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The Ecological and Cultural Importance of a Species at Risk of Extinction, Pacific Lamprey

ABSTRACT

The cultural and ecological values of Pacific lamprey (*Lampetra tridentata*) have not been understood by Euro-Americans and thus their great decline has almost gone unnoticed except by Native Americans, who elevated the issue and initiated research to restore its populations, at least in the Columbia Basin. They regard Pacific lamprey as a highly valued resource and as a result *ksuyas* (lamprey) has become one of their cultural icons. *Ksuyas* are harvested to this day as a subsistence food by various tribes along the Pacific coast and are highly regarded for their cultural value. Interestingly, our review suggests that the Pacific lamprey plays an important role in the food web, may have acted as a buffer for salmon from predators, and may have been an important source of marine nutrients to oligotrophic watersheds. This is very different from the Euro-American perception that lampreys are pests. We suggest that cultural biases affected management policies.

Introduction

Lampreys have experienced declines in abundance throughout the world due to human disturbances (Renaud 1997). Causes of these declines include flow regulation (Wallace and Ball 1978; Beemish and Northcote 1989), channelization (Kirchhofer 1995), poor water quality (Myllynen et al. 1997), and chemical treatments (Schuldt and Goold 1980). Flow regulation, which is common throughout most of the United States, impacts adults by impeding passage at dams, while larvae are affected by the dewatering of rearing habitat. River channelization negatively impacts larval lamprey habitat by increasing velocity, thereby reducing depositional areas. Furthermore, larvae are more susceptible to toxicological effects from contaminants due to their sedentary life in the benthos, as demonstrated by chemical treatments in the streams to control nonnative sea lamprey (*Petromyzon marinus*) in the Great Lakes, resulting in declines in native lamprey populations.

Conservation of native lampreys has not been a fisheries management priority in the United States. Even though these primitive fish share many of the same habitats as salmonids, lampreys have received little attention. Most of the interest in lampreys has been focused on controlling exotic sea lamprey populations in the Great Lakes in the United States. It is likely that human disturbances have impacted Pacific lamprey (*Lampetra tridentata*) along the Pacific coast. For example, Pacific lamprey counts at Winchester Dam located in the coastal Umpqua River, decreased exponentially in numbers from a maximum of 46,785 in 1966 to 34 fish in 2001 (Oregon Department of Fish and Wildlife, unpublished data). Counts at Ice Harbor Dam in the Snake River, a tributary of the Columbia River, decreased from a maximum of 49,454 in 1963 to 203 lamprey in 2001 (U.S. Army

Corps of Engineers, unpublished data). The state of Oregon listed Pacific lamprey as a sensitive species in 1993 and followed with protected status in 1996 (Kostow 2002). Because Pacific lamprey has significantly declined along the Oregon coast and in the Columbia River Basin (Close 2001) in sympatry with salmonids, lamprey decline is very likely correlated with habitat disturbance.

From a tribal perspective, the decline of lamprey has had at least three negative effects: (1) loss of culture, (2) loss of fishing opportunities in traditional fishing areas, and (3) tribal members must travel to a lower Columbia River tributaries to harvest lamprey. For example, many young tribal members do not know how to catch and prepare lamprey for drying. In addition, young tribal members are losing important myths and legends associated with lamprey. These are symptoms caused by the decline of Pacific lamprey in the interior Columbia River tributaries traditionally fished by the basin tribes. Furthermore, interior Columbia Basin tribal members must travel long distances away from traditional fishing areas to harvest Pacific lamprey in Oregon's Willamette River.

Attention to the ecological and cultural importance of Pacific lamprey has been negligible in the

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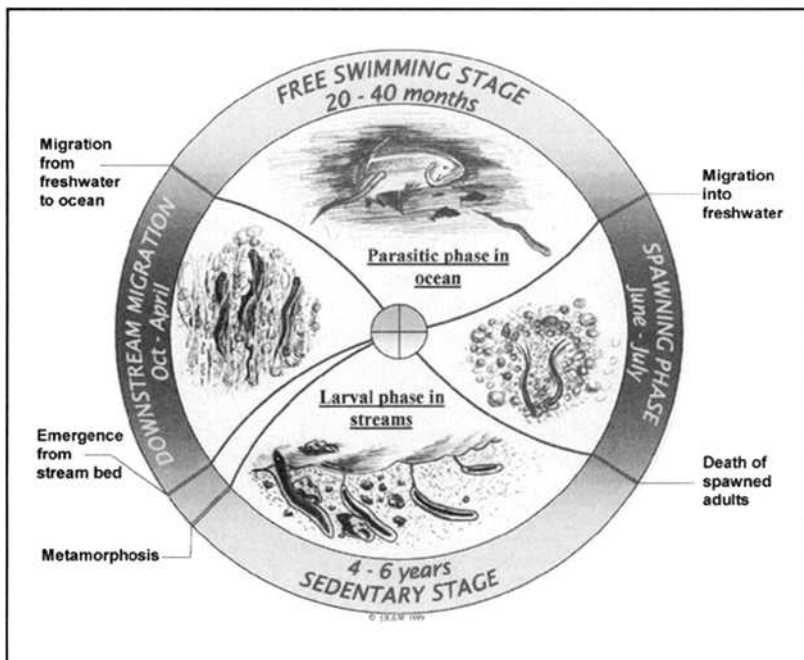
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United States due to the negative perception that most people have toward lampreys. Many people still believe that all lampreys are pests as they associate their ecology with the sea lamprey problem in the Laurentian Great Lakes. However, we argue that Pacific lamprey are an important part of the ecosystem and have cultural value to the peoples of the Pacific Northwest.

Life History

Pacific lamprey is distributed in North America from the Aleutian Islands south along the Pacific coast to Baja California, Mexico, and inland to the upper reaches of most rivers draining into the Pacific Ocean (Ruiz-Campos and Gonzalez-Guzman 1996). The present state of knowledge suggests that the life history of Pacific lamprey is very similar to sea lamprey. They spend the early part of their life burrowed in fine silt or sand filtering detritus and other particulate matter. After an extended time (4 to 6 years), larvae go through metamorphosis which includes major morphological and physiological changes. The juveniles then move to the ocean to feed before returning as adults for reproduction (Figure 1).

Figure 1. Life cycle of the Pacific lamprey (credit: Jeremy Red Star Wolf).



Ecological Importance

Larval stage

Pacific lamprey exhibits a protracted freshwater juvenile residence in the stream benthos. Larvae, often referred to as ammocoetes, leave the nest approximately two or three weeks after hatching, drift downstream (usually at night), and settle in slow

depositional areas such as pools and eddies (Pletcher 1963). The larvae then burrow into the soft sediments in the shallow areas along the stream banks (Richards 1980). The larval stage has been estimated to range from 4–6 years (Pletcher 1963; Kan 1975; Richards 1980) although it may extend up to 7 years (Hammond 1979; Beamish and Northcote 1989).

Larval Pacific lampreys can represent a large portion of the biomass in streams where they are abundant, thus making them an important component along with aquatic insects in processing nutrients, nutrient storage, and nutrient cycling (Kan 1975). Larval lampreys process nutrients by filter feeding on detritus, diatoms, and algae suspended above and within the substrate (Hammond 1979; Moore and Mallatt 1980). Larvae also possess high entrapment efficiency for food coupled with low food assimilation rates. For example, based on studies of other lamprey species (*L. planeri*), larval Pacific lamprey may digest only 30-40% of the food taken in while passing large amounts of undigested food (Moore and Mallatt 1980). Larvae facilitate the conversion of the nutrients derived from detritus and algae into stored biomass, while the undigested material is processed into fine particulate matter. The reduced matter is then exported from the system or taken up by other organisms such as filter feeding insects (Merritt et al. 1984).

Larval Pacific lamprey constitutes a food source for other animals. There are two periods when larvae are subjected to predation: during emergence from nests and during scouring events that dislodge the larvae from their burrows. Pfeiffer and Pletcher (1964) found coho salmon (*Oncorhynchus kisutch*) fry ate emergent larval lampreys. In addition, larvae are commonly used for bait to catch the exotic smallmouth bass (*Micropterus dolomieu*) in the lower reaches of the John Day River, Oregon (J. Bronson, Confederated Tribes of the Umatilla Indian Reservation, Tribal Fisheries Program, pers. comm.).

Downstream migrants

During metamorphosis, the larvae go through morphological and physiological changes to prepare for a parasitic lifestyle in salt water. Transformation of Pacific lamprey from the larval to young adult life stage generally occurs during July through November (Pletcher 1963; Hammond 1979; Richards and Beamish 1981).

Young adult lampreys begin their migration to the Pacific Ocean in the fall and continue through the spring. Time of entrance into salt water may differ among populations of Pacific lamprey due to environmental conditions (R.J. Beamish, Pacific Biological Station, Nanaimo, BC, pers. comm.). Kan (1975) suggested that coastal populations enter salt water in the late fall while inland populations enter in the spring. In the Nicola River of British Columbia, 99% of all metamorphosed lampreys migrated by April and May (Beamish and Levings 1991).

Young adult lampreys migrating downstream may have buffered salmonid juveniles from predation by fishes and birds. Pacific lamprey is found in the diets of northern pikeminnow (*Ptychocheilus oregonensis*) and channel catfish (*Ictalurus punctatus*) in the mainstem Snake River (Poe et al. 1991). Further, Merrell (1959) found that lampreys comprised 71% by volume of the diets in California gulls (*Larus californicus*), ringbill gulls (*Larus delawarensis*), western gulls (*Larus occidentalis*), and Fosters tern (*Sterna forsteri*) in the mainstem Columbia River during early May. This is interesting, in light of the controversy concerning waterbird predation on salmon smolts in the Columbia River estuary (Collis et al. 2001). Historically large numbers of outmigrating lampreys may have reduced predation rates on salmon smolts by avian and aquatic predators in the Columbia Basin.

Ocean life

The ocean life history stage of Pacific lamprey is not well understood, but the duration of ocean residency may vary. The parasitic-phase has been estimated to last for periods of up to 3.5 years for Pacific lamprey in the Strait of Georgia, British Columbia (Beamish 1980). Off the coast of Oregon, the duration of the ocean phase was estimated to range from 20 to 40 months (Kan 1975). Parasitic-phase Pacific lampreys have been collected at distances ranging from 10 to 100 km off the Pacific coast and at depths ranging from 100 to 800 m (Kan 1975; Beamish 1980).

The Pacific lamprey preys on a variety of fish species and marine mammals in the Pacific Ocean. Beamish (1980) reported five salmonid and nine other fish species that are known prey of Pacific lamprey (Table 1). In addition, Pacific lamprey has been reported to feed on finback (*Balaenoptera physalus*), humpback (*Megaptera nodosa*), sei (*Balaenoptera borealis*), and sperm (*Physeter catodon*) whales (Pike 1951).

Anadromous Pacific lamprey should not be viewed as a pest species like sea lamprey of the Laurentian Great Lakes (e.g., Eschmeyer 1955; Moffett 1956; Coble et al. 1990). In the Great Lakes, an entire community of naive prey was exposed to an exotic predator. Most lampreys around the world live in equilibrium with their hosts (Renaud 1997). Pacific lamprey has co-adapted with its prey, which includes Pacific salmon. Beamish (1980) could find no evidence that increased lamprey production in the Skeena River would lead to predation problems on its sockeye salmon. Although Pacific lamprey will prey on salmonids, lampreys also feed on a variety of midwater species such as Pacific hake (*Merluccius productus*) and walleye pollock (*Theragra chalcogramma*) in the open ocean (Beamish 1980). The effect of intense commercial harvests of Pacific hake, walleye pollock, and groundfishes on the food chain dynamics of the north Pacific Ocean ecosystem and on Pacific lamprey is not well understood, but likely substantial.

Adult lampreys may have been an important buffer for upstream migrating adult salmon from predation by marine mammals. From the perspective of a predatory sea mammal, lampreys have at least three virtues: they are easier to capture than adult salmon, they have higher caloric value per unit weight than salmonids, and their migration in schools means fertile feeding patches. Pacific lamprey is extraordinarily rich in fats, much richer than salmon. Caloric values for lamprey range from 5.92 to 6.34 kcal/g wet weight (Whyte et al. 1993), whereas salmon average 1.26 to 2.87 kcal/g wet weight (Stewart et al. 1983). In fact, the work of Roffe and Mate (1984) revealed that the most abundant dietary item in seals and sea lions was Pacific lamprey. As a result, marine mammal predation on salmonids may now be much more severe because lamprey populations have declined.

Spawning migration

Beamish (1980) suggested that returning adult lampreys enter freshwater between April and June and complete migration into streams by September. Pacific lamprey overwinters in freshwater and spawns the following spring (Beamish 1980). Pacific lampreys do not feed during the spawning migration—they utilize stored carbohydrates, lipids, and proteins for energy (Read 1968). Beamish (1980) observed a 20% shrinkage in body size from the time of freshwater entry to spawning. Pacific lamprey along the coast of Oregon usually begin to spawn in May when water temperatures reach 10°C to 15°C and continue to spawn through July. In the Babine River system in British Columbia, Pacific lampreys were observed spawning from June through the end of July (Farlinger and Beamish 1984).

Returning adult Pacific lampreys are an important part of the food web for many species of freshwater fishes, birds, and mammals. Spawning out carcasses of lampreys are important dietary items for white sturgeon (*Acipenser transmontanus*) in the Columbia and Fraser Rivers (Semakula and Larkin 1968; Galbreath 1979). Wolf and Jones (1989) reported the great blue heron (*Ardea herodias*) as a predator of spawning adult Pacific lamprey. In addition, mink (*Mustela vison*) are also noted by Beamish (1980) as a predator of adult lampreys.

Pacific lamprey has very high fecundity compared to North American Pacific salmon species. Fecundity for Pacific lamprey in Oregon streams ranged from

Table 1. Prey of adult Pacific lamprey (Table based from Beamish 1980).

Name
sockeye salmon (<i>Oncorhynchus nerka</i>)
coho salmon (<i>O. kisutch</i>)
pink salmon (<i>O. gorbuscha</i>)
chinook salmon (<i>O. tshawytscha</i>)
steelhead trout (<i>O. mykiss</i>)
rockfish (<i>Sebastes aleutianus</i> and <i>S. reedi</i>)
Pacific cod (<i>Gadus macrocephalus</i>)
lingcod (<i>Ophiodon elongatus</i>)
sablefish (<i>Anoplopoma fimbria</i>)
Pacific halibut (<i>Hippoglossus stenolepis</i>)
Greenland turbot (<i>Reinhardtius hippoglossoides</i>)
arrowtooth flounder (<i>Atheresthes stomias</i>)
Kamchatka flounder (<i>A. evermanni</i>)
Pacific ocean perch (<i>Sebastes alutus</i>)

98,000 to 238,400 eggs per female (Kan 1975), while fecundities for five North American Pacific salmon species ranged from 1,200 to 17,000 eggs per female (Burgner 1991; Heard 1991; Salo 1991; Healey 1991; Sandercock 1991). Relative fecundity in Pacific lamprey was significantly lower in an interior Columbia River tributary compared to Oregon coastal streams. Relative fecundity was 522.15 and 503.44 eggs/g body wt. in lamprey from the Umpqua and Molalla Rivers, and 417.94 eggs/g body wt. in the John Day River (Kan 1975). Kan (1975) suggested that the lower relative fecundity in the John Day lampreys was due to a higher cost of migration.

Pacific lamprey spawning success and production of larvae are not well understood. However, sea lampreys in the Great Lakes were estimated to only deposit 14% of their eggs in nests. The survival of sea lamprey eggs deposited in the nests was estimated to be up to 90% (Manion and Hanson 1980). During Pacific lamprey spawning, eggs have been observed to overflow the nests and were actively eaten by rainbow trout (*O. mykiss*) and speckled dace (*Rhinichthys osculus*) in the Umatilla River, Oregon (J. Bronson, Confederated Tribes of the Umatilla Indian Reservation, Tribal Fisheries Program, pers. comm.). After spawning, Pacific lamprey die within 3 to 36 days (Mattson 1949; Pletcher 1963; Kan 1975). Adult carcasses are likely a major contributor of nutrients in oligotrophic streams (Wilpfli et al. 1998; Fisher Wold and Hershey 1999).

Cultural Significance

Native Americans

Pacific lamprey is one of the many religious foods of the indigenous peoples in the mid-Columbia River Plateau. In the traditional mid-Columbia Plateau tribal worldview, animals, plants, water, rocks, etc. are believed to have a *shukwat* (spirit) and a conscience. This worldview promotes respect for all things in nature and is interwoven into the Sahaptin culture by myths and legends. These typically reinforce the *tamanwit* (sacred law) of how humans are supposed to live with our brothers and sisters of the natural world. When individuals abuse *tamanwit*, it is believed that the *shukwat* of that being will go against that individual, making life difficult. Therefore it is in the best interest of the individual to respect nature. In addition, the *shukwat* can be very helpful to an individual. The belief is that an individual can attain a *shukwat* of some being to increase one's power. This type of *shukwat* is considered a spirit helper, which an individual can call upon for strength in times of need. There are many songs that are specific for different animals, plants, or other beings to help that person pay respect to the beings before and sometimes after their harvest. In addition, the beings are believed to give themselves up to the humans for subsistence or use in daily life. However, mid-Columbia Plateau tribal culture places humans at the same level with the other beings.

Pacific lamprey also has medicinal value to tribal peoples in the mid-Columbia Plateau. Oil collected from drying lamprey is applied to skin or ailing parts of the body in conjunction with a purifying sweat bath. It was used historically to condition hair and to cure ear aches. Lamprey oil is also important in the diets of tribal peoples in the mid-Columbia Plateau. Lampreys continue to be an integral part of tribal culture in the Pacific Northwest.

Pacific lamprey is one of the many subsistence foods of indigenous peoples in the mid-Columbia Plateau. Lampreys are called *ksuyas* or *asum* in the native tongue (Sahaptin) of the mid-Columbia Plateau tribes. However, many people use the common name "eel" when referencing Pacific lamprey. Lamprey is often harvested by hand, dip net, or jigging with a long pole and hook (Figure 2). Fishing for lamprey is usually done at night when the fish are most active. Generally fishing sites are located at falls or fast water areas that cause the lamprey to congregate prior to spawning. Before the dams turned the Columbia River into a series of lakes, many tribal peoples fished falls and rapids for lamprey. The fish were then prepared traditionally by drying or roasting (Figure 3). Lamprey continue to be part of the Columbia River tribal culture and are as important in ceremonies and celebrations as many other foods collected during seasonal harvests (Figure 4).

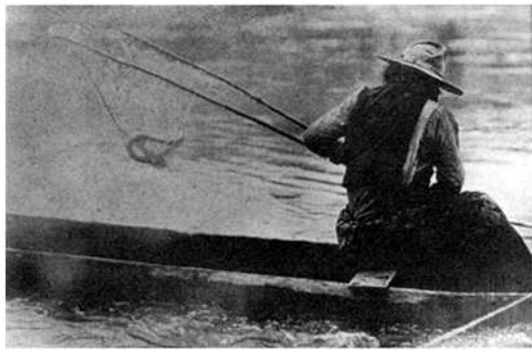
Euro-Americans

The early fur trappers in the Pacific Northwest of the United States used Pacific lamprey as food. In 1812, Robert Stuart led members of the Astor party on a voyage up the Columbia River. In July of 1812, Stuart and his party traded with the Umatilla Tribe for lamprey. In Robert Stuart's narratives, he wrote, "Saturday 25th This day we found intolerably hot, and after coming 15 miles stopped at an Indian Village where traded 4 horses having in the course of our [today's] journey procured 5 others- Here we got some Lamper Eels, which with a Kind of Chub seem peculiar to these waters above the Falls- Stayed here the 26th" (Stuart 1812). In the early 1900s, fur trappers utilized Pacific lamprey as bait to catch coyotes (*Canis latrans*) in the Pacific Northwest (Mattson 1949).

Adult Pacific lamprey was important in the development of fish culture in the Pacific Northwest. In the late 1800s, fish culturists in Oregon began developing artificial propagation of salmonids. Fish culturists soon discovered a need to hold fish longer and to increase growth while doing so. The need to find a large and cheap food supply to accomplish the task led fish culturists to experiment with different foodstuffs, including ground raw Pacific lamprey, which was found to be a premium feed for young salmon. Adult lampreys were collected at Willamette Falls, Oregon, and then transferred to cold storage to be processed (Figure 5). During the year 1913, 24.5 metric tons were harvested for this purpose (Clanton 1913). In

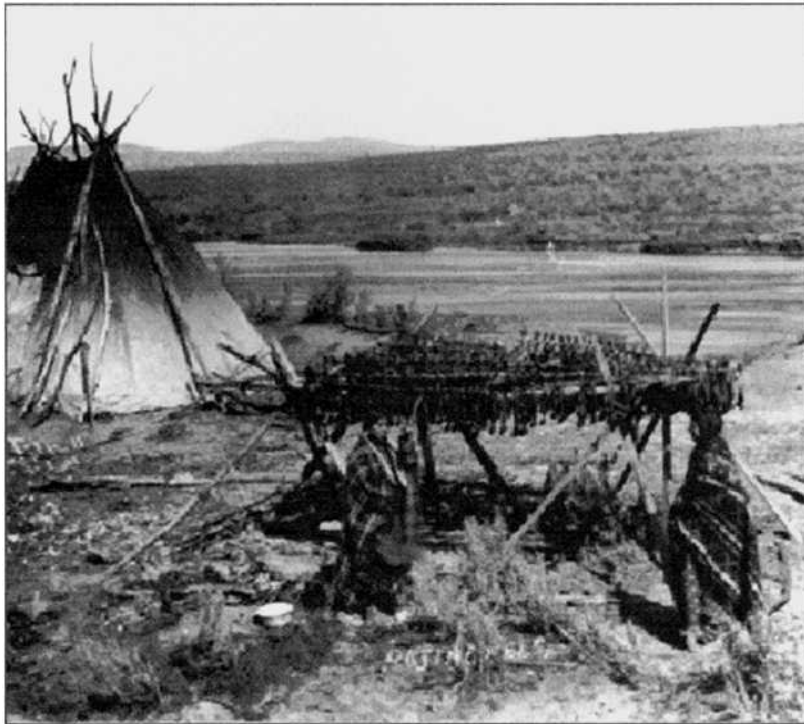
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Figure 2.
Nez Perce tribal member James Williams from Lapwai, Idaho, dip netting Pacific lamprey in the Clearwater River, circa 1920.



NATIONAL PARK SERVICE, NEZ PERCE NATIONAL HISTORICAL PARK

Figure 3.
Umatilla tribal members drying Pacific lamprey near the Umatilla River, Oregon, 1903.



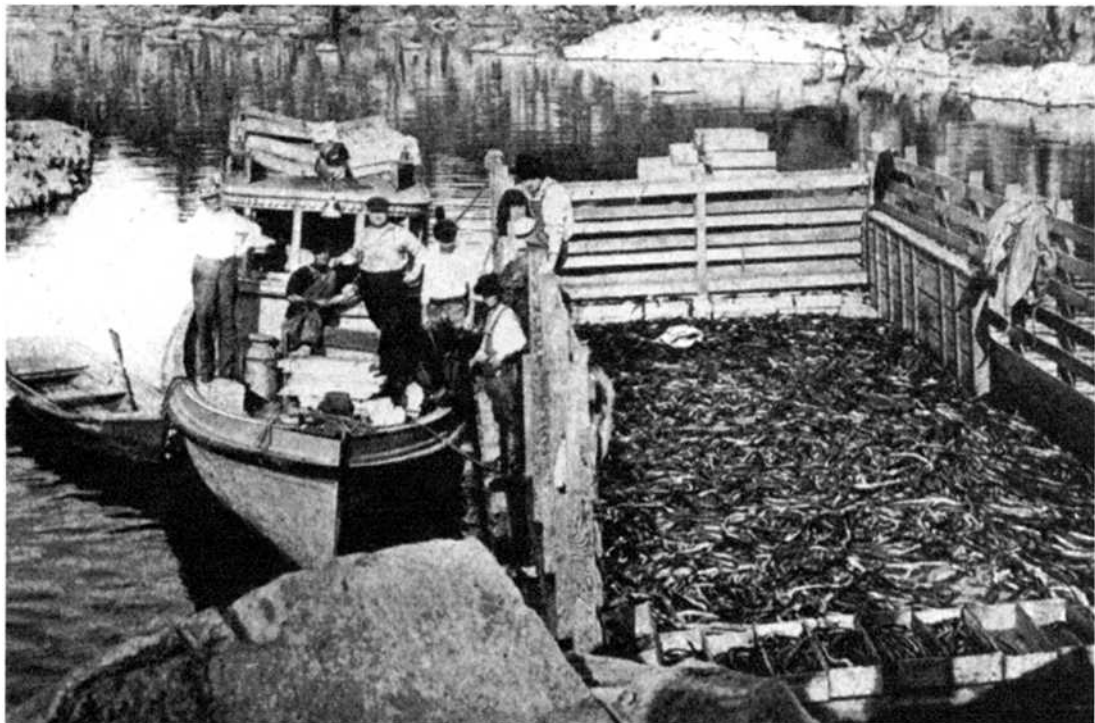
UNIVERSITY OF OREGON, MAJOR LEE MOORHOUSE COLLECTION

Figure 4.
Umatilla tribal member Inez Reeves preparing Pacific lamprey for drying, 1999.



DAVID A. CLOSE, CONFEDERATED TRIBES OF THE UMATILLA INDIAN RESERVATION, TRIBAL FISHERIES PROGRAM

Figure 5.
Pacific lamprey (13.6 metric tons) aboard a scow for delivery to a cold storage plant to be preserved as food for hatchery salmon fry, 1913.




OREGON DEPARTMENT OF FISH AND WILDLIFE

the following years, lampreys became commercially important. A commercial fishery for Pacific lamprey at Willamette Falls started in 1941. Between 1943 and 1949 a total of 740,419 kilograms of lamprey were harvested. The primary use of the fish was for vitamin oil, protein food for livestock, poultry, and fishmeal (Mattson 1949). Presently, Pacific lampreys are important for scientific research (medicinal anticoagulants), for teaching specimens (North Carolina Biological Supply House regularly collects at Willamette Falls), and for food (in 1994, approximately 1,816 kg were exported to Europe).

Conclusion

Pacific lamprey is an important component to the ecosystem both as a predator and prey. As a predator, Pacific lamprey has coevolved with native fish assemblages in the Pacific Ocean and freshwater ecosystems. Pacific lamprey preys upon a variety of fishes and mammals in the Pacific Ocean. As prey, lamprey is important to many species of fish, birds, and mammals (including humans). Like other anadromous fish species, they transport nutrients from the ocean to the freshwater environment. The decline of lamprey abundance has probably had a myriad of effects on the trophic relationships within the freshwater and Pacific Ocean ecosystems.

The cultural values of Pacific lamprey are recognized through a short history of utilization by early Euro-Americans and a long history of use by Native Americans in the Columbia River Basin that continues to this day. However, because Euro-American society places little value on Pacific lamprey, ecologically or culturally, this species was largely ignored by federal, state, and land-use management agencies. The federal government has trust obligations with regards to treaty tribes fishing rights, which have not been met with regards to many fish species including Pacific lamprey.

Conservation of this species is crucial to the integrity of the Pacific coast and Pacific Ocean ecosystems. The first step is the recognition that the Pacific lamprey is important and there is a need for conservation. Gaining a greater understanding about the problems that the Pacific lamprey is experiencing and its biology is the second step that should follow. Ultimately, there is a need to change the management emphasis towards the conservation of Pacific lamprey. 

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