale population structure of the Pacific lamprey that can be used to evaluate reproductive isolation and inform conservation unit delineation. Goodman et al. (2008) investigated population structure of Pacific lampreys through RFLP and sequence analysis of the mtDNA among populations from central British Columbia to southern California. In this study, no significant population structure was identified among populations or regions. This data indicates a level of historical gene flow sufficient to homogenize mtDNA differences. Higher proportions of drainage specific or “private” haplotypes were identified in southern regions, but were present in a low number of samples and therefore the implications on Pacific lamprey population structure are equivocal. However, this is evidence of some level of reproductive isolation from the Southern to Northern extent of sampled lampreys. Lin et al. (2008) investigated population structure of the nuclear genome using AFLP analyses among populations from northern California to Alaska and Japan. The data was characterized by a high proportion of shared AFLP bands among populations and no population specific band patterns. This data indicates significant levels of historic gene flow among populations. Significant differences in AFLP frequencies were identified among geographical regions and among populations within the Pacific Northwest. In this study, levels of population differentiation did not correspond to geographic distances within the Pacific Northwest.

The results of the two genetic studies on Pacific lampreys indicate high levels of historic gene flow identified among collection localities, even those separated by large geographic distances (Northern California to Japan). When interpreted on an evolutionary timescale these data indicate a shared evolutionary history and a lack of reproductive isolation. Several components of the available data suggest the possibility of geographic population structure: 1) higher number of private haplotypes in southern regions, and 2) significant differences in AFLP frequencies among collection localities. The relationship of these components to reproductive isolation and conservation unit designation is difficult to interpret in terms of delineation of conservation units and identifies the need for additional genetic and behavioral studies.

What approach should be taken to identify Pacific lamprey conservation units? What are the research, monitoring, and evaluation needs for determining and refining conservation units?

By definition, a conservation unit is a group representing a separate segment of intraspecific biological diversity. Therefore delineation of conservation units needs to have a biological basis. We will utilize the pertinent biological information, such as different life history expressions, that is currently available to identify several different conservation unit scenarios and identify additional information gaps. We may also consider biogeographical information to delineate conservation units in the absence of biological evidence. Without information on many of the characters that can be used to delineate conservation units, it is possible that the conservation units will shift when additional biological information becomes available. With this in mind, we will employ a risk assessment framework to evaluate the risks and benefits of the different scenarios when working toward a Pacific Lamprey conservation unit structure for the North American populations.

Several information needs have been identified that could help guide the identification and refinement of Pacific lamprey conservation units. One component is to develop detailed current and historic distributional information. This information will help us understand where lampreys have been extirpated from historical habitat, the extent of potential conservation units, as well as help inform decisions on where to focus conservation efforts. Additional genetic data is needed to investigate some of the patterns identified in the current genetic work that suggest some degree of reproductive isolation. An assessment of population structure using microsatellite loci combined with multi-year sampling may help resolve some of the genetic patterns that are difficult to interpret. Behavioral data can be used to aid in the delineation of conservation units as well as interpretation of genetic patterns. Behavioral information is needed to assess Pacific lamprey migratory cues, mechanisms and behaviors.

Question 3. What is known or may be hypothesized about Pacific lamprey habitat preferences by lifestage?

- **Are there regional differences in habitat preferences?**
- **What approaches should be taken to determine habitat preferences by lifestage?**

The deposition, incubation and emergence life stage is rarely observed and not well studied. It is surmised that eggs hatch in graveled upstream areas and that newly emerged ammocoetes drift downstream to silt areas (Stone and Barndt 2005). There is some data that exists regarding the effects of temperature on egg stage (see Question 1).

Depth of egg deposition and newly emerged ammocoetes are unknown. Effects of water chemistry and sedimentation within nests on egg development and emergence are unknown.

At large scales larvae are most abundant where the stream channel is relatively deep (0.4-0.5 m), gradient is low (<0.5%) and the riparian canopy is open (Torgerson and Close 2004). Ammocoetes rear in areas located near reaches where spawning occurred (Pletcher 1963). At small scales, larval occurrence corresponds positively with low water velocity, pool habitats and the availability of suitable burrowing habitat (Torgerson and Close 2004). Ammocoetes are known to use slow depositional areas along streambanks and burrow into fine sediments during rearing periods (Pletcher 1963; Richards 1980; Potter 1980; Torgeson and Close 2004; Graham and Brun 2005). Individual ammocoetes throughout the Clearwater River basin of Idaho were mostly found inhabiting sand and silt substrates in calm water sites, low velocity pockets behind boulders, or adjacent to overhanging riparian canopy cover in low velocity pockets behind boulders (Cochnauer et al. 2006). The size of ammocoetes appears to be correlated with substrate size (Kostow 2002); however, tiny ammocoetes in large gravel-cobble and large ammocoetes in small substrate have been observed (C. Luzier, USFWS; B. Streif, USFWS, personal communication).

It is important to consider whether preferred habitat versus available habitat is being used. Graham and Brun (2005) and Roni (2002) indicated that ammocoete habitat is positively correlated with wood. Roni (2002) found ammocoetes in pools more often than riffles. Moreover, a positive relationship was found with low water velocity (Graham and Brun 2005; Torgerson and Close 2004; Pirtle et al. 2003). In Cedar Creek, WA ammocoetes were sampled in habitats with average dissolved oxygen of 83% (Pirtle et al. 2003). Ammocoetes were collected where average canopy cover was 71.8%; however, they were observed over a wide range of cover from 7.5% to 100% (Pirtle et al. 2003). There are observations of lamprey ammocoetes in sediment at greater depth in mainstem areas (up to 57 ft) (Lower Willamette Group, personal communication). It is unknown whether beaver dams, reservoirs, mussel beds or the hyporheic zone are preferred habitat for ammocoetes though they have been collected in all of these habitat types (T. Whitesel, USFWS, personal communication).

To determine ammocoete habitat suitability and preference, sampling techniques and design including efficiency of collection methods, habitat variable selection, spatial scales and analytical techniques need to be developed. It would be useful to have these studies conducted over a wide distribution of the species range and over a range of habitat conditions. Better field identification is also needed to discriminate Pacific lamprey from sympatric lamprey species. The use of lacustrine and estuarine habitats should also be used in determining habitat suitability or preference. US Army Corps of Engineer dredge surveys could provide a potential tool for assessing presence/absence at various depths. These data could also be helpful in developing longitudinal and cross section data. Our assumptions about ammocoete habitat need to consider how the distribution of preferred habitat has changed over time. We also need to consider that habitat preferences also change during the year because of variations in the hydrograph.

Metamorphosing lamprey move from fine substrate in low velocity areas to silt covered gravel in moderate current. When fully transformed they are found in gravel or boulder substrate where currents are moderate to strong (Beamish 1980; Richards and Beamish 1981; Potter 1980). Close et al. (1995) found young adult lampreys migrating lower in the water column in the mainstem Columbia River. Other studies such as Moursund et al. (2003) found juvenile lampreys distributed throughout the depths of the water column. This is probably because they lack a swim bladder and cannot regulate their location in the water column (Moursund et al. 2000).

There is a regional data gap with respect to understanding the habitat needs of macropthalmia based on migration distances. Macropthalmia that migrate greater distances must deal with greater habitat variations. The estuarine and nearshore habitat requirements for macropthalmia are unknown.

There is a need for development of a monitoring and evaluation program to determine habitat suitability and preferences for migrating habitat. To determine macropthalmia habitat suitability and preference, sampling techniques and design including efficiency of collection methods, habitat variable selection, spatial scales and analytical techniques need to be developed. It would be useful to have these studies conducted over a wide distribution of the species range and over a range of habitat conditions.

Time spent in the marine habitat for adults is thought to be 6 months to 3.5 years (Beamish 1980; Richards 1980; Kan 1975). Upon entering the ocean they move quickly offshore into waters 70m deep (Beamish 1980). They have been caught at depths ranging from 90 to 800 m and as deep as 100 km in ocean haul nets (Close et al. 2002; USFWS 2004). It is unknown what habitat adult lampreys use when between hosts.

After feeding and growing adult lamprey transition from the ocean to fresh water for spawning. They may remain in freshwater for a few months up to 2 years (Whyte et al. 1993). Lampreys enter freshwater up to one year prior to spawning, hence the term overwintering may not be appropriate. Perhaps this theme should be expanded to encompass entry into freshwater, through summer, fall and winter, and then prespawning habitat.

Lamprey have been observed “overwintering” in areas other than spawning tributaries, for example in the Lower Columbia River as documented by their recovery in mainstem fish ladders when dewatered for maintenance (R. Graves, NOAA; Bob Cordie, COE personal communication), the lower mainstem Willamette River (D. Domina, PGE Willamette Falls radio telemetry studies – 2001, 2005, 2006) and the Deschutes River (Fox and Graham 2008). In coastal streams, lamprey have been observed holding during winter and summer (S. Gunckel, ODFW, unpublished data). In the Deschutes drainage Fox and Graham (2008) suggest Pacific lamprey hold in fast water sections (White River Rapids, Oak Springs Rapids, Boxcar Rapids) or tailout areas; while lamprey in tributaries overwinter in riffles and glides. The size of the Deschutes River prohibits pinpointing exact locations for individual tagged fish. Other substrates used for overwintering include large boulders and bedrock crevices (S. Gunckel, ODFW, unpublished data). In the Elwha River, tagged adults held in off-channel habitat (L.Ward, Lower Elwha Klallam Tribe, personal communication). Slower and deeper water (up to 10 meters) areas may be used (work session attendees [Umpqua, Smith, Columbia]).

Adult lamprey spawn in low gradient stream reaches, in gravel, at the tailouts of pools and riffles (Mattson 1949; Pletcher 1963; Kan 1975). Velocities over nests generally range from 0.5 – 1.0 m/s and spawning depths between 30 cm and 4 m (Pletcher 1963; Kan 1975). Nest dimensions are generally between 20 – 30 cm in diameter and range in depth from 4 – 8 cm (Kan 1975; Russell et al. 1987). It is reasonable to expect that spawning habitat is associated with good habitat for the young ammocoetes and anecdotally this has been observed (A. Brumo [S. Fork Coquille, OR]; C. Luzier [Cedar Creek, WA], personal communication).

Spawning habitats have been described for the Smith River in Oregon. Gunckel et al. (2006) found that Pacific lamprey nests were most frequently observed in low gradient riffles (50.4%), pool tailouts (36.8%) and lateral scour pools (11.2%). Only 43.2% of Pacific lamprey nests were associated with cover, predominately large substrates (26.4%), vegetation (8.0%) and wood (6.5%). The remaining 56.8% of the 125 nests were observed away from channel features that could serve as cover. Median water velocity was 0.6 m/s over nests. Nest dimensions ranged between 21.3 – 210 cm for length and 20-270 cm for width. Spawning substrate ranged in size from 27.0- 88.8 mm (measured as average maximum diameter for 30 pebbles).

Howard et al. (2005) found nest dimensions in the Umatilla River to have a mean length of 95 cm with a range of 62 – 171 cm, mean width of 73 cm with a range of 31 – 147 cm, a mean nest depth of 10 cm with a range of 7 – 16 cm, and water depths over the nest ranging from 20 – 40 cm.

It is unknown whether the extent of the Pacific Lamprey historical range (i.e., the far reaches of the range) are a result of the sheer number of individuals trying to use the lower reaches of the river for spawning and rearing (i.e., was there overcrowding in the lower reaches forcing more and more lamprey to look further upstream for suitable spawning habitat). These reaches might then have been maintained over time by the release/presence of migration-triggering pheromones by returning lamprey. This would be consistent with an underlying or historic preference for lower river spawning/rearing.

In general there was consensus that information needed to evaluate or detect regional differences in habitat preferences for Pacific lamprey is currently unavailable. We are only able to see which habitats they are currently using and a decrease in habitat complexity due to dams and other alterations makes it difficult to determine what preferred habitats are. However, we may be able to observe some regional behavioral differences in response to availability of and difference in habitats. Development of a monitoring and evaluation program to determine habitat suitability and preferences for migrating, pre-spawning and spawning habitats is needed. To determine adult habitat suitability and preference, sampling techniques and design including efficiency of collection methods, habitat variable selection, spatial scales and analytical techniques need to be developed. It would be useful to have these studies conducted over a wide distribution of the species range and over a range of habitat conditions.

Possible approaches could be to analyze places with high historical abundance and low current abundance to provide useful information regarding habitat preferences. Also, degraded and non-degraded habitats could be sampled and compared. To build habitat preferences, less managed areas such as coastal and wilderness areas where there are still viable lamprey populations could be studied. NOAA conducts ocean transect operations that collect data on fish species present. These data could be checked for information on presence/absence of juvenile and/or adult lamprey. Perhaps data could be collected from salmon fishing. Data could include salmon with lamprey scars and those with attached lamprey. Investigating types of hosts that lampreys use could provide marine habitat use information. The possible influence of tagging on behavior of lamprey should be evaluated with respect to habitat preference suitability studies. A survey could be designed to study the association between spawning and ammocoete habitat. It would be beneficial to develop habitat data inputs for one- or two-dimensional habitat models that are currently in use for salmonids.

Question 4. What is known about the range wide threats to Pacific lamprey?

- **What life stages do we believe these threats effect?**
- **What do we know about the region specific threats to Pacific lamprey?**
- **Develop a matrix of threats by life-stage for the work session (e.g. eggs, ammocoetes rearing and migrating, macropthalmia rearing and migrating stage, adults migrating and spawning stage).**

Range Wide Threats

Pacific lamprey face a variety of threats to its various life history stages, including artificial barriers to migration, poor water quality, predation by nonnative species, stream and floodplain degradation, decline in prey, ocean conditions, dredging, dewatering and others (Jackson et al. 1996; Close et al. 1999; BioAnalysts, Inc. 2000; Close 2000; Nawa et al. 2003). There are many reasons for the observed reductions in range and abundance of Pacific lampreys, and no single threat can be pinpointed as the primary reason for their decline.

Artificial Barriers

Artificial barriers impact distribution and abundance of lamprey by impeding upstream migrations by adult lampreys and downstream movement of ammocoetes and macropthalmia. Downstream migrating macropthalmia and drifting ammocoetes may be entrained in water diversions or turbine intakes and due to their size and weak swimming ability; they can be impinged on the diversion and intake screens resulting in injury or death. Outmigrant lampreys travel deeper in the water column (no air bladder) compared to salmonids, therefore, traditional spill gates may block passage (Moursund et al. 2003). Upstream adult migrations can be blocked by fish ladders and culverts designed to pass salmonids that do not effectively pass lampreys due to sharp angles and high water velocities (Close et al. 1995; Vella et al. 1999; Ocker et al. 2001; Kostow 2002). Culverts that have a drop at the outlet or insufficient resting areas will block passage. Pacific lamprey populations persist for only a few years above impassable barriers before dying out (Beamish and Northcote 1989).

Passage barriers affect the amount of marine-derived nutrients available to the basin. They also affect other threats to lamprey, such as water quality, predation, toxicity, decreased habitat availability, stream and floodplain degradation, etc.

Dewatering and Flow Management

Rapid fluctuations in reservoir and stream water levels, irrigation diversions, and stream dewatering can strand ammocoetes in the substrate (J. Brostrom, USFWS, personal communication [Clearwater River, ID]). A single event can affect multiple year classes (all lifestages) therefore significantly impacting a local lamprey population. Restoration efforts targeting other species, such as Pacific salmonids (channel reconstruction projects), can result in rapid and sometimes extensive dewatering of existing channels and negatively impact lamprey populations. Salmonid rescue/salvage has not typically included efforts to rescue ammocoetes which may “emerge” well after salvage/rescue efforts cease.

Lampreys may burrow through the substrate and migrate under diversions. Screening needs to accommodate all life stages. Lampreys are weak swimmers and depend upon flow to migrate downstream. Decreased flows can also cause outmigration delays.

Dredging

Eggs and ammocoetes rearing in stream substrates can be impacted by mining or dredging activities. Suction-dredge mining may be one of the reasons for the decline or even loss of lampreys in some basins (i.e., Kostow 2002 [Upper John Day River, OR]). Dredging activities associated with irrigation screen maintenance can also remove ammocoetes (J. Crandall, personal communication; E. Egbers, WDFW personal communication).

Chemical Poisoning and Toxins

Ammocoetes are relatively immobile in the stream substrates and can concentrate in areas of suitable habitat that include many age classes making them susceptible to chemical spills or chemical treatment (rotenone) targeting other species. They spend 3-7 years filter feeding and accumulate chemicals such as PCB’s, mercury and other heavy metals. There may be significant toxicology issues associated with lamprey residence in sediments, but the threat is not well assessed. Pacific lamprey ammocoetes in the Trinity River were found to have 70% higher mercury levels in an historically mined area when compared to a non-mined reference reach (Bettaso and Goodman 2008). Newer fish screens may also be leaching metals such as zinc. More study is needed to determine potential impacts.

Ocean Conditions

Pacific salmon (), Pacific hake (*Merluccius productus*), and walleye pollock () have declined in numbers and/or are commercially harvested. Reductions in the availability of these host/food species may be affecting adult lamprey survival and growth. Little information exists on lamprey use of the ocean; hence, changes in ocean upwelling, acidification, coastal runoff, food availability, and temperature may influence lamprey survival.

Poor Water Quality

Elevated water temperature has been documented as a factor resulting in mortality of eggs and early stage ammocoetes under laboratory conditions (Meeuwig et al. 1999). Water temperatures of 22° C may cause significant death or deformation of eggs or ammocoetes (Meeuwig et al. 2005). A water temperature of 22° C or higher may be a common occurrence in degraded streams during the early-to-mid-summer period of lamprey spawning and ammocoete development.

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 U.S. Fish and Wildlife Service (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 and western Oregon. The causative agent for Bacterial Kidney Disease, *Renibacterium salmoninarum*, was found in Pacific lamprey sampled in the ponds at Entiat Hatchery in Washington (J. Evered, USFWS, personal communication). Disease may influence lamprey health resulting in reduction in their ability to reproduce and survive.

Overutilization

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

Predation

Fish, marine mammals, and birds prey upon lampreys. As Pacific lampreys migrate through reservoirs, they may be more susceptible to predation. American mink, birds, raccoons, various fish, and other species feed upon ammocoetes . Adult lampreys are eaten by otters, sea lions, seals and sturgeon (Roffe and Mate 1984).

Stream and Floodplain Degradation

Many age classes of ammocoetes in stream substrates can be affected by channel alterations. The loss of riffle and side channel habitats may reduce areas for spawning and ammocoete rearing.

Non-native Species

Non-native species are natural threats. Non-native freshwater fish prey on juvenile and adult Pacific lampreys (Close et al. 1995; Moyle 2002) and may pose a threat to lamprey abundance. Non-native fishes such as bass (Micropterus spp.), sunfish (Lepomis spp.), walleye (*Stizostedion vitreum vitreum*), striped bass (*Morone saxatilis*), and catfish (Ictalurus spp.), among others, have become established over the last century in some rivers in the western U.S. State protection and enhancement of these species has contributed to the problem.

Translocation

Whether or not adult Pacific lampreys home to their natal streams or are attracted by larval pheromones is unknown. The lack of this critical information makes translocation a potential threat to Pacific lamprey populations. If there is no homing or pheromone attraction, the translocation of adults from a healthier population to one that is declining or to an area that has been extirpated will likely fail to produce an improvement in recruitment and production. If habitat degradation has occurred or a barrier is blocking the downstream migration of macropthalmia and/or upstream return of adults, the translocation will also fail to produce the desired results. If translocation fails, it could result in a decrease in the donor population and the potential loss of currently unrecognized genetic diversity.

Climate Change

Climate change may exacerbate many of the threats listed above, especially flow, ocean conditions, water quality, disease, predation, and stream conditions.

Extirpation

If migrating adults cue solely into ammocoete pheromones then extirpation could have large consequences on re-colonization.

Lack of Awareness

Lampreys have a bad reputation, primarily from the impacts of sea lamprey in the Great Lakes, and their ecological and cultural benefits are not well understood. Information on their role as an important component of the ecosystem needs to be disseminated. Identifying and overcoming funding bias and barriers to lamprey-friendly salmon restoration work is needed.

The following research needs concerning threats to Pacific lamprey were identified in the Work Session:

1. Further identify and assess threats and effectiveness of treatments to reduce effects of threats to Pacific lampreys.
2. Identify specific structures or operations that obstruct migrating lampreys, develop aids to passage (e.g., modify structures or operations, provide lamprey-specific passage criteria for fishways, or bypasses), and develop passage criteria.
3. Assess the influence of disease on Pacific lamprey populations.
4. Assess the influence of contaminants, toxins, herbicides, metals, and pharmaceuticals on Pacific lamprey populations.
5. Assess the influence of current and forecasted climate change to adult holding and juvenile incubation temperature tolerances.
6. Assess the impacts of dredging in the mainstem and tributary habitats.
7. Assess the impacts of reservoirs.
8. Assess the range wide impacts of climate change.
9. Life stage specific mortality rates for Pacific Lamprey are needed.
10. Assess the impacts of invasive species on lampreys.

Other needs identified at the Work Session include:

1. A workshop (perhaps annual) focused on lamprey passage issues to be attended by agency staff who routinely deal with passage issues.
2. Assess the current rules and regulations for the design of passage facilities to determine if lamprey are or should be considered. For example, the state of Oregon has a mandatory fish (not just salmon) passage law which facilitates protection of lamprey (C.

Corrarino, ODFW, personal communication). Do the culvert evaluations by WDFW include lamprey needs?

3. Regulatory agencies should integrate lamprey issues with the regulatory process including that for passage, dam removal, and flow agreements.

Table1. Threats to Pacific lamprey and the life stage that each threat impacts.

Threat	Egg	Ammocoete	Macropthalmia	Adult
Passage (dams, culverts, water diversions, tide gates, other barriers)		X	X	X
Dewatering and flow management (reservoirs, water diversions, instream projects).	X	X	X	
Dredging (channel maintenance and mining)	X	X		
Chemical poisoning, toxins (accidental spills, chemical treatment)	X	X		
Ocean conditions (loss of prey, change in conditions)				X
Poor water quality	X	X	X	X
Disease	X			X
Over Utilization	X			X
Predation	X			X
Stream and Floodplain degradation (channelization, loss of side channel habitat, scouring)	X	X		
Non-native species	X	X	X	X
Translocation				X
Climate Change	X	X	X	X
Extirpation	X	X	X	X
Lack of Awareness (outreach and education)	X	X	X	X

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