Introduction

Lamprey are one of the oldest living vertebrates on earth. Despite this longevity, little quantifiable information concerning lamprey populations exists. The majority of scientific studies on lamprey have investigated biological attributes, with few studies investigating historic abundance, detailed distribution and specific ecological requirements and role. Because of the paucity of information and concerns of declining lamprey population in the Pacific Northwest, the Applegate River Watershed Council (ARWC) with the Medford District of the Bureau of Land Management (BLM) collaborated to study lamprey populations in the Applegate River watershed of southwest Oregon (Close *et al*. 1995, Larson & Belchik 1998, Kostow 2002). The objectives of the study included: (1) Identifying species composition; (2) determining the distribution of lamprey species; and (3) relating the distribution of lamprey ammocoetes (juveniles or larvae) to physical stream characteristics.

This paper summarizes the life histories of the two most common lamprey species in the Oregon, the Pacific (*Lampetra tridentata)* and Western Brook (*Lampetra richardsoni*), details the methods of study, reports the results and summarizes the findings. Also included are recommendations and suggestions for future lamprey work in the Applegate basin.

Setting

The Applegate River watershed is located in southwest Oregon and northern California (Fig. 1.) Comprising 500,000-acres, the watershed is a 4th field tributary to the Rogue River. Situated in the Klamath Mountain eco-province, the watershed is of varying topography and geology. Elevations range from 1,200-7,200 feet. Cool-wet winters and dry-warm summers broadly characterize the climate of the region. In turn, the region supports a large diversity of flora and fauna species as related to this varying geology, topography and climate. Land use in the watershed is comprised of residential and agriculture in the low-elevation valleys and industrial forest and non-commercial woodlands in the uplands.

Life History

There are two ubiquitous lamprey species found in Oregon, the anadromous and parasitic Pacific and the freshwater and non-parasitic Western Brook. The summary of life histories focuses upon these species due to the likelihood of occurrence in the Applegate basin. The other likely species, as documented by Oregon Fish & Wildlife (ODFW), distributed in western Oregon, is the River lamprey (*Lampetra ayersi)* (Kostow 2002). The River lamprey is not covered in this report due to its current unknown status in Oregon. No accounts for this species have occurred for years in Oregon. Interested readers are referred to Kostow (2002) for additional information regarding this species.

Pacific Lamprey

The distribution of Pacific lamprey occurs from the Aleutian Islands to Baja, California and Hokkaido, Japan (Close *et. al.* 1999). Subsequently, the majority of lamprey information concerns the Pacific species, due to this large distribution range.

Pacific lamprey are anadromous and parasitic. They are born and reared in freshwater streams, migrate to the ocean as immature adults and return to freshwater to spawn as mature adults.

Adult lamprey are reported as migrating in the Applegate basin during the months of July and August (Chinn, personal communication, 2002). They over-winter in the stream and spawn the following spring (Beamish 1980, Doino, personal communication 2002). Spawning occurs along low-gradient stream habitat in sand and gravel substrates. Upon completion of spawning most adult lamprey die.

Following an incubation period of 10-21 days, lamprey ammocoetes emerge from the redd. Upon emergence from the redds, ammocoetes drift downstream into areas of fine sediment. Within this habitat ammocoetes burrow into silts and sandy material. The ammocoetes remain in the sediment from 3-7 years filter feeding on diatoms and algae (Close *et. al.* 1999). Ammocoetes under go a metamorphosis stage before migrating to the ocean. Morphological changes consist of eye development, distinct fins, enlargement of the oral disc, gonad formation, and development of a naso-pineal gland for light detection and chemical stimuli (Potter 1980, Kostow 2002). In addition, physiological changes occur in an increase in lipid reserves and alterations in blood chemistry for entry into the ocean.

Upon entering the ocean, the lamprey becomes parasitic, preying on fish and whales. Lamprey reside in the ocean from 6 months to 3.5 years and then return to freshwater to spawn (Kostow 2002). It is unknown if adult lamprey return to their natal stream for spawning.

Western Brook Lamprey

Western Brook lamprey are the second most common and distributed lamprey in Oregon (Kostow 2002). They range from California to British Columbia. The Western Brook lamprey spends its entire existence in freshwater and is non-parasitic. They migrate very little in their life, with the exception of passive movement.

Spawning occurs in spring. Occurring upstream of riffles, both sexes construct a redd for incubation of the eggs. Upon completion of spawning lamprey die. The fertilized eggs hatch after 15-20 days and emerge from the redd after an additional 30 days (Kostow 2002). Emerged ammocoetes move to areas of shallow water

and silt deposits. Older ammocoetes move downstream and reside in deeper water with sandy substrates and abundant organic matter.

During this period, ammocoetes are filter-feeding on diatoms (Kostow 2002). Following a 4-6 year period ammocoetes under go a metamorphism. From August to September, ammocoetes develop eyes and gonads. In addition, there are increases in size of their oral disc, gills and naso-pineal glands. Following these changes, lampreys burrow into sediment and become dormant. The following spring they emerge ready to spawn.

Methods

Species Identification

To identify the composition of lamprey species in the Applegate basin, ammocoetes were collected throughout the basin that varied in size and season harvested. The collected specimens were preserved in formalin. Fish systematic expert Dr. Douglas Markle, of Oregon State University identified the ammocoetes. Markle identified the preserved specimens by taxonomic characteristics.

Sampling

To determine presence of lamprey ammocoetes, low elevation perennial streams in the Applegate basin were sampled using hand held scoop nets. Sampling targeted sites of low gradient and slow water habitat. Depositional areas of fines (silt and/or sand) and organic matter (leaves and/or woody material) were sampled for presence of lamprey larvae.

Sites where ammocoetes were identified were continually monitored for 2-3 years to track seasonal and yearly changes in presence/absence.

The sites monitored are as follows:

- Applegate River at Jackson Campground; River Mile 42
- Little Applegate River at confluence with the Applegate River; River Mile 0.1
- Little Applegate River below confluence with Yale Creek; River Mile 6.6
- Little Applegate River at Tunnel Ridge Trailhead; River Mile 9.8
- Little Applegate River at Rush Creek; River Mile 11.6
- Williams Creek upstream of Williams Highway Bridge; River Mile 5.8
- East Fork Williams Creek at Brown's Road; River Mile 0.2
- Slate Creek at Mouth; River Mile 0.1

Distribution

The minimum distribution of lamprey was determined by the farthest upstream presence of larvae.

Physical Characteristics of Ammocoete Habitat
At sites were ammocoetes were collected physical stream parameters including habitat type, microhabitat, time, stream gradient, along with qualitative estimates of sediment composition and relative organic amounts were noted.

To evaluate larger-scale fluvial geomorphic features in the context of ammocoetes, stream channel type, valley type and reach-scale stream gradient were examined. Physical stream parameters from the ODFW Level II Stream Habitat Surveys along with 7.5' USGS quadrangle maps were used.

Results

- *Species Identification*
  Dr. Markle identified all of the collected specimens as Pacific lamprey (*L. tridentata*).

- *Distribution & Habitat*
  Lamprey ammocetes have been identified in the following streams: Applegate River, Little Applegate River, Slate Creek, East Fork of Williams Creek and Williams Creek (see fig. 2.).

  All ammocoetes were found in depositional habitat with characteristically slow-water velocities. Juveniles were *always* found within depositional material. The amount and type of depositional material (mineral and/or organic) varied in accordance to season and stream flow. Correspondingly, stream reaches in which ammocoetes were found were all low-gradient streams slope ranged from 0.4-3.0% (see Table 1.).

  Below are summaries of the distribution of lamprey grouped by sub-watershed, along with habitat characteristics of continual monitored sites, and date of lamprey collected.

- *Monitored Stream Sites*
  - *Applegate River Watershed*
    In the Applegate River lamprey larvae occur from the confluence with the Rogue River to river mile 44, no lamprey occur above the Applegate dam.

    Applegate River at Jackson Campground
    Repeat sampling on the Applegate River at river mile 42 found ammocoetes throughout the year. Ammocoetes were routinely sampled throughout the year in a low gradient side channel. The larvae inhabited a small pool comprised of medium to coarse grain sands with seasonal differences in organic matter. Depth of water in which the lamprey resided varied in depth from .08-.75 m. The channel at this site is constrained in a narrow valley with an open "V-shape". The slope of the reach is 0.4%.

Upstream of Applegate Dam
Above the Applegate dam, no lamprey were found in the main tributaries of the reservoir, Elliott Creek, Middle Fork of the Applegate River and Carrberry Creek.

- *Little Applegate River Watershed*

In the Little Applegate River lamprey larvae occur from the confluence with the Applegate River to the confluence with Rush Creek, river mile 11.6.

Little Applegate River at Mouth
Repeat sampling on the Little Applegate River at the mouth collected ammocoetes in August of 1999. Juvenile lamprey have not been captured at this site since this date. The larvae were collected on the margins of a riffle with substrate composed of silt and organics. The channel at this site is constrained by multiple terraces in a broad valley. The slope of the reach is 1.0%.

Little Applegate River at Yale Creek
Sampling immediately below the confluence of Yale Creek ammocoetes were found in the spring and fall. The larvae were collected on the margins of a lateral scour pool. The substrate consisted of medium to coarse grain sands with little to moderate amounts of organics. Depth of water in which the lamprey resided varied in depth from .03-.4 m. The channel at this site is constrained by multiple terraces set with in a broad valley. The slope of the reach is 1.5%.

Little Applegate River at Tunnel Ridge
Repeat sampling at the Tunnel Ridge site found larvae. Ammocoetes were routinely sampled throughout the year on the margins of a large scour pool and glide. The substrate consisted of medium to coarse grain sands with little to high concentrations of organics. Lamprey resided in water depths varying from .25-1.5 m. The channel at this site is constrained by a V-shaped valley. The slope of the reach is 2.4%.

Little Applegate at Rush Creek
Repeat sampling on the Little Applegate River below the confluence of Rush Creek collected ammocoetes in October of 1999. Juvenile lampreys have not been captured at this site since this date. The larvae were collected on the margins of a riffle. The channel at this site is constrained by a V-shaped valley. The slope of the reach is 2.5%.

- *Williams Creek Watershed*

Distribution of ammocoetes occurs from the confluence with the Applegate River to river mile 7. Lamprey juveniles are also found in the East Fork of Williams Creek from the confluence with Williams Creek to river mile 1.

Williams Creek
In Williams Creek, lamprey larvae were continuously sampled from Williams Highway bridge to Meadowview Lane. Ammocoetes were present in both spring and fall. Ammocoetes were sampled on the margins of pool and riffle habitat composed of silt to medium sized sand with little to high concentrations of organic matter. Lamprey resided in water depths varying from .3-.7 m. Multiple terraces confine the channel at this location. The slope of the reach is 1.5%.

East Fork Williams Creek
Juveniles were sampled in the East Fork of Williams Creek from Brown's Road to the confluence of Clapboard Gulch. The ammocoetes were located on the margins of pools in a substrate composed of silt and fine-grained sand. The stream at this location is constrained by a broad valley. The slope of the reach is 3.8%.

- *Slate Creek Watershed*

Ammocoetes occur from the confluence with the Applegate River to river mile 0.1.

Slate Creek
Lamprey larvae were found at the confluence of Slate Creek and the Applegate River. Juveniles were present in fall and winter. Ammocetes were collected on pool margins in substrate composed of fine sand and silt. Organic matter varied from little to moderate amounts. Lamprey resided in water depths varying from .3-.4 m. Multiple terraces confine the channel at this location. The slope of the reach is 1.1%.

Summary

The Pacific lamprey is distributed in many low gradient streams in the Applegate basin. Pacific lamprey ammocoetes were sampled at most sites throughout the year. At sites displaying variation of ammocoete presence, the low-repeatability of the sampling method could account for this variability.

No other lamprey species were identified during the identification-sampling period. The presence of Western Brook and River lamprey are feasible in the Applegate basin. Modifying sampling techniques of lamprey is necessary to confidently determine if these species are present (see Suggestions & Recommendations).

Distribution of lamprey partially corresponds to physical stream attributes. Lamprey ammocoetes were found in stream reaches that had less than a 3% gradient. Larger-scale fluvial geomorphic features did not appear to influence ammocoete presence. Valley and stream channel type as determine by ODFW Habitat Surveys had no bearing on lamprey distribution. Ammocoetes were sampled across a range of valley shapes and stream channel types. Stream

gradient and substrate were the limiting physical parameters for lamprey distribution. Ammocoetes were *always* sampled in areas of slow water velocities, shallow depths and substrates composed of fines and/or sand. These findings are consistent with the research of Beamish & Jebbink (1994), who related the distribution of lamprey to physical stream attributes.

In the Applegate basin, numerous streams possessing ideal ammocoete habitat lacked lamprey presence. This lack of lamprey presence regardless of habitat, suggests that physical stream habitat is not the only parameter dictating lamprey distribution. It is theorized that returning adult lamprey navigate to spawning areas by chemicals emitted by ammocoetes (Kostow 2002). Applying this theory, the complete extirpation of lamprey from a sub-basin, would ensure that future generations would not return to spawn, regardless of habitat, due to the absence of navigational cues from ammocoetes.

Much is still unknown about lamprey in the Applegate basin. Species identification and distribution allows us to refine sampling methods to increase consistency and efficiency for lamprey, while abundance data continues to be problematic. Lamprey abundance data, in the Applegate basin, continues to be collected incidental to salmonid monitoring. This current method is inadequate to evaluate lamprey population trends, due to the sampling techniques based upon salmonid life history patterns. Consequently, the ability to quantitatively evaluate lamprey population decline is doubtful.

Developing appropriate sampling techniques and methodologies for lamprey abundance is essential. A uniform and appropriate sampling design will allow for statistically valid population data interpretation. The collection of long-term data sets will allow us to determine the magnitude and rate of population changes among lamprey populations. Until then, the continual usage of inference and testimonial accounts of population trends in the Applegate basin will be subjective to interpretation.

Suggestions and Recommendations

- *Species Identification*

  Continue to be vigilant for other lamprey species besides the Pacific lamprey. The difficulty of identifying juvenile lamprey in the field lends to the need of becoming more cognizant of the life history patterns of the Pacific lamprey. Abrupt changes or abnormalities in the timing of the downstream migration of Pacific lamprey juveniles could be an indication of another lamprey species (Markel, personal communication, 2001).

  Determine if lamprey populations in the Rogue basin are significantly different in genetic composition from lamprey of southern Oregon coastal, Klamath and Umpqua drainages. Also, identify if genetically distinct sub-populations of lamprey exists within the major sub-basins of the Rogue River watershed.

- *Presence/Absence*

  Periodically perform presence/absence surveys to reconfirm distribution. In addition, survey streams that possess perennial stream flow and low gradient habitat that have not been surveyed for ammocoetes. These streams included Humbug Creek, Forest Creek, and Cheney Creek.

- *Abundance*

  Historic records or data sets of lamprey populations do not exist for the Applegate basin. As a result, the perceived notion of lamprey numbers declining in the Applegate watershed is nearly impossible to validate. Current methods of collecting lamprey data are imprecise in identifying lamprey species and relative abundance. The need to develop methods to determine abundance of lamprey populations is therefore well warranted.

  To determine the timing and extent of out migration of lamprey, a year-round rotary screw trap on the lower Applegate River is needed. Furthermore using coded wire tags, PIT technology and radio-telemetry is feasible to elucidate the migration patterns and return intervals of adult lamprey in the Applegate basin.

  With the lack of historic records of lamprey populations, the use of anecdotal accounts to reconstruct timing and place of significant life history events, such as spawning, would further contribute to understanding the life history and historic distribution patterns. Testimony of irrigation employees, long time residents and tribal member accounts are possible sources of information.

- *Water Quality*

  Endemic to cold-water streams lamprey larvae are documented as preferring water temperatures less than 20°C (Close *et al*. 1995). Long residency time and the relative sedentary lifestyle of ammocoetes leave the lamprey susceptible to minor changes in water temperatures. High water temperatures are identified as a major impairment to native aquatic organisms in the Applegate basin (Mathews

2001). Further study where ammocoetes are present, examine temperature differences in the water column. Investigate for evidence of upwelling from hypoheric zones and other cold-water intrusion sources.

- *Barriers and Passage Issues*
  The ability of adult lamprey to pass artificial barriers is acknowledged as a major habitat issue in factors affecting lamprey populations (Kostow 2002). In the Applegate basin, irrigation dams and diversions are present on all streams identified as possessing ammocoete populations. It is unclear the degree of impact these diversions have on migrating lamprey. In examining ammocoetes presence above barriers, spawning adults are able to negotiate the numerous barriers on the Applegate River, Little Applegate River and Williams Creek. No juvenile lamprey have been sampled above the lowest downstream diversions on the East Fork of Williams Creek (Beaver Dam; river mile 1.8) and Slate Creek (Lovelace Dam; river mile 3). Additional studies would determine if these structures are barriers to adult lamprey.

  With no information existing on the historical distribution of lamprey and inadequate fish passage facilities for lamprey it is unknown if the completion of the Applegate dam in 1980 led to the extirpation of lamprey in these watersheds. Collecting anecdotal accounts is the only source of information to determine distribution of lamprey before the dam.

  Also warranted is surveying for presence/absence of ammocoetes in the irrigation ditches of sub-basins with lamprey populations.

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