BEST MANAGEMENT PRACTICES TO MINIMIZE ADVERSE EFFECTS TO PACIFIC LAMPREY

(*Entosphenus tridentatus)*

(Photo courtesy of U.S. Fish and Wildlife Service)

U.S. Fish and Wildlife Service

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FOREWORD

The abundance and distribution of Pacific lamprey (*Entosphenus tridentatus,* formerly *Lampetra tridentata*) has significantly declined throughout its range over the past three decades. Many factors have contributed to this decline, including: impeded passage at dams and diversions, altered management of water flows and dewatering of stream reaches, dredging, chemical poisoning, poor ocean conditions, degraded water quality, disease, over-utilization, introduction and the establishment of non-native fishes, predation, and stream and floodplain degradation (Luzier et al 2009). Mitigation and restoration actions focused on habitat restoration of salmonid species within tributary habitats may also have contributed to this decline as they may not have considered needs unique to lampreys.

Pacific lampreys are important for many reasons:

- They have high cultural significance to Native American tribes from California to Alaska and;
- May have served as a primary food source for aquatic, mammal, and avian predators that also prey on ESA-listed salmonids and other recreational and commercially important fish species.

In July, 2008 the four treaty tribes within the Columbia River basin (Umatilla, Warm Springs, Nez Perce, and Yakama Nation) released a draft of the Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin (CRITFC 2008). This plan described an explicit and time-sensitive path over the next ten years for implementing conservation actions in both the mainstem Columbia/Snake Rivers and associated tributary rivers and streams. The ultimate goal of the plan is to restore Pacific lamprey populations to levels supportive of their unique cultural and ecosystem values.

In 2004 and 2008, the treaty tribes held Summits that included the executives from federal agencies who have authority and/or legal obligations for managing fish and aquatic habitats within the basin. At these Summits, tribal leaders communicated the urgency to begin implementing protective measures and restoration of Pacific lampreys using their authorities and funding. The executives agreed to implement the Tribal Plan and various agency actions are currently underway, including incorporation of the Tribal Plan into the U.S. Fish and Wildlife Service's Rangewide Conservation Plan for Pacific Lampreys.

For aquatic restoration actions on federally-managed lands, the primary emphasis is to improve tributary habitat for salmonids. While these aquatic strategies are consistent with meeting the needs of Pacific lamprey, changes made to a project for protection of salmon or other ESA- listed aquatic species should incorporate additional adjustments to prevent direct adverse effects to individual lampreys or populations of Pacific lamprey residing in the affected areas. These adjustments should be made at the project design phase to accommodate lamprey passage, lamprey spawning periods, existence of nests, upstream and downstream movement, and avoid direct mortality to ammocoetes burrowed in the substrate.

The purpose of this document is to provide information on Best Management Practices for Pacific lamprey that can be incorporated into any stream disturbing activity (e.g., aquatic habitat restoration, prescribed fire, recreational development, grazing, gravel extraction/mining, water diversions, etc.) on lands managed by the Forest Service and Bureau of Land Management throughout the range of Pacific lamprey. In addition, this information can help other federal, state, tribal and private land managers with implementing stream disturbing activities that also afford protection for individual lamprey and lamprey populations.

This document will be updated periodically as research and management activities increase our knowledge of the species and standardized sampling, passage and screening methods are developed.

Compiled by:
Jody K. Brostrom and Christina Wang Luzier, U.S. Fish and Wildlife Service
Katherine Thompson, U.S. Forest Service

Introduction

The Pacific lamprey (*Entosphenus tridentatus* formerly *Lampetra tridentata)* is an anadromous and parasitic fish widely distributed along the Pacific coast of North America and Asia. Historic runs of Pacific lamprey in the Columbia River basin numbered in the hundreds of thousands at Bonneville Dam as recently as 1965 (Figure 1) but the distribution and abundance of lampreys have been reduced by construction of dams and diversions as well as degradation of spawning and rearing habitat (Quigley et al. 1996). Pacific lamprey returns to coastal streams have shown a similar decline.

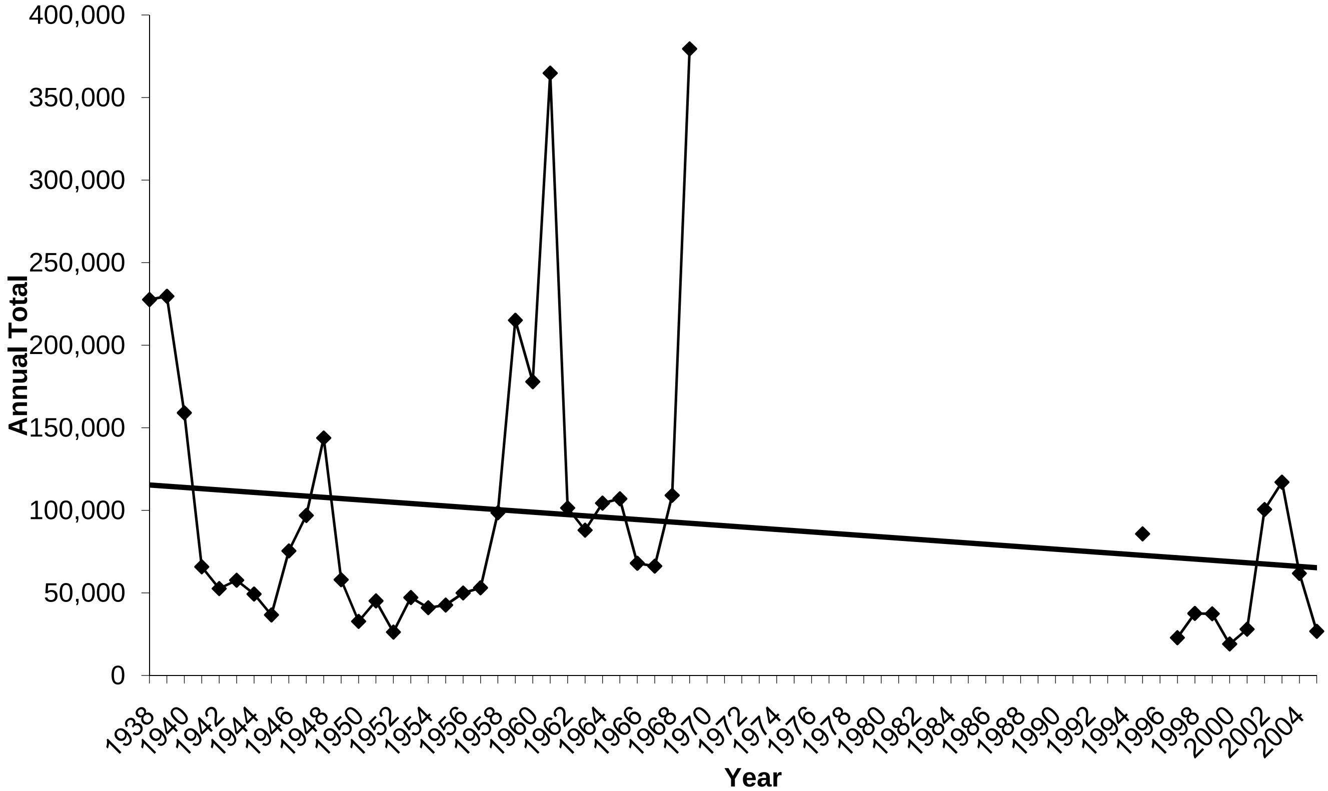


Figure 1. Pacific lamprey adult upstream passage day counts at Bonneville Dam, OR (USACE 2006). Trend line fitted through regression. From Cochnauer and Claire 2009.

The Pacific lamprey is included as a State sensitive species in Oregon and Washington, state-listed endangered species in Idaho, designated tribal trust species, and a 'species of special concern' for the U.S. Fish and Wildlife Service (USFWS). The Pacific lamprey has been designated as a Forest Service Sensitive Species in Regions 1 and 4, and is classified as a Type 2 species (Rangewide/Globally imperiled) by the Bureau of Land Management.

A petition in 2003 (Nawa 2003) to list the Pacific lamprey under the Endangered Species Act was determined to be not warranted. However, in their determination, the USFWS acknowledged that Pacific lamprey have declined in the Columbia River Basin and in many parts of their range. The Pacific lamprey has and continues to face a variety of threats associated with: passage and entrainment at dams and water diversion structures, altered stream flows including dewatering of stream reaches, dredging, chemical poisoning, degraded water quality, poor ocean conditions, disease, over-utilization, introduction and establishment of non-native fishes, predation, and stream and floodplain degradation/simplification (Luzier et al 2009).

For the purposes of this document, only those threats to upstream and upriver lamprey habitat on federal lands will be discussed. However, it is worth noting that passage issues within the Columbia and Snake River basin have been identified as significant threats to lamprey persistence, for many of the same reasons associated with the decline of salmonids. It should also be noted that declines in Pacific lamprey have occurred in coastal, undammed streams and rivers so the entire suite of threats needs to be addressed in efforts to restore this species throughout their range.

Pacific Lamprey Life History Synopsis

The following is a general description of Pacific lamprey life history. Like salmonids, factors such as latitude, elevation, hydrology, distance from the ocean and climate introduce variability and influence adaptations in life history expression. Figure 2 depicts the generalized life cycle of Pacific lamprey (Streif 2009).

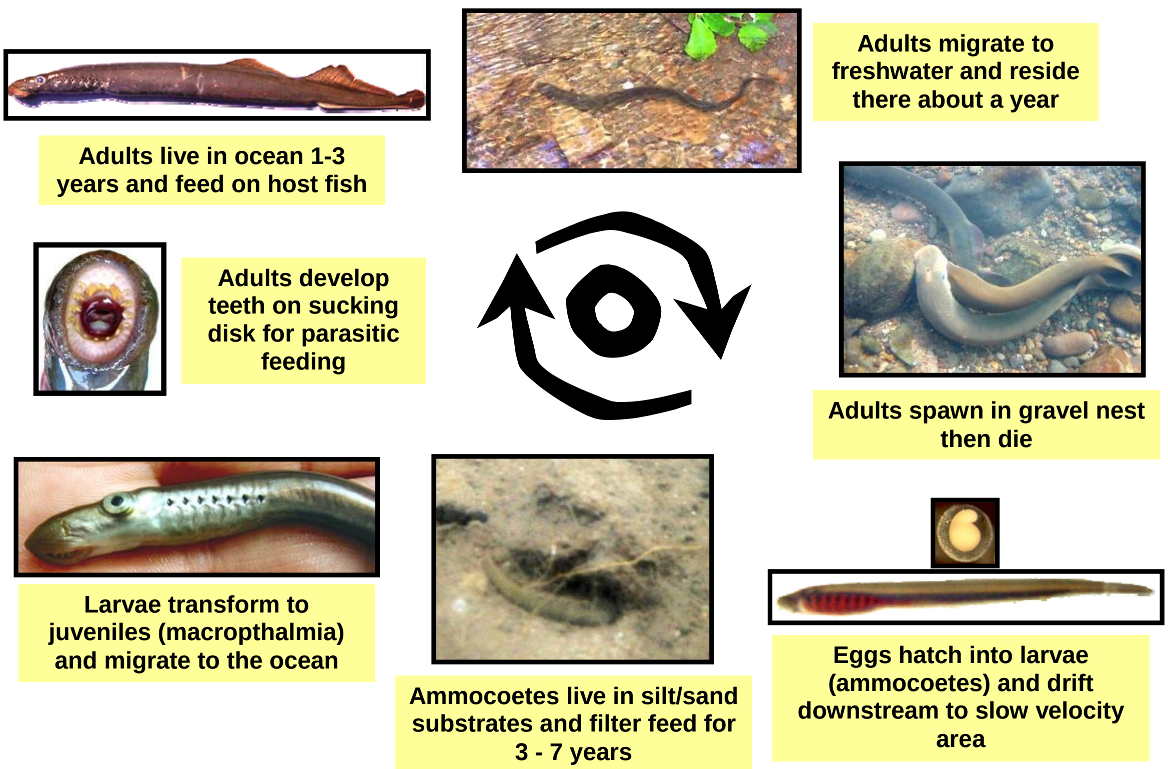


Figure 2. General life cycle of Pacific lamprey (Streif 2009).

The physical form of Pacific lampreys plays a major role in their life history and habitat requirements. Pacific lampreys are jawless fishes which lack paired fins, vertebrae or a swim bladder and possess an elongated, cylindrical body and suctorial disk mouth. Swimming is accomplished through rhythmic lateral undulations of the body axis from nose to tail, or anguilliform swimming (Mesa et al 2003). Adult Pacific lampreys cannot jump, but can pull themselves over obstacles if the surface is wetted and they are able to get a complete seal with their suctorial disk. The suctorial disk allows Pacific lampreys to cling to surfaces, thus propelling themselves forward with a burst and attach pattern, especially in higher velocities. Lampreys avoid light, so most movement occurs during hours of darkness (Chase 2001).

After spending between 6 months to 3.5 years in the marine environment (Beamish 1980, Kan 1975), Pacific lampreys return to fresh water primarily during spring and summer months. They often spend about 1 year in freshwater habitat before spawning, usually holding under large substrate (e.g., large boulders, bedrock crevices) associated with low water velocities until the following spring, when they move to spawning areas. Adults observed in freshwater range in size from 350 mm to 650 mm (Beamish 1980).

Adult lampreys spawn generally between March and July in gravel bottom streams (Figure 3a, 3b, 3c), usually at the upstream end of riffle habitat near suitable habitat for larvae (ammocoetes), and die after spawning (Beamish 1980). Suitable habitat for ammocoetes includes low velocity pools and stream margins with a dominant substrate of fine silt, sand, or small gravels (Torgerson and Close 2004, Graham and Brun 2005). Low to moderate gradient stream reaches with a mix of silt and cobble substrate may offer optimal spawning and rearing habitat. Streams and rivers where natural flows are low velocity, such as those in low gradient reaches, are important characteristics associated with lamprey presence (Kostow, 2002). Pacific lamprey are often sympatric with native freshwater mussels (Bettaso and Goodman 2008; J.Dunham personal communication),

The incubation period has been observed to be between 18-49 days (Brumo 2006) and ammocoetes drift downstream to areas of low stream velocity and burrow into sand or silt substrate (Figure 4a and 4b). They are mostly sedentary, remaining burrowed in the stream substrate for 3 to 7 years, filter feeding on algae, diatoms, and detritus. Generally, depositional areas with soft substrate near stream margins associated with pools, alcoves and glides are where most ammocoetes burrow (Graham and Brun 2007) as seen in Figure 5a, 5b, 5c and 5d. Ammocoetes move downstream during high flow events or if disturbed.

Metamorphosis of ammocoetes (Figure 6a) into the sub-adult form or “macropthalmia” (Figure 6b), occurs generally from July through November but is variable depending on distance from salt water. Out-migration to the ocean occurs during or shortly after transformation (Beamish 1980). Out-migration generally peaks with rising stream and river flows in late winter or early spring (Kostow 2002). Larval lampreys generally begin transforming to the sub-adult stage when they are 100 mm in length but it is variable depending on location (Kan 1975). Most downstream movements occur at night (Gritsenko 1968 cited in Potter 1980),

The onset of parasitism in Pacific lampreys occurs during metamorphosis when the foregut lumen has opened and tooth development is complete (Richards and Beamish 1981). Thus macrophalmia can begin parasitic feeding prior to entering saltwater. Pacific lampreys enter salt water after transformation. They have been documented to move quickly off shore, into waters up to 70 m deep (Beamish 1980) but there is little information regarding their ocean residence beyond this study. Adults in saltwater feed on a variety of marine and anadromous fish, and are preyed upon by sharks, sea lions, birds, and other marine mammals (USFWS 2004).

a. (photo courtesy of U.S. Fish and Wildlife Service, Christina Luzier)

b. *(photo courtesy of Oregon Department of Fish and Wildlife, Michael Gray)*

c. *(photo courtesy of U.S. Geological Survey, Steven Clark)*

Figure 3. Photos of Pacific lamprey nests in a) Cedar Creek, Washington; b) Coastal Oregon and c) Western Washington. Lamprey nests are similar to salmonid redds, and can be difficult to distinguish from salmonid redds where both animals occur.

a. (European brook lamprey photo courtesy of Bernt René Voss Grimm)

b. (photo courtesy of Oregon Department of Fish and Wildlife, Michael Gray)

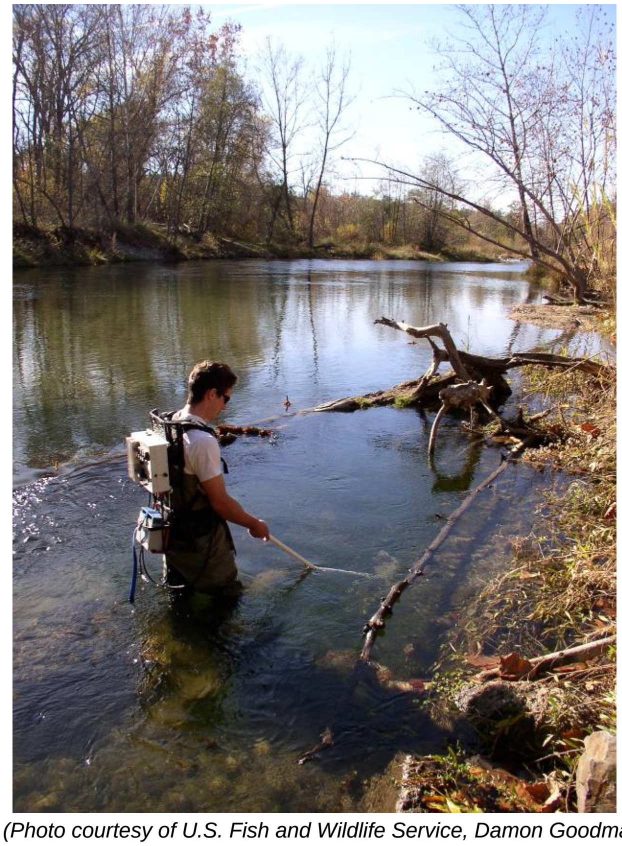
Figure 4. Photos of (a) larval European brook lamprey in substrate and (b) larval Pacific lamprey sampled from substrate. Pacific lamprey use substrate similar to European brook lamprey.

a. *(Photo courtesy of Confederated Tribes of the Warm Springs Reservation, Jen Graham)*

b. (*Photo courtesy of U.S. Geological Survey, Steven Clark)*

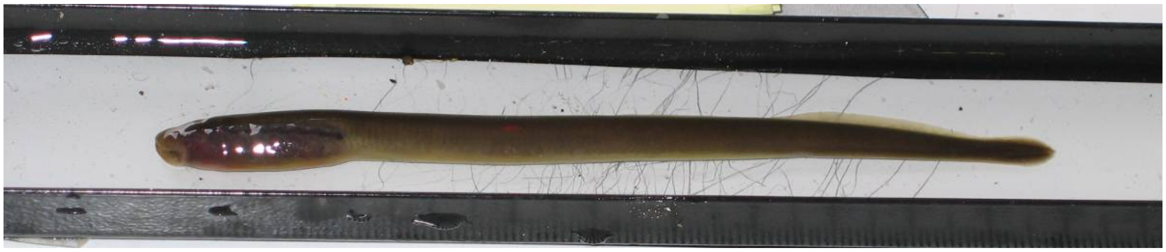
Figure 5. Typical habitat where ammocoetes are found in (a) Deschutes River Basin, Oregon, (b) Western Washington.

c. *(Photo courtesy of Idaho Department of Fish and Game, Christopher Claire)*



d. (Photo courtesy of U.S. Fish and Wildlife Service, Damon Goodman)

Figure 5 continued. Typical habitat where ammocoetes are found in (c) Clearwater Drainage, Idaho and (d) Northern California.



a. (photo courtesy of U.S. Fish and Wildlife Service, Gregory Silver)

b. (photo courtesy of U.S. Fish and Wildlife Service

Figure 6. Photos of (a) Pacific lamprey ammocoete and (b) Pacific lamprey macropthalmia after transformation.

Threats to Pacific Lampreys Residing in Upper Portions of Stream/River Habitats

Ammocoetes spend most of their time burrowed in stream substrates, moving during flow events and mostly at night. Many age classes can concentrate together in the same areas because of habitat preference, making ammocoete populations particularly susceptible to activities that involve dredging/excavating, stranding and use of toxic chemicals. Adults also prefer to move at night, hiding in large rock and boulder substrate during the day. Activities posing a threat to lampreys include:

Passage and entrainment. Culverts, water diversions, hydroelectric dams and other passage barriers can impede upstream migrations by adult lampreys and downstream movement of ammocoetes and macropthalmia. Culverts that have a drop at the outlet, high velocities, inadequate attachment surfaces or insufficient resting areas, will block upstream passage (Figure 7a) but those that simulate streams (Figure 7b) will provide passage for all life stages. Fish ladders designed for salmonids are usually impediments to lamprey passage as they do not have adequate surfaces for attachment, velocities are often too high and there are inadequate places for resting (Figure 8a). Rounding corners, providing resting areas or providing a natural stream channel or wetted ramp for passage over the impediment (Figure 8b) have been effective in facilitating lamprey passage. Ammocoetes and macropthalmia may also become entrained at un-screened water diversions due to their size and weak swimming ability and adults can be blocked from moving upstream (Figure 9). All life stages can be impinged on screens resulting in injury or death. At present, there are no criteria for lamprey when designing fish screens.

De-watering and streamflow management from water diversions, instream projects and hydropower peaking can cause rapid fluctuations in stream water levels and strand ammocoetes in the substrates. A single event can have a significant effect on a local lamprey population. Upstream passage can also be impacted, and nests can be dewatered, killing eggs and larvae.

Dredging from construction, channel maintenance and mining activities can impact all age classes of ammocoetes. Removal of substrate with a backhoe or trackhoe could remove several hundred lamprey per bucket load.

Chemical poisoning from accidental spills or chemical treatment can harm or kill ammocoetes burrowed in streams. As ammocoetes spend 3 – 7 years filter feeding, they may have a higher propensity for accumulating toxins such as PCBs, mercury, and other heavy metals (Bettaso and Goodman, 2008).

Poor water quality. Water temperatures of 22^{o} C (72^{o} F) or higher may cause significant mortality or deformation of eggs or ammocoetes (Meeuwig et al 2005). Accumulated toxins in the lower reaches of streams and rivers may affect ammocoetes because they are often found in these areas.

Stream and floodplain degradation (channelization, loss of side channels, scouring) can result in the loss of riffle, suitable stream edge and side channel habitats, reducing areas for spawning and ammocoete rearing.

a. *(Photo courtesy of U.S. Forest Service)*

b. *(Photo courtesy of U.S. Forest Service)*

Figure 7. (a) Culvert that would block upstream passage for Pacific lamprey, and (b) stream simulation culvert that would provide passage to all life stages of Pacific lamprey.

a. *(Photo from Moser et al 2004)*

b. *(Photo courtesy of Bob Heinith)*

c. *(Photo courtesy of Bob Heinith)*

Figure 8. (a) Fish ladder built for salmonid passage impedes lamprey passage due to the 90 degree angles and corners, high velocity chutes, minimal resting areas; (b) Constructed natural stream channel that is the approach to a (c) wetted sloped ramp that provides lamprey passage over a steep dam. Arrow denotes adult Pacific lamprey climbing sloped ramp.

(Photo courtesy of Idaho Department of Fish and Game, Paddy Murphy)

Figure 9. Irrigation diversion that blocks upstream movement, entrains lamprey and other fish into the ditch, and dewaters downstream reaches.

General Considerations for Pacific Lamprey When Designing Instream Activities

Instream activities resulting from aquatic habitat restoration, prescribed fire, recreation, grazing, gravel extraction, water diversions, etc. can impact tributary habitat important for Pacific lamprey. For aquatic restoration actions on federally-managed lands, the primary emphasis is to improve tributary habitat for salmonids. To ensure the long-term protection of these aquatic habitats, the US Forest Service and Bureau of Land Management have adopted the riparian and stream management principles outlined in the PACFISH and INFISH (Forest Service only) Environmental Assessments and associated Decision Notices (1995) within the Interior Columbia River basin. West of the Cascades, the Northwest Forest Plan's Record of Decision (1994) put in place an Aquatic Conservation Strategy that applies to both Oregon and Washington.

These aquatic habitat conservation strategies have been incorporated into agency land use plans and provide Standards and Guidelines for all categories of management actions (recreation, roads, grazing, restoration, etc.) to ensure impacts to riparian and instream habitats are minimized. While these aquatic strategies are consistent with meeting the needs of Pacific lamprey, changes made to accommodate salmon or other ESA- listed aquatic species should incorporate additional adjustments to prevent direct adverse effects to individual lampreys or populations of lampreys residing in the affected areas. Examples of changes to protect ESA-listed salmonids include:

- Instream work periods (e.g., work in specific times of the year are avoided to protect spawning salmonids and their redds);
- Dewatering regimes with specific design criteria implemented to avoid stranding juvenile salmonids and/or meeting Clean Water Act requirements;
- Modifications to structure design to accommodate salmon and steelhead swimming abilities.

Further adjustments to minimize adverse effects to Pacific lamprey should be made at the project design phase to accommodate lamprey passage, lamprey spawning periods, existence of nests, upstream and downstream movement, and avoid direct mortality to ammocoetes burrowed in the substrate. See Streif (2007) and Streif (2009) for a discussion of what can be done to minimize impacts.

Steps that can be taken to minimize adverse effects to lampreys at the initiation of the planning phase include (Streif 2007):

- Consider lampreys in all stream disturbing activities;
- Identify locations within streams where activities have the greatest potential to affect lampreys (both positive and negative effects);
- Modify project design to protect lampreys (refer to sections below);
- Modify passage project designs to accommodate lamprey passage
- Post-project, monitor and document successes and failures for items 2 and 3. Provide this information to the US Fish and Wildlife Service: http://www.fws.gov/pacific/fisheries/sp_habcon/lamprey/index.html).

In addition, the attributes of desirable habitat characteristics for lampreys should be considered in the design of projects. Desirable habitats include:

- Stream and river reaches that have relatively stable flow conditions (sustained increases or decreases that take place over days and weeks rather than hours) and that are not extreme or flashy, offer the best opportunities to support all life stages of lampreys;
- Large substrates (i.e. very large cobble and boulders) submerged in low or no flow areas of rivers and streams may provide high quality adult overwintering habitat.
- Areas of small to medium cobbles, free of fine sediment, serve as spawning habitats. Spawning habitats created or enhanced for salmonids are generally compatible with the needs of lampreys;

- Depositional areas, including alcoves, side channels, backwater areas, pools, and low velocity stream and river margins that recruit fine sands and silts, downstream of spawning areas, provide ideal ammocoete rearing areas and should not be reduced.
- A mix of deep pools, low velocity rearing areas with fine sand or silt, and silt-free cobble areas upstream of rearing areas, all combined with summer temperatures that rarely or never exceed 20^{o} C (68^{o} F) , is believed to provide high quality habitat conditions for all life stages.
- Studies with European lamprey species have shown that the occurrence of substantial areas of juvenile lamprey habitat may not signify presence of lamprey populations as populations have a disparate distribution (King et al 2008). However, it is important to maintain the integrity of these areas as their use by lamprey may vary temporally.

Best Management Practices for Instream Activities to Avoid Adverse Effects to Pacific Lampreys

1. Consult with local federal, state and tribal biologists to obtain information on known lamprey populations in the drainage. Perform a site reconnaissance to identify locations of lamprey spawning and rearing habitat, and if possible, lamprey presence with nest surveys or methods outlined in Attachment A. This information will facilitate planning the project and influence work windows.

2. Timing of instream activities is critical to avoid adversely affecting spawning adults and dewatering or disrupting existing nests. Critical time periods include the following:

- Dependent on location within their distribution range, adult lampreys can be present at spawning areas and preparing to spawn from **February to September**. The peak period within the Columbia River basin is primarily from ***March 1 through July*** 1 in lower and mid elevation reaches;
- Nests present: March 1 through August 1 but time period is dependent on geographical location within the range of lamprey and elevation of spawning sites;
- Embryos hatch in approximately **19 days at 15^{o} C (59^{o} F)**;
- Emergence and settling into suitable habitat: **April to August** but time period is dependent on geographical location within the range of lamprey and elevation of spawning sites

Instream operating windows to avoid adverse effects to anadromous fish is most commonly from July 1 through August 15, which under most conditions would be sufficient to protect Pacific lamprey nests, eggs, and emerging larvae. Exceptions may include high elevation river and stream reaches (>5,000 ft), where spawning would be expected to occur later in the spring, or if information obtained during the planning phase indicates different timing. If this is the case, surveys for nests should be initiated, and if found, defer instream work until August 1.

Recommendation:
- ***Avoid working in stream or river channels from March 1 to July 1 in low to mid elevation reaches (<5,000 ft). In high elevation reaches (>5,000 feet), avoid working in stream or river channels from March 1 to August 1. If either timeframe is incompatible with other objectives, survey affected area for nests and lamprey presence, and avoid disturbing them.***

3. Temporary dewatering associated with instream channel work, stream crossing replacement, etc. can result in the loss of an entire population of ammocoetes and many year classes as lampreys often occur in large clusters in discrete sites where habitats are optimal.

- Ammocoetes are present at all times of the year;
- They remain burrowed in stream substrates for 3 – 7 years primarily moving seasonally and with flow events;
- They can and will move IF flows decrease slowly enough for them to respond.

Recommendation:
- ***Avoid dewatering stream reaches where lampreys are known to exist.***
- ***Survey using methods outlined in Attachment A to determine ammocoete presence, preferably at the project planning stage and when the project is implemented.***
- ***Ramping flows, particularly during hours of darkness, can be effective in encouraging ammocoetes to move out of areas of impact.***

4. Dewatering associated with instream or channel construction/reconstruction and stream crossing upgrade projects is often a required design criterion for avoiding adverse effects to ESA-listed salmonids.

- Salvage techniques for salmonids are often not effective for salvaging ammocoetes;
- Ammocoetes may not "emerge" from dewatered substrates until they begin to desiccate; which is often at night after other fish salvage operations have ceased. They are difficult to see in dewatered areas (Figure 10).

(Photo courtesy U.S. Fish and Wildlife Service)

Figure 10. Ammocoete stranded during dewatering.

Recommendations for Dewatering Reaches Where Lampreys Are Present:

- ***Attempt salvage using methods outlined in Attachment A before dewatering, and move ammocoetes to a safe area;***
- ***Dewater slowly over several days or at a minimum overnight;***
- ***Identify areas adjacent to ammocoete habitat outside of the disturbance area but within the channel and dig holes (e.g., few scoops with a backhoe, etc.) where ammocoetes may take refuge as dewatering occurs. Cover these 'refuge' holes to protect them from predators;***
- ***Anecdotal information suggests ammocoetes will move into areas that retain water;***
- ***Try an experimental technique – there is some evidence to suggest that if straw bales are placed in habitats where ammocoetes are present, they will move into the straw as dewatering occurs and can be safely removed the next day. If successful, document and provide this information to the US Fish and Wildlife Service.***

5. Instream channel reconstruction, re-routing, dredging, and other activities that disturb or remove substrate materials may result in ammocoetes being trapped or killed.

- Ammocoetes burrowed in the substrate can and will move if disturbed but are very susceptible to being trapped given their reluctance to move and propensity to avoid light;
- Timing restrictions do not address this risk of direct mortality.

Recommendations:

- ***Avoid these activities where ammocoetes are known to exist. Where this is not possible, salvage efforts using methods outlined in Attachment A should be attempted prior to activity***
- ***Sift through the removed substrate and salvage any ammocoetes within and return them to the stream away from the construction activity.***

Best Management Practices for In-Channel Diversion Structures to Minimize Adverse Effects to Pacific Lampreys

1. Diversion of water into irrigation canals and ditches removes water from the stream channel.

- Reduced flows decrease the amount and quality of habitat available to Pacific lampreys;
- Flows that are diverted **quickly** into canals and ditches may strand ammocoetes and migrating macropthalmia as occupied habitats are dewatered;
- Flows that are diverted may result in desiccation of lamprey nests.

Recommendations:

- ***Negotiate water savings and ditch consolidation wherever possible to provide more instream flow.***
- ***Avoid reduction in streamflows of a magnitude that nests would be exposed and desiccated.***
- ***When diversion structures are opened for irrigation, request that they are opened during the day and operated slowly to allow ammocoetes to escape to a watered area.***
- ***When shutting off a diversion, do so slowly, ideally starting at night and lasting for several days, so the lamprey can escape if they are between the headgate and any fish screen, or trapped behind the screen in the ditch. Start by cutting flow to 50% for the first 24 hours, and then to 75% over the next two days. Then, drop flow to 80-90% for a few days with the screen lifted (if applicable). This technique is also used for salmonids. The goal is to keep a continuously wetted channel between the diversion point and downstream wetted area in the ditch to facilitate movement out of the ditch.***
- ***Salvage using methods outlined in Attachment A.***

2. Diversion of water at water diversion structures may result in impingement of larval and juvenile lampreys (both ammocoetes and macropthalmia) on screens installed to prevent juvenile salmonids from moving into ditches, canals, and hydropower turbines.

- Approach velocities greater than 0.40 ft/s for active screens or 0.20 ft/s for passive screens have been shown to make it difficult if not impossible for ammocoetes and macropthalmia to avoid the structure (Dauble et al. 2006);
- Ammocoetes were found to become impinged on bar screens at hydroelectric facilities at velocities of 1.5 ft/s or higher (Moursund et al. 2001);
- In testing three types of screen materials, no lampreys became permanently stuck on 3/32 inch bar screen in front of turbines (Moursund et al. 2001).

Recommendations:

- ***Different screen types (materials, orientation and siting) may have different effects on lamprey. At present (2009) little is known about what types of screens, water velocities, orientations of the screen and screen material are effective at reducing impacts to lampreys. Criteria developed for salmonids may or may not be appropriate for protecting lamprey. As criteria are developed for lamprey, step up replacement of fish screens at diversion structures known to entrain or cause mortality to lamprey with those that prevent entrainment of lamprey, in streams where lamprey are known to exist.***
- ***Use methods outlined in Attachment A to determine if lamprey are being entrained in an irrigation ditch.***

3. Diversion structures and dams may block adult lampreys migrating upstream or result in diversion into ditches and canals.

- Flows greater than 5 - 6 ft/s have been found to be difficult to negotiate and swim through for adult Pacific lamprey (Mesa et al. 2003).
- Adults may encounter difficulties negotiating structures with square corners (Moser et al. 2004) because they cannot form a complete seal with their oral disks. Rounded corners are more suitable because they provide more surface area for attachment and a tighter seal.

Recommendation: Provide passage over irrigation diversions or dams that currently block upstream migration of Pacific lamprey. There are existing designs of structures that will pass lampreys*. *Contact the US Fish and Wildlife Service for assistance in choosing a passage structure.

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ATTACHMENT A
Electrofishing Recommendations for Sampling Larval Pacific Lampreys

(*Photo courtesy of U.S. Geological Survey, Steven Clark)*

(Photo courtesy of Confederated Tribes of the Warm Springs Reservation, Jen Graham)

Electrofishing Techniques for juvenile Pacific lamprey

Electrofishing Recommendations for Sampling Larval Pacific Lampreys
(from: Moser et al. 2007; and G. Silver and C. Luzier, USFWS, personal communication)

a. Most surveys rely on a backpack or shore-based electrofishers in small streams, most effective in waters less than 0.8 m in depth.

b. Generally three types of electrofishers are suitable for ammocoete sampling: 1) AbP-2 “Wisconsin” electrofisher (ETS Electrofishing, Verona, WI); 2) Smith-Root LR-24 model electrofisher with lamprey settings; and 3) conventional electrofisher traditionally used for salmonids.

c. Electrofishers used for ammocoete sampling should be set with two wave forms, a lower frequency “tickle” wave form to coax ammocoetes out of the substrate and a higher frequency “stun” wave form to immobilize ammocoetes for netting.

d. Effective sampling involves this 2-stage method:
   i. First stage: use 125V direct current with a 25 percent duty cycle applied at a slow rate of 3 pulses per second, to induce ammocoetes to emerge from the sediment.
   ii. Use a pattern of 3 slow pulses followed by a skipped pulse (bursted pulse) helps ammocoetes to emerge.
   iii. Second stage: immediately after ammocoetes emerge, use a fast pulse setting of 30 pulses per second to immobilize and net them.

	Bursted Slow Pulse Primary Wave Form	Standard Fast Pulse Secondary Wave Form
Voltage	125 v	125 v
Pulse Frequency	3 Hz	30 Hz
Duty Cycle	25%	25%
Burst Pulse Train	3:1	X

e. A conventional electrofisher can be used but the 2-stage settings/method described above should be used. Conventional electrofishing gear set for salmonid capture uses higher voltage and frequencies which potentially causes electronarcosis of buried ammocoetes, resulting failure to emerge and therefore a recording of false absence. Additionally, a conventional electrofisher has only one switch making the transition from slow (tickle) to fast (stun) pulse pattern more difficult as the switch needs to be released and pressed again. This technique can be learned with practice

f. Avoid exposing ammocoetes to extended periods of electrofishing as it has also been linked to electronarcosis.

g. Use dip nets to capture ammocoetes where they are readily visible. Where not visible, seines may be effective.

h. Capture efficiencies may vary according to site characteristics, electrofishing gear used and electrofishing techniques.

i. Within each reach, electrofishing should be conducted in a downstream to upstream direction (for the purpose of reducing turbidity/maintaining visibility) with one person operating the electrofisher and at least one person netting ammocoetes. Each reach should be thoroughly and slowly sampled, with more effort directed at suitable lamprey rearing habitat and less effort in areas with hard substrates or high water velocity.

j. Using the 2-stage method described above, the electrofisher should mainly be operated in the lower frequency output mode to irritate ammocoetes out of the substrate. When necessary, the higher frequency mode should be activated for capturing emergent ammocoetes.

k. Multiple electrofishing passes should be made to ensure a more complete removal of ammocoetes. A fifteen minute break between passes should be taken to reduce the chance of electronarcosis.