PACIFIC LAMPREY RESEARCH AND RESTORATION

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MASTER TABLE OF CONTENTS

INTRODUCTION

The once abundant stocks of Pacific lamprey (*Lampetra tridentata*) above Bonneville Dam are currently depressed (Close et al. 1995). It is likely that many of the same factors that led to the decline of wild stocks of Columbia River Pacific salmon and steelhead have impacted Pacific lamprey populations. The Pacific lamprey is an important part of the food web of North Pacific ecosystems, both as predator and prey. Lamprey (a.k.a. eels) are also a valuable food and culture resource for American Indian Tribes of the Pacific Northwest. Depressed Pacific lamprey runs have impacted treaty secured fishing opportunities by forcing tribal members to gather this traditional food in lower Columbia River locations.

The Pacific Lamprey Research and Restoration Project, funded by Bonneville Power Administration, is a cooperative effort between the Confederated Tribes of The Umatilla Indian Reservation, the Columbia River Intertribal Fish Commission, and Oregon State University with the goal to increase Pacific lamprey stocks above Bonneville Dam. The initial objectives of the project are to determine the past and current abundance of Pacific lamprey stocks in major mid Columbia tributaries and at various hydroelectric facilities, and to determine factors limiting Pacific lamprey abundance and distribution. Ultimately, Pacific lamprey restoration plans will be developed and implemented.

Part (A)-CTUIR
1) determine past and present abundance and distribution in NE Oregon and SE Washington tributaries.
2) determine limiting habitat factors.

Part (B)-CRITFC
1) adult abundance monitoring at Columbia and Snake River dams.
2) juvenile abundance monitoring at Columbia and Snake River dams.
3) juvenile passage impediments and needed improvements at Columbia and Snake River dams.

Part (C)- OSU
1) adult passage impediments and needed improvements at Columbia and Snake River dams.
2) juvenile passage impediments and needed improvements at Columbia and Snake River dams.

Pacific Lamprey Research and Restoration

Part (A)

Historic and Current Pacific Lamprey (*Lampetra tridentata*) Abundance and Possible Reasons for Population Decline, Based on Oral Interviews and Review of Records and Literature, in CTUIR Ceded Areas of Northeast Oregon and Southeast Washington Subbasins of the Columbia River.

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ABSTRACT

Based on oral interviews with tribal informants, current and former state and federal fisheries personnel, and review of records and literature it is apparent that Pacific lamprey were once abundant in ceded area streams of the Umatilla Indian Reservation (John Day, Umatilla, Walla Walla, Tucannon, and Grande Ronde subbasins). Current population levels appear severely depressed in all subbasins except possibly the John Day, which could be classified as depressed. The most probable reasons for population declines include: dams, chemical treatment activities, declining habitat quality (e.g. high water temperatures, poor water quality, low instream flows), and angle-iron in fishways.

TABLE OF CONTENTS- PART (A)

INTRODUCTION

"The Pacific lamprey maintains a place of cultural significance in the Columbia and Snake River Basins. Tribal people of the Pacific Coast and interior Columbia Basin have harvested these fish for subsistence, ceremonial, and medicinal purposes for many generations" (Close et al.1995).

Because of the severely depressed status of Pacific lamprey populations in ceded area streams above Bonneville Dam, tribal elders had discussed the restoration of "eels" in various ceded area streams with Umatilla Tribal Fisheries Staff for at least the last eight years. This project was a direct result of their diligent efforts.

Before reintroduction or rehabilitation was feasible, it was critical to determine the current status of indigenous Pacific lamprey populations in the John Day, Umatilla, Walla Walla, Tucannon, and Grande Ronde subbasins. Another important consideration was to understand the reasons for the decline in lamprey populations. The following information was the first years results of gathering past and current population data. Subsequent study years will build upon this effort and eventually lamprey restoration plans and recommendations will be made for each subbasin.

METHODS

Phone and/or personal interviews were conducted with tribal informants and past and current employees of various state and federal agencies who work or have worked in the subject subbasins. Past and current records and literature were reviewed to document past and current Pacific lamprey abundance and possible reasons for population decline in each subbasin.

In this report the word "eel" and "lamprey" is used interchangeably with the same meaning.

JOHN DAY SUBBASIN

Historic Abundance:

The John Day Subbasin has historically produced many species of salmonids including: spring and fall races of chinook salmon (*Oncorhynchus tshawytscha*), summer steelhead (*Oncorhynchus mykiss*), red-band rainbow (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), western-slope cutthroat (*Oncorhynchus clarki lewisi*), and mountain whitefish (*Prosopium williamsoni*), and two species of lamprey: western brook lamprey (*Lampetra richardsoni*), and Pacific lamprey (*Lampetra tridentata*).

Historic estimates of Pacific lamprey abundance are unavailable but according to Claire (ODFW, personal communication) they were once very numerous. This subbasin was historically utilized for fishing purposes by the Umatilla, Columbia River, Pauite, Shoshone-Bannock, and Warm Springs Indian Tribes (A. Minthorn, CTUIR, personal communication). The subbasin was also utilized by the Rock Creek Indian Tribe (Swindell Report 1941). Although Celilo Falls was the major fishing site for Columbia Basin Tribes, the John Day River and tributaries supported a fishery at one time (Swindell Report 1941). The John Day River primarily was utilized for salmon and trout fishing but harvest of Pacific lamprey did occur within the subbasin (A. Minthorn, CTUIR). The Middle and North Forks were the most popular areas chosen for harvesting. Lane and Lane (1979) noted one area in the John Day River utilized by the Umatilla and Columbia River Tribes was known as "*tuck-pus*", near Albert Phillipi Park. Salmon, eels, and whitefish were harvested near this area. Camas Creek and the North Fork John Day were also noted as areas that eels were once harvested. Percy Brigham, CTUIR elder and fisherman, stated that he harvested eels at the mouth of the John Day River, and at an area he called "little falls' on the John Day River.

Current Abundance:

The John Day Subbasin currently supports a remnant run of anadromous Pacific lamprey and non-anadromous western brook lamprey (E. Claire, ODFW, pers. comm.). Although adult population levels are unknown, screen trap operators have observed a few Pacific lamprey in screen trap boxes. The most recent sighting of adult Pacific lamprey on the spawning grounds was in the spring of 1992. Two live adults, two dead adults, and two redds were observed on the lower John Day River (RM 80), and a spawning pair of Pacific lamprey were also observed on a redd on the Middle Fork John Day River near river mile 65 (E. Claire, ODFW, pers. comm). After a hydrochloric acid spill in 1990, it was estimated that 9500 Pacific lamprey (mostly ammocoetes) died in the North Fork John Day River.

The John Day Subbasin produces the largest remaining run of wild spring chinook salmon in the Columbia River Basin. Up to 4,000 wild spring chinook adults annually return to this system. Fifteen thousand to 40,000 adult wild steelhead also return to this subbasin yearly (E. Claire, ODFW, pers. comm.). Fall chinook salmon are extinct.

Currently, the John Day River supports a token tribal spring chinook salmon fishery each year. Over the last five years in the North Fork John Day drainage, an average of 25 spring chinook salmon were annually harvested by tribal members. Tribal harvest of Pacific lamprey currently does not occur in this subbasin.

Man Caused Habitat Alterations:

Adult Pacific lamprey prefer low gradient stream sections, where gravel is deposited, for spawning (Kan 1975). Spawning Pacific lamprey were often observed while conducting steelhead spawning ground surveys and often spawn in similar habitat (Claire, Witty, ODFW, pers. comm). The ammocoetes are usually found in cold water (Mallatt 1983). It appears that the habitat requirements for Pacific lamprey during most freshwater life history stages are somewhat similar to those preferred by salmonids. Thus, degradation of freshwater habitat that has affected salmonid abundance and distribution has probably affected Pacific lamprey abundance and distribution. Historical descriptions of the John Day Subbasin indicate that the John Day River was once a relatively stable river with good summer stream flows, good water quality, and heavy riparian cover. The North Fork tributaries were well wooded with aspen, poplar, and willow; had good streamflows, and good channel structure. These conditions are common in undisturbed river systems, which have a tendency to meander and form a sequence of pools and riffles (ODFW et al. 1990).

In the late 1800’s mining became a major factor in the John Day system. Placer mining channelized streams, left little shade, created high silt loads, and diverted flows. In the 1930’s and 40’s, dredge mining overturned the stream channels in the larger streams. This activity often changed stream courses, silted gravel, and destroyed riparian areas (ODFW et al. 1990).

Extensive timber harvest followed the discovery of gold in the John Day Subbasin. Roads were built on steep slopes, along streambanks, and across watersheds where timber was removed to supply growing communities (OWRD 1986).

Farming and ranching practices starting in the 1860’s and 1870’s led to loss of native riparian grasses in summer range areas in the upper watershed of the John Day Subbasin. Livestock foraged primarily on perennial grasses and shrub cover. During this time many rangelands, under grazing pressure, converted from grass-forb-browse ecosystems to weed-forb ecosystems. As grass rangelands declined in the subbasin, and wildfire suppression increased, the invasion of juniper and sage increased (ODFW et al. 1990).

Today, livestock overgrazing, water withdrawals for irrigation, landowner clearing, road building, timber harvest, and stream channelization has created further fish habitat problems by disturbing or destroying riparian vegetation and destabilizing streambanks and watersheds.

Riparian habitat degradation is the most serious habitat problem in the John Day River Subbasin with approximately 660 degraded stream miles identified (ODFW et al. 1990). Degradation has resulted in low summer flows, high summer and low winter water temperatures, high spring flows, depressed beaver populations, accelerated bank erosion, excessive sedimentation, and reduced cover (ODFW et al. 1990). The Oregon Water Resource Department (1986) states that “activities in the last 125 years may have had a significant impact on the basin’s capacity to retain water and release it later in the season. Analysis of historical flow data suggests that more precipitation falling in the subbasin during winter now runs off immediately instead of staying in the subbasin. The use of the watershed's resources to satisfy consumer demand for forest products, grains, minerals, and other commodities probably has increased winter runoff and decreased spring runoff."

Warm water temperatures limit the downstream distribution of fingerling chinook salmon in the Middle and North Forks during the summer (ODFW 1986). Claire stated that marginal habitat suitable for rearing rainbow/steelhead during the summer months was as follows: the entire Middle Fork, North Fork from Baldy Creek to the mouth of the Middle Fork, South Fork from South Fork Falls to the mouth, and in the mainstem John Day River from the headwaters to Kimberly. Areas above the marginal areas are most utilized by salmonids because of the cooler water temperatures during the critical summer months. Juvenile rainbow/steelhead range further downstream in the John Day system than juvenile chinook salmon, because they have adapted to slightly higher water temperatures. The habitat available for steelhead and spring chinook salmon may also be utilized by Pacific lamprey since they prefer similar habitat and water quality as salmonids.

Claire stated that passage barriers within the John Day Subbasin have not been and are currently not significant enough to impede Pacific lamprey.

Many chemical treatments designed to eradicate rough fish have occurred in various areas of the John Day Subbasin. From 1962 to 1982, chemical treatment projects took place in the Middle Fork John Day River as follows: the lower 68km were treated in 1966; the lower 5km were treated in 1973, the reach from Phipps Meadow to Vincent Creek was treated and the lower 104km were treated with squoxin in 1974; and, the reach from Phipps Meadow to the mouth was treated with rotenone in 1982 (ODFW 1986). Claire stated that most ammocoetes that were observed by ODFW were following chemical treatment projects. When fish kill assessments were conducted, Pacific lamprey were not enumerated separately, instead they were included in the "other" and "rough fish" columns and lumped into one numerical number with other non-salmonids. Therefore, numbers that were eradicated through chemical treatment projects are not known.

In February 1990, a hydrochloric acid chemical spill occurred in the North Fork John Day River below the Camas Creek Bridge near the town of Dale. Approximately 3,500 gallons of acid spilled into the river and killed an estimated 4,000 juvenile salmon and steelhead, 300 bull trout and 9,500 Pacific lamprey. Claire stated that most lamprey killed by the hydrochloric acid were ammocoetes and the loss of Pacific lamprey was important because it may have been a significant portion of the total outmigrant population for that year.

Discussion:

Most information gathered on Pacific lamprey in the John Day Subbasin is anecdotal. Past and current estimates of population abundance are unavailable. Data collected by ODFW from 1955 to present is being summarized by E. Claire and will be completed in the summer of 1997 for inclusion in the 1997 annual report. ODFW screen trap technicians and area biologists state that lamprey were once very numerous in this subbasin. According to E. Claire various agencies attempting to halt the decline of Pacific salmon and steelhead did not have time to concern themselves with the decline of Pacific lamprey. Claire stated that Pacific lamprey were very numerous in the John Day Subbasin prior to the completion of the John Day Dam in 1968. Claire also stated that lamprey populations have drastically declined possibly due to inbasin habitat degradation and passage problems in the mainstem Columbia River.

In researching weekly screen trap reports for this subbasin, it was found that most lamprey enumerated were not keyed to species. Therefore, it is not known if the lamprey observed were Pacific lamprey. Claire stated that he felt most lamprey observed by screen trap technicians were Pacific lamprey ammocoetes. Gray and Unterwegner (pers. comm. 1996) stated that lamprey that were identified by screen trap operators were keyed to species by the development of the eye, a fully developed eye was considered a western brook lamprey.

Although John Day Basin lamprey populations are probably a fraction of past abundance, the remaining population (like wild salmon and steelhead) is thought to be the most abundant today relative to other subbasins in this report. We will attempt to further document the current abundance of Pacific lamprey and investigate the feasibility of John Day Pacific lamprey as a candidate for a donor stock in subsequent years of this study.

Recommendations:

1) Request that ODFW enumerate lamprey at all trap boxes, key to species (when possible) at all trapping sites, and document capture locations and life history stage (ammocoetes vs. macrophathalmia) of lamprey observed.

2) Conduct random spot checks within the subbasin to determine presence/absence.

3) Request that ODFW continue to document adult Pacific lamprey observed during stream surveys.

4) Collect Pacific lamprey ammocoetes for scientific analysis.

UMATILLA SUBBASIN

Historic Abundance:

In 1812, Wilson Price Hunt lead members of the Astor party down the Umatilla River on a voyage to the Columbia River. Wilson stated that the Indians called the river "Eo-u-tal-la (Umatilla), and it was abounded with beaver". Historically, Pacific lamprey were abundant in this subbasin (H. Campbell, ODFW, pers. comm., N. Bean, ODFW, pers. comm., D. Heckeroth, ODFW, pers. comm., E. Quaempts, CTUIR, pers. comm.). Prior to the 1900's, wild summer steelhead, chinook, coho and chum salmon were also present in the Umatilla River. Other wild salmonids historically present were as follows: bull trout, red-band trout, and mountain whitefish. The Umatilla River was primarily utilized by the Umatilla, Cayuse, Nez Perce and Columbia River Tribes (Swindell Report 1941, Lane 1979). Fishing for salmon, trout, whitefish and eels by tribal members historically occurred throughout the subbasin. Much of the eel harvesting occurred at Three Mile Falls Dam and at this site prior to construction of the dam. Harvest also occurred in the North and South Forks (Swindell, 1941 and Lane and Lane, 1979).

Tina Jackson-Norvell and Donald Jackson, both CTUIR enrollees, remember seeing Pacific lamprey near Cayuse, Oregon in the Umatilla River prior to chemical treatment during the summer months in the late 1960's. Donald Jackson stated that he witnessed both ammocoetes and adult lamprey near this site.

Virgil Bronson, CTUIR enrollee, stated that "after the second treatment in 1974, the south bank of the Umatilla River near Cayuse, Oregon had thousands upon thousands of dead eels about 8" to 10" long".

Alphonse Halfmoon, CTUIR enrollee, stated that he remembers seeing ammocoetes "dying in the mud" during times of rotenone in the Umatilla River, and collected trout that had died from the effects of rotenone.

Elias Quaempts, CTUIR enrollee, also stated that they used to catch lots of eels until the fish poisonings started occurring in this subbasin. Mr. Quaempts used to fish at Three Mile Dam for eels in the 1930's, and said eels were abundant at that time in the Umatilla River.

Armand Minthorn stated that Jasper Shippentower used to collect eels at the mouth of Meacham Creek. Minthorn also stated that Jasper Shippentower witnessed spawning activity at this same site.

Jimmy Clark, CTUIR enrollee, stated that he observed ammocoetes and adults in Buckaroo Creek in the late 1950's and early 1960's. Clark stated that tribal members occasionally collected Pacific lamprey in Buckaroo Creek, and Pacific lamprey utilized the stream for spawning and rearing.

Norman Been, former ODFW screen trap operator stated that "there were so many adult Pacific lamprey in the Umatilla River that they were a nuisance"

Weekly screen trap reports for the Umatilla River Subbasin show that lamprey were not specifically enumerated from 1960 through 1969. From 1970 through 1973 during May and June, 115 lamprey were enumerated near RM 49.5. Lamprey captured in traps were not keyed to specific species or life history stage. Information for 1974 through 1985 was not available for review.

Current Abundance:

Pacific lamprey populations in the Umatilla River Subbasin are at a very low level. Zimmerman (CTUIR, pers comm.) stated that he observed one adult Pacific lamprey at Westland Irrigation Diversion (RM 27) in July of 1996, and also observed 12 adult Pacific lamprey in the ladder at Three Mile Dam during dewatering in April of 1996. Zimmerman further stated that facility operation technicians have observed one or two adult Pacific lamprey several times per year in the viewing window and ladder at Three Mile Dam during spring operations. From December 1994 to May 1996, 68 lamprey (adults and juveniles) were sampled by ODFW (Knapp, personal communication) at rotary screw trap sites below Three Mile Dam, or at the West Extension Irrigation District canal (RM 3.7). Forty percent of the lamprey captured ranged from 130mm to 190mm. Eleven lamprey captured at West Extension Irrigation District canal ranged from 450mm to 610mm. Hoverson (CTUIR, pers. comm) and the CTUIR electroshocking crew observed one live, one dead, and one near dead adult Pacific lamprey below Three Mile Dam in June, 1996.

The Umatilla Basin Natural Production Monitoring and Evaluation Project has operated rotary screw traps in Meacham Creek and in the mainstem Umatilla River, both above and below the Meacham Creek confluence and at Barnhart at various times during the past five years and electroshocking crews have intensively sampled many areas of the mainstem and lateral tributaries. No Pacific lamprey have ever been observed or captured above Three Mile Dam.

In 1986, 1988, 1989, 1990, 1992, 1993, and 1994 records show that no juvenile lamprey were captured at any of the screen trap boxes in this subbasin. It may have been that lamprey were counted as “other fish”, and combined into one numerical number. As lamprey appear in the screen trap boxes, rotary traps, and other sampling operations, ODFW will now start enumerating, and identifying each specimen captured.

Currently, the Umatilla River Subbasin does not support a tribal harvest of Pacific lamprey.

Man Caused Habitat Alterations:

The Umatilla River begins on the west slope of the Blue Mountains and flows northwesterly across the Umatilla Plateau for about 115 miles until its confluence with the Columbia River at River Mile 289. Historically, the Umatilla River headwaters contained several species of trees; lodgepole pine, ponderosa pine, Douglas fir, white fur, grand fir, Engelmann spruce, and larch which provided shading in the headwaters. High elevation lands are dominated by forest with an understory of grass and brush; making watershed conditions generally good. Mid-elevation lands are characterized by strips of timber shading into brush and grass as elevation declines; large areas cleared for farming operations have created vast amounts of sediment (CTUIR et al. 1990).

Livestock grazing, road and railroad building, irrigation practices, timber harvest, and extensive and intensive farming operations have led to the decline of adequate habitat for fish in the Umatilla River Subbasin. Riparian conditions, for the most part, are good in the upper headwaters as compared to the lower river conditions where farming operations and industries have invaded the riparian areas of the Umatilla River eliminating adequate shade in some areas (CTUIR et al. 1990).

Irrigation is the principal water use competing with fish production in the Umatilla River Subbasin. Until recent years many irrigation diversions were unscreened. Salmonids would enter these unscreened diversions and become mortalities (CTUIR et al. 1990). Pacific lamprey ammocoetes probably suffered the same fate. The lower mainstem usually is dewatered during the irrigation season, impeding emigrant juvenile and late arriving adults in the late spring, and early arriving adults in the fall (CTUIR et al. 1990). These passage problems and the dewatering process likely had a negative affect on migrating juvenile and adult lamprey.

Irrigation occurs throughout the mid to upper reaches of this subbasin. Most irrigation diversions are registered to private individuals irrigating vegetable gardens and small pastures. Small pumps are utilized to obtain water, and surveys conducted show that pumps appear to be screened. None of these irrigation diversions in the mid to upper mainstem Umatilla are believed to be passage barriers for Pacific lamprey.

If adequate instream flows are present, this subbasin has several passage barriers that Pacific lamprey would have minimal or no trouble negotiating. The major artificial passage barriers are: 1) Three Mile Dam; 2) Westland irrigation diversion; 3) Feed canal; and 4) Stanfield irrigation diversion. These are passage barriers for salmonids, and were recently modified providing new fish ladders to improve salmonid passage. There are several artificial and natural passage barriers on lateral tributaries in this subbasin. These barriers would not affect lamprey passage.

Two chemical treatment projects occurred in the Umatilla River Subbasin. In 1967 and 1974, 85 and 90 miles of stream were rotenoned to eliminate targeted areas of rough fish. Norman Been, former ODFW screens operator (1964 to 1995), stated that "there were so many adult Pacific lamprey in the Umatilla River that they were a nuisance". He primarily saw adults at Westland and Three Mile Dam and viewed ammocoetes near the mouth of Meacham Creek prior to chemical treatment. Been further stated that he "saw few lamprey after the chemical treatment in 1967", and that he never saw any lamprey after the chemical treatment in 1974.

Chemical treatment projects were targeted at eliminating "rough fish", but areas that were rotenoned included areas that were known to be utilized by steelhead spawning and juvenile rearing. These areas were also used by Pacific lamprey.

Discussion:

Several tribal members were interviewed about the decline of Pacific lamprey in the Umatilla River Subbasin. Percy Brigham, Elias Quaempts, Alphonse Halfmoon, and Armand Minthorn, all CTUIR enrollees, believe that lamprey populations drastically declined during times of fish poisonings. Most members interviewed also stated that they harvested eels at Three Mile Dam as children.

As was the case for salmon, complete water withdrawal for irrigation and unscreened diversions may have been a major factor in the decline of the Pacific lamprey population.

The Umatilla Basin salmon restoration program is now a model of success in the region due to numerous efforts such as enhanced instream flows, passage improvements at ladders and screens, instream/watershed enhancements and hatchery supplementation. If common habitat factors lead to the demise of both salmon and lamprey and improvements of those factors are resulting in salmon restoration, the Umatilla Basin may be an ideal candidate for lamprey restoration also. As occurred during salmon reintroduction, it may be necessary to utilize a stock from outside the subbasin due to the very low current population status. Further discussion on specific Umatilla Basin lamprey restoration plans will be forthcoming as this study continues.

Recommendations:

1) Request that ODFW enumerate lamprey at all trap boxes, key to species (when possible) at all trapping sites, and document capture locations and life history stage (ammocoetes vs. macrophathalmia) of lamprey observed.

2) Request that ODFW and CTUIR document any adult Pacific lamprey observed during stream surveys.

3) Conduct random spot checks within the subbasin to determine presence/absence of Pacific lamprey.

4) Collect Pacific lamprey ammocoetes for scientific analysis.

WALLA WALLA SUBBASIN

Historic Abundance:

The Walla Walla River Valley Indian name is "*Wai-i-lat-pu*", the place of rye grass. The Walla Walla River once supported runs of steelhead, chinook, coho, sockeye, and chum salmon. Historic abundance estimates for Pacific lamprey are not available. Harvest information gathered from tribal informants suggests that Pacific lamprey were once abundant in the subbasin. Armand Minthorn (CTUIR, pers. comm.) stated that the North and South Forks of the Walla Walla River were utilized for eel harvesting. Eels were also collected near Skiphorton Creek on the Walla Walla River by CTUIR members (Swindell 1941). These areas where Pacific lamprey were harvested had good riparian habitat, high water quality, and low gradient for spawning and rearing, similar to spawning and rearing habitat preferred by salmon and steelhead.

Current Abundance:

Currently, no accurate numerical information is available on Pacific lamprey in the Walla Walla Subbasin. Weekly screen trap reports reviewed for the Walla Walla River indicate lamprey were enumerated at different times during the last several years. In the 1960's and from 1985 to 1990 lamprey were either not enumerated at different trap box sites, or counted as rough fish and lumped into a numerical number with other non-salmonid species. Information for 1970 through 1984, and 1991 was not available for review. From 1992 through 1995, 246 lamprey were enumerated in the Walla Walla Subbasin trap boxes. Seventy-three percent of all lamprey were captured at the Little Walla Walla diversion, river mile 47. Lamprey captured were not keyed to specific species, nor life history stage. Therefore it is not known whether lamprey captured were Pacific lamprey or resident western brook lamprey.

In May 1997, CTUIR sampled fifty-five lamprey from two dump truck loads of sand and sediment removed from in front of the rotary screens at the Little Walla Walla diversion. Many more lamprey were present but impossible to access. Of the 55 sampled, 51 were western brook lamprey, and four were Pacific lamprey. The sediment and lamprey were returned downstream of the collection site.

In 1996, WDFW electroshocked nine lamprey in the South Fork Touchet River, five lamprey in the North Fork Touchet and three lamprey in Wolf Creek. Although lamprey captured were not keyed to species, Mendel (WDFW, pers comm,) stated that he felt most lamprey that were captured during electrofishing operations were Pacific lamprey ammocoetes.

CTUIR electroshocked approximately 50 western brook lamprey in Mill Creek in July 1996. 15 were collected; releasing 12 upstream and sacrificing 3 for future identification purposes. The area surveyed in Walla Walla, WA, near the Wilbur Street bridge was chosen because of an oral reference stating that lamprey were once numerous at this site.

In the fall of 1993, CTUIR electroshocked 5 ammocoetes, in the South Fork Walla Walla River near RM 6. Lamprey captured were ammocoetes, but were not keyed to specific species.

James Pearman, a Walla Walla College student, noted collecting western brook lamprey in Yellowhawk and Cottonwood creeks in July, 1977.

Presently, there is no harvest of adult Pacific lamprey in this subbasin.

Man Caused Habitat Alterations:

The Walla Walla River originates in the Blue Mountains in northeast Oregon. The river flows west and north and meets the Columbia River, near Wallula, Washington at river mile 315. The river drains 1,785 square miles of northeastern Oregon and southeastern Washington. This subbasin lies within Walla Walla and Columbia counties in Washington and Umatilla, Wallowa, and Union counties in Oregon (CTUIR et al. 1990).

The subbasin is comprised of two major physiological regions. The Walla Walla region is characterized by rolling, treeless upland formed by deep deposits of loess overlying multiple lava flows. The Blue Mountain region consists of the long tilted plateaus formed by uplifting, folding, faulting and erosion of the Columbia River basalt and is characterized by flat-topped ridges, steep-walled canyons, and mountain slopes. Though minimal in percentage of subbasin area, the Blue Mountains are the major source for water in the subbasin (CTUIR et al. 1990).

The high elevation of the Blue Mountains are dominated with interspersed grasses. Forest species include lodgepole pine, ponderosa pine, Douglas fir, white fir, grand fir, subalpine fir, Engelmann spruce and larch. Mid elevation uplands have little or no vegetation cover due to extensive and intensive dry-farming. The river valley is suited to agriculture and extensively irrigated (CTUIR et al. 1990).

Extensive and intensive irrigation in the Walla Walla valley is the primary cause of low instream flows during critical summer months in the mid subbasin. A network of irrigation diversions within the subbasin present significant barriers to fish passage. The Little Walla Walla Diversion at river mile 47 completely dewaters the river during summer months and in the spring in years of low streamflow. This diversion impedes and/or blocks upstream migrant fish. The Touchet River had 20 unscreened diversions in 1935, the Walla Walla River diversions below “Tumalum Branch” in 1936 were screened, but none of those above had protective devices (Neilson 1950). The two major diversion on the lower mainstem Touchet, the largest tributary to the Walla Walla River, partially block adult and juvenile fish passage (USFWS 1982). Currently, one irrigation diversion has non-functional screens and one is unscreened (G. Mendel, pers. comm.). In Oregon, unscreened diversions on the mainstem Walla Walla River, and the North and South forks have posed “serious problems to downstream migrants” (ODFW 1987).

Irrigation-depleted streamflows is the major factor limiting production of anadromous fish in the Walla Walla Subbasin. By May or June, the mainstem Walla Walla River is dry near the state line due to irrigation withdrawals. Irrigation-depleted streamflows in the lower reaches of the Touchet River impede fish passage at irrigation diversions and contribute to poor water quality, including elevated water temperatures.

Discussion:

Information gathered dealing with Pacific lamprey in the Walla Walla Subbasin is very limited. As in other basins, population numbers are not available. CTUIR has documented the presence of western brook lamprey and Pacific lamprey in the Walla Walla Subbasin. In February 1996, ODFW observed thousands of lamprey ammocoetes at the Little Walla Walla Diversion, but did not key them to species.

Extensive irrigation, and farming practices have had substantial impacts on Pacific lamprey populations in this subbasin. Throughout the summer months, the Walla Walla River lacks adequate flow for fish survival and migration needs below Milton-Freewater, Oregon.

Diversion of water for irrigation is the primary factor limiting lamprey survival in the Walla Walla River Subbasin. A network of irrigation diversions braid the Walla Walla River into several small, unshaded ditches and during much of the year the river is dewatered. As a result, lamprey rearing and spawning habitat have been diminished.

Prior to 1997, the Walla Walla Subbasin had received little or no mitigation for anadromous fish losses (CRITFC 1995).

A salmon and steelhead restoration program which began in 1997 includes stream habitat/watershed enhancement, passage improvements at ladders and screens, instream flow enhancement and hatchery supplementation. It is likely that these salmon and steelhead projects will also benefit lamprey. In continuing Walla Walla Basin lamprey restoration efforts, it will be critical to better determine the status (abundance and composition) of existing lamprey populations.

Recommendations:

1) Request that WDFW and ODFW enumerate lamprey at all trap boxes, key to species (when possible) at all trapping sites, and document capture locations and life history stage (ammocoetes vs. macrophathalmia) of lamprey observed.

2) Request that WDFW and ODFW document any adult Pacific lamprey observed during stream surveys.

3) Conduct random spot checks within the subbasin to determine presence/absence of Pacific lamprey.

4) Collect Pacific lamprey ammocoetes for scientific analysis.

TUCANNON SUBBASIN

Historic Abundance:

This system was historically utilized by the Umatilla, Walla Walla, Nez Perce, Palouse, and Cayuse Tribes. Tribal members historically harvested eels, chinook salmon, steelhead and trout. Armand Minthorn, CTUIR enrollee, stated that his family had specific sites on the Tucannon River where his family fished for salmon, trout, and eels.

Pacific lamprey historically were common in the Tucannon Subbasin (Mendel,1997). Spring and fall chinook and coho salmon were also historically present. Other salmonids present were: mountain whitefish, rainbow and bull trout.

Current Abundance:

No estimate of population size is available for this subbasin. Mendel feels the Pacific lamprey population is rapidly declining. WDFW has operated a smolt collection trap and conducted electroshocking for many years. Mendel stated that he has captured some Pacific lamprey ammocoetes in recent years in various areas of the Tucannon River by electroshocking and in downstream migrant traps. In 1995, two Pacific lamprey adults were captured at the smolt trap at river mile 12.5.

Presently, the Tucannon supports an annual average run of 200 spring chinook, approximately 125 fall chinook, and a minimum estimate of 200 steelhead (G. Mendel, pers. comm). Coho salmon are extinct.

Man-Caused Habitat Alterations:

The Tucannon River originates in the Umatilla National Forest area of the Blue Mountains at an elevation of 6,387 feet above sea level at Oregon Butte in southeast Washington (Fuller 1986). The Tucannon drainage consists of forests, rangelands, and agricultural land (Kelley et al. 1982). The growing season in the area generally runs 110 to 140 days per year. Temperatures range from minus 22 degrees Fahrenheit in the winter to 109 F in the summer months (USDA 1984 draft).

Hecht et al. (1982) identified and evaluated changes in the riparian, channel and streambed conditions of the Tucannon River between 1937 and 1978. The changes suggested a regression in the stream’s natural succession process. Thirty-three to 55 percent of riparian woodland was lost as results of major floods after 1964. Open zones replaced wooded riparian zones, shade was diminished and banks likely became less stable (Hecht et al. 1982).

The principal habitat alteration in the channel from 1937 to 1978 was the widening and straightening of the stream channel, as a result stream length decreased by seven to 20 percent (Hecht et al. 1982). Many of the bends and irregularities in the channel, which provided much of the salmonid rearing habitat, were eliminated (WDFW et al. 1990). At the same time, Pacific lamprey habitat for rearing juveniles may have been decreased.

Pataha Creek, a major tributary of the Tucannon River, has some of the poorest conditions for salmonid production. Some constraints are: 1) elevated summer water temperatures, 2) heavy sediment deposits that infiltrate gravels, 3) flash flooding events, 4) an irrigation diversion that likely impedes migrating salmonids, 5) little or no riparian vegetation, 6) channelization, 7) unstable streambanks, 8) problems with livestock management. Pataha Creek is utilized by steelhead for spawning and rearing (WDFW et al. 1990), and since lamprey are known to prefer habitat similar to steelhead it is possible that these conditions impacted lamprey populations as well.

Fish production within the basin has been degraded as a result of human activities and catastrophic events. Degradation accelerated over the last two to three decades. Agricultural and livestock management practices have contributed to increased sedimentation and a general reduced riparian vegetation and stream shade cover. The later has likely contributed elevated stream temperatures in the lower basin. Channeling activities have reduced pool-riffle ratios and riparian vegetation (WDFW et al. 1990).

In the 1960's flood events straightened the river, eliminating streamside vegetation and instream habitat, and increasing the general gradient of the system (WDFW et al. 1990).

In the early 1970's, a group known as FURPAC (which consisted of various state and federal agencies, excluding tribes) recommended placing angle-irons in the fishways at Ice Harbor Dam (J. McMichael ,COE, pers. comm). The angle-irons were placed on the sides of the fishway, preventing lamprey from passing through Ice Harbor Dam. McMichael stated that many people thought that Pacific lamprey were impacting Snake River salmon populations and further stated that the angle-iron was very effective. The angle-irons were removed five to seven years ago during dewatering.

According to Mendel, no chemical treatment projects for rough fish control have occurred in this subbasin.

Mendel stated that Starbuck Dam (Fletcher's Diversion) used to be higher than the dam's current height, and it may have limited Pacific lamprey passage upriver. In recent years, the dam was modified for salmonid passage.

Discussion:

Pacific lamprey populations in the Tucannon Subbasin are depressed. Mendel stated that lamprey population has declined rapidly since 1981. Besides instream habitat degradation, one of the major reasons for the decline of the Pacific lamprey population was the placement of angle-irons in the fish ladders at Ice Harbor Dam to preclude lamprey passage in the Snake River system.

It is hoped that ongoing salmon and steelhead restoration measures (insteam/watershed habitat enhancement and fish passage improvements) being implemented will also benefit lamprey. Further understanding is needed regarding current lamprey abundance and species composition (Pacific or western brook) before restoration planning can proceed.

Recommendations:

1) Request that WDFW enumerate lamprey at all trap boxes, key to species (when possible) at all trapping sites, and document capture locations and life history stage (ammocoetes vs. macrophathalmia) of lamprey observed.

2) Request that WDFW to document any adult Pacific lamprey observed during stream surveys.

3) Conduct random spot checks within the subbasin to determine presence/absence of Pacific lamprey.

4) Collect Pacific lamprey ammocoetes for scientific analysis.

GRANDE RONDE SUBBASIN

Historic Abundance:

Historical estimates of the Pacific lamprey population are not available. Oral interviews with tribal members indicate that the Grande Ronde River Subbasin once supported a fishery for Pacific lamprey. This area was utilized by the Nez Perce, Cayuse, Walla Walla, Palouse, and Sho-Ban Tribes (Lane and Lane 1979 and Swindell 1941). Tribal members historically harvested eels, bull trout, whitefish, chinook and sockeye salmon, and steelhead. Tribal members spoke of catching and observing lamprey in Catherine Creek, Tony Vey Meadows, Lookingglass Creek, and the upper Grande Ronde River.

Wayne Huff, former ODFW screens operator, stated that Pacific lamprey disappeared in the 1970's. He stated that the Wallowa and Imnaha (another Snake River tributary) had thousands of Pacific lamprey prior to the 1970's.

Bob Sayre, former ODFW biologist, stated that he viewed both adults and ammocoetes in Catherine Creek in the 1950's. He stated that Pacific lamprey were abundant throughout the whole Grande Ronde system during the 1950's and 1960's.

Duane West, former ODFW employee, stated that his crew electroshocked ammocoetes near La Grande in the mainstem Grande Ronde River in 1962.

Ken Witty, former ODFW district biologist, stated that there used to be large numbers of Pacific lamprey in the Imnaha, and Wallowa systems. He stated that during his years as district biologist (from 1964 to 1990) he noticed lamprey populations were rapidly declining. Witty stated that fish agencies were too worried about declining salmon populations to worry about Pacific lamprey. The Grande Ronde Subbasin and tributaries once supported large runs of summer steelhead, sockeye (*O. nerka*), coho, and spring and fall chinook salmon (ODFW et al. 1990).

Melvin Farrow, CTUIR enrollee and CTUIR Fisheries technician, stated that he observed ammocoetes at Tony Vey Meadows in the 1960's.

Armand Minthorn, CTUIR enrollee, spoke of fishing sites on Lookingglass Creek, Catherine Creek, Grande Ronde, Minam, and Wallowa rivers. These are areas that were also likely utilized by Pacific lamprey for spawning and rearing.

Current Abundance:

The Pacific lamprey population in the Grande Ronde Subbasin and tributaries are likely near extinction. Keefe (ODFW, pers. comm.) stated that they are operating rotary traps on the Wallowa River and upper Grande Ronde and have captured no lamprey. Lofy (CTUIR, pers. comm.) stated that no lamprey have been captured in Lookingglass Creek during trapping operations.

Currently, spring chinook are endangered in the Grande Ronde system. Restoration efforts are being implemented to restore spring chinook salmon and steelhead.

Man Caused Habitat Alterations:

The Grande Ronde River originates in the Blue Mountains of northeast Oregon. It is bounded by the Blue Mountains to the west and northwest and the Wallowa Mountains in the southeast. The river enters the Snake River system at river mile (RM) 168.7 in the Hells Canyon reach. The major tributaries to the system are the Wenaha, Wallowa, and Minam rivers, and Catherine and Lookingglass creeks. The smaller tributaries are Bear, Joseph, Hurricane, Sheep, and Indian creeks (CRITFC 1995).

The Grande Ronde River is located above eight dams in the Columbia River system, of which four are located in the Snake River Subbasin. The basin encompasses an area of about 3,950 square miles in the extreme northeast corner of Oregon. A small portion of the northern part of the basin is in Washington.

Riparian and instream habitat in parts of the Grande Ronde Subbasin has been impacted by a number of land-use activities. Pine beetles have infested some areas of this subbasin deteriorating riparian along streambanks. However, there are areas such as the Minam and Wenaha drainages that still remain pristine (ODFW et al 1990).

Rearing habitat in some parts of the subbasin is of poor quality due to land management practices and is the major inbasin factor limiting fish production. Spawning habitat is adequate to support increased escapement levels (ODFW et al 1990).

Riparian habitat degradation is the most serious habitat problem in the basin. Approximately 379 degraded stream miles have been identified (ODFW et al 1990). Several factors have contributed to the problem. Stream channelization for field development, livestock grazing, agricultural practices, poorly designed roads, and timber removal have done the most damage. Mining and recreation development have also contributed to the loss of riparian habitat.

The combination of wider and shallower stream channels, reduced streamflows, and a decrease in abundance and diversity of riparian vegetation contribute to increased water temperatures. Increased water temperature have unfavorable effects on juvenile salmonids (ODFW et al 1990), and likely impact juvenile Pacific lamprey as well.

Excessive livestock grazing has caused extensive loss of riparian vegetation along the upper Grande Ronde, Catherine Creek, Joseph Creek, and Wallowa River drainages (ODFW et al 1990).

As of 1985, unscreened or poorly screened irrigation diversions existed on the upper Grande Ronde and Wallowa rivers, Catherine Creek, and Joseph Creek. Diversions direct migrating juvenile fish out of streams into irrigated fields (ODFW 1985). In addition, outmigrating juvenile Pacific lamprey may have also been diverted into fields because of similar outmigration timing as salmonids. An ongoing screening program, funded by the National Marine Fisheries Service and implemented by the Oregon Department of Fish and Wildlife, has corrected and will continue to correct many screening problems within the subbasin. Projects on the upper mainstem Grande Ronde and Wallowa rivers, and Catherine Creek have the highest priority (ODFW 1985). Currently, all streams utilized by chinook salmon have been screened. Streams utilized by steelhead are now starting to be properly screened. The screening project is a voluntary program with area landowners. This will be an ongoing project until completion. No projected completion date is known.

Low summer flows occur in the lower reaches of the mainstem and tributaries due to naturally low flows, extensive irrigation withdrawals, and watershed manipulation through timber harvest and agricultural practices. Extreme low flows occur generally between La Grande and Wallowa on the mainstem, Catherine Creek below Union, Joseph Creek, and the lower reaches of all Wallowa tributaries that flow through areas utilized by agricultural operations (ODFW et al 1990). These low flows and resulting high water temperatures may impede how Pacific lamprey migrate to suitable spawning areas in the upper reaches of these systems.

Water quality in the headwaters is generally good. In the lower mainstem and lower reaches of tributaries, non-point sources significantly reduce water quality by increasing turbidity, excessive water temperatures, and having low dissolved oxygen levels. Runoff from urban, agricultural, and forest areas all contribute to the non-point pollution problems (ODFW et al 1990).

Several potential point sources of pollution have been identified. Bulk gasoline, waste treatment, and chemical plants all have potential impacts on ground and surface waters within the subbasin (ODFW et al 1990).

Joe McMichael and Leonard Mayfield, Corps of Engineers employees, stated that angle-iron were placed in the fishway at Ice Harbor Dam under the direction of a group known as FURPAC (which consisted of state and federal agencies, excluding tribes). The angle-iron was very effective at eliminating upstream lamprey passage. McMichael stated that Pacific lamprey were thought to be impacting Snake River salmon populations.

At the same time as Pacific lamprey populations were declining, Lower Monumental (1968), Little Goose (1970), and Lower Granite (1975) dams were all completed and operating.

This may have also impacted adult Pacific lamprey and their ability to migrate upstream into suitable spawning habitat, and may have also impacted juvenile Pacific lamprey and their survivability through these dams during outmigration periods. In addition, the completion of Dworshak Dam (1972) eliminated over 600 miles of spawning and rearing habitat for lamprey. No mitigation was ever received for this loss.

Discussion:

Limited information on Pacific lamprey for the Grande Ronde Subbasin is available. It is known that Pacific lamprey were once abundant in the Grande Ronde River and tributaries, but are now likely near extinction.

Ken Witty, former ODFW employee, stated that Pacific lamprey may have been eliminated by design. Witty stated that angle-irons were placed in the fishways at Ice Harbor Dam in the early 1970's to eliminate upstream lamprey passage.

Recommendations:

1) Request that ODFW enumerate lamprey at all trap boxes, key to species (when possible) at all trapping sites, and document capture locations and life history stage (ammocoetes vs. macrophathalmia) of lamprey observed.

2) Request ODFW to document any adult Pacific lamprey observed during stream surveys.

3) Conduct random spot checks within the subbasin to determine presence/absence of Pacific lamprey.

4) Collect Pacific lamprey ammocoetes for scientific analysis.

Table A-1. Subbasin contacts and sampling devices used in NE Oregon and SE Washington, 1997.

SUBBASIN	CONTACT	PHONE NO.	SAMPLING DEVICE
John Day	Tim Unterwegner/Mike Gray	(541) 575-1167	Rotary/Screen Traps
Umatilla	Sue Knapp/Craig Contor	(541) 567-5318	Rotary Traps and WEID
Walla Walla	Brian Kilgore/Glen Mendel	(541) 276-2344	Screen Trap Boxes
Tucannon	Glen Mendel	(509) 382-1005	Rotary Traps
Grande Ronde	Peter Lofy/Mary Lou Keefe	(541) 962-3777	Rotary Traps
Imnaha	Don Bryson	(541) 426-0119	Rotary Traps
Yakima	Ken McDonald	(509) 662-4361	
Bonneville Dam	Jim Kuskie	(503) 374-8375	
McNary Dam	Brad Ebbie/Paul Wagner	(541) 922-3211	Smolt Collection Facility
Lower Granite Dam	Marc Peterson	(509) 332-1625	
Ice Harbor Dam	Steve Richards	(509) 382-1187	

Table A-2. Lamprey Status for NE Oregon and SE Washington
(Word Table-Landscape)

ACKNOWLEDGMENTS

This program was funded by Bonneville Power Administration. The Confederated Tribes of the Umatilla Indian Reservation thank the efforts of Deborah Docherty and other Bonneville Power Administration personnel for their assistance.

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We would also like to thank members of the Nez Perce Tribe: Loretta Halfmoon, Loretta Scott, Si Whitman, Rudy Miles, Orrin Allen, Horace Axtell, Jesse Green, Richard Powaukee, Sr. for providing valuable historical information.

CTUIR would also like to thank numerous former and current employees from various federal and state fish agencies for providing valuable information: Norman Been, Homer Campbell, Errol Claire, Mike Gray, Dave Heckeroth, Wayne Huff, Brian Kilgore, Robert Sayre, Tim Unterwegner, Tim Walters, Duane West, Ken Witty from the Oregon Department of Fish and Wildlife; Glen Mendel and Robert Bugert with the Washington Department of Fish and Wildlife, and Joe McMichael and Leonard Mayfield with the US Army Corps of Engineers.

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ACRONYMS

CRITFC	Columbia River Inter-Tribal Fish Commission
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
NPPC	Northwest Power Planning Council
ODFW	Oregon Department of Fish and Wildlife
OWRD	Oregon Water Resource Department
OSU	Oregon State University
TMD	Three Mile Falls Dam
USFWS	United States Fish and Wildlife Service
USDA	United States Department of Agriculture
WDFW	Washington Department of Fish and Wildlife

Lamprey Research and Restoration Project

1996 Annual Report

Part (B) Abundance Monitoring for Columbia and Snake Rivers

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Table of Contents

List of Tables

List of Figures

Abstract

In 1996, a field study was begun to investigate the declining population of Pacific lamprey *Lampetra tridentata* in the Columbia River. The study was headed by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) in cooperation with the Columbia River Inter-Tribal Fish Commission (CRITFC) and Oregon State University (OSU). The CRITFC primarily concentrated on two objectives in 1997. The first objective was to determine abundance, passage trends, length frequencies and life phases of juvenile Pacific lamprey migrating past mainstem Columbia and Snake river dams and project tributaries; and, the second objective was to determine the current abundance, passage trends, and length frequency of adult Pacific lamprey crossing mainstem Columbia and Snake river dams. In 1996, the juvenile lamprey migration through the Columbia River system had concluded before this project began. In future years, data on general passage trends and life phase characterizations will be collected at juvenile salmond collection facilities operated at Federal hydroelectric projects in the Columbia River system. Adult lamprey fish ladder passage estimates are presented from Bonneville, Ice Harbor, Lower Granite, Rock Island, Rocky Reach, and Wells dams for 1995 and 1996. Hydroelectric projects located upstream of Bonneville Dam had three times the number of lamprey in 1996 compared to 1995. Counting adult Pacific lamprey was very problematic, resulting in a net negetive count at Bonneville Dam in 1996. We believe that enumerations would be more accurate if fish count stations were modified. Adult lamprey counts were hindered by poor viewing conditions in the floor of the fish counting chamber, and by the tremendous amount of up- and downstream movement displayed during nighttime periods.

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Introduction

Pacific lamprey *Lampetra tridentata* is an endemic anadromous fish to the Columbia River Basin. This fish is highly prized by native Americans as a ceremonial and subsistence food item. Often found in sympatry with native anadromous salmonids *Oncorhyncus* sps., the Pacific lamprey shares similar life history needs that include pristine freshwater spawning and rearing habitat, mainstem passage corridors to the ocean and back, and productive ocean rearing habitat. Unlike anadromous salmonids, the Pacific lamprey is not highly prized or utilized by non-Indians, consequently, recent declines in Pacific lamprey abundance and distribution had gone largely unnoticed by regional fishery managers. Diligent efforts by tribal and Columbia River Inter-Tribal Fish Commission (CRITFC) staff secured funding and support to investigate the declines in distribution and abundance of Pacific lamprey. The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) in cooperation with the CRITFC and Oregon State University (OSU) have initiated a multi-faceted, multi-year approach to investigate and determine the mechanisms behind the declines and subsequent strategies for recovery. This report covers the initial year of the CRITFC portion of this study. The main emphasis will be data summary and report for this first year. Detailed analysis will be completed in years when sufficient data exist for analysis. Two primary objectives in this project include:

1) Determine abundance, passage trends, length frequencies and life phases of juvenile Pacific lamprey migrating past mainstem Columbia and Snake river dams and project tributaries; and,

2) Determine the current abundance, passage trends, and length frequency of adult Pacific lamprey crossing mainstem Columbia and Snake river dams.

Methods

Juvenile Lamprey Investigations

Data collection and reporting for this objective was limited to coordination for the 1997 field season and a literature review, since project initiation in fiscal year 1996 occurred after the juvenile lamprey outmigration. Contacts were made with project managers at the juvenile fish collection projects at selected hydroelectric dams. These projects collect juvenile lamprey incidently while conducting juvenile salmonid collections. In addition, historic data, grey literature, and other written materials were reviewed for information regarding juvenile lamprey passage and migration patterns.

Adult Lamprey Investigations

Study Area

Data on adult lamprey fish ladder passage were obtained at Bonneville, Rock Island, Rocky Reach, Wells, Ice Harbor, and Lower Granite dams (Figure 1). These hydroelectric projects were chosen because fish passage is recorded on videotape at these sites and/or on-site lamprey counts are made there.

Abundance Estimates

Fish ladder counts of adult lamprey were used as an index of abundance. We attempted to estimate fish ladder passage for both 1995 and 1996. Fish ladder counts were obtained by reviewing time-lapse recorded videotape, or from on-site counts. On-site lamprey counts were available for Ice Harbor, and Lower Granite dams on the Snake River and at Rock Island, Rocky Reach, and Wells dams on the Columbia River. Videotape records were obtained from Bonneville Dam and reviewed by CTUIR to enumerate lamprey passage.

The lamprey count at Bonneville Dam in 1995 was incomplete because videotapes were reused before we could review them to estimate lamprey passage. There was a tremendous amount of lamprey movement (upstream and downstream) at the count station windows in both 1995 and 1996. Therefore, we treated upstream and downstream estimates separately instead of recording net upstream passage. The videotape record of fish ladder passage at Bonneville Dam was sampled using a stratified systematic sampling design. Generally, a 1 in 7-day sample was obtained and samples were stratified into ½ month units. Lamprey passage was estimated for each strata and combined to estimate annual passage. Tallies of upstream and downstream moving lamprey were made.

Figure 1. Map of the Columbia River Basin. The dams that are labeled are locations of adult lamprey count data.

For videotapes from Bonneville Dam, the large volume of fish movement in the counting station windows made it very time consuming and difficult to perform a total enumeration of lamprey. For example, over 7d period nearly 38,000 lampreys were counted passing upstream in the observation window and during the same period, nearly 33,000 were counted passing downstream in the observation window. We therefore, began subsampling fish passage videotapes. Lamprey were counted for 10 or 12 minutes per hour and then expanded by the appropriate value (6 or 5, respectively) to estimate hourly passage.

To demonstrate the effectiveness of counting lamprey for 10 or 12 minutes out of each hour and expanding that count to estimate hourly passage, we analyzed lamprey counts taken over a 7d period. These total enumerations were recorded in 10-minute intervals over seven different 24h periods. We compared the total enumerations for up- and downstream moving lamprey with estimates calculated from each of 6 "10 minute" counts.

Length Frequency Estimates

We estimated lengths of lamprey from videotape recorded at Ice Harbor, Lower Granite, and Wells dams. First, we determined what the magnification factor was at each count station window (this was also repeated if changes were made to the camera). The magnification factor was calculated by measuring the known distance between the "jack" as they appeared on the video monitor. The images of individual lamprey were measured to the nearest mm with a ruler on a video monitor. These image lengths were then converted to fish lengths (in inches) by:

Fish length = FI / MF

where: FI = fish image length measured in mm; and,
MF =distance between "jack" lines (mm) on the monitor / 22.

Results and Interpretation

Juvenile Lamprey Investigations

Published and unpublished literature described juvenile lamprey passage and migration patterns in the Columbia River basin. Juvenile lamprey rear in freshwater tributaries and rivers for a period of 5 to 7 years (Hammond 1979, Richards 1980, Richards and Beamish 1981). More detailed information on Pacific lamprey early life history are available in Close et al. (1995). Outmigration of juvenile Pacific lamprey generally commences with late winter and early spring freshets and the rising hydrograph (Hammond 1979, Potter 1980). Migrating juvenile lamprey, correctly know as macrophathalmia, begin appearing at private and federal hydropower projects in March or April and continue into summer (Close et al. 1995), although heavy runoff periods in mid-winter can result in migration or movement of large numbers of juvenile lamprey with many still in the larval stage (e.g. ammocoetes) (Roseann Tudor, personal communication, ODFW).

Early juvenile salmonid investigations at The Dalles Dam noted large numbers of migrating juvenile lamprey concentrated in the lower and center fyke nets placed in front of turbine intakes (Long 1968). Long (1968) found that juvenile lamprey were spatially separated from the juvenile salmonids, with only minor overlap at the mid point area of the turbine intake. This may be related to physiological differences between salmonids and lamprey, since lamprey have no swim bladder and thus cannot easily regulate their location in the water column. Extensive fyke net studies by fisheries staff at Wells Dam in the 1980's and 1990's revealed similar findings (Klinge 1985-1995). Juvenile lampreys exhibit a nocturnal migration pattern (Hawkes 1993, Klinge 1995), which may serve to protect them from predation. Both avian (e.g. gulls *Larus* sps. and terns *Sterna* sps.) and piscverous predators (e.g. northern squawfish *Ptychocheilus oregonensis* and channel catfish *Ictalurus punctatus*) prey on juvenile lamprey (Merrell 1959, Poe 1991). Dam passage through turbine units may subject migrating juvenile lamprey to increased predation risks since both avian and piscervous predators are attracted to prey items (e.g. juvenile lamprey and salmonids) that have been concentrated spatially and temporally by dam operations.

Dam operations may directly result in juvenile lamprey mortality from turbine passage and the associated pressure changes and from contact with juvenile bypass systems. The greatest concern centers on the use of fixed bar screens used to divert juvenile salmonids for collection and transport. Juvenile lampreys appear to be highly sensitive to impingement between the individual bars of these bypass devices. In two separate unsubstantiated events, large numbers (> 100 individuals) of juvenile lamprey were impinged between the individual bars of these deflection devices during tests conducted at The Dalles Dam and McNary Dam in recent years . The small diameter of juvenile lamprey combined with the interstitial spaces between the bars and the extended deployment of the extended bar screens creates a situation in which confirmation of these alleged events is difficult to confirm or deny. Since these and other devices are intended for salmonids, monitoring and data collection regarding juvenile lamprey is often limited with regard to the quantity and quality of information collected.

Similarily, data collection of some aspects of juvenile lamprey passage information is possible via the juvenile salmonid collection and transportation systems in operation at Federal projects on the Snake and Columbia rivers, although is limited in use and interpretation. The systems operate on a 24 hour sampling schedule that collects hourly subsamples of the total diversion from the juvenile bypass system. Using this system it is not possible to identify at what time juvenile lamprey were collected nor is possible to extrapolate the total passage of juvenile lamprey from the previous 24 hours, since lamprey guidance efficiencies have not been calculated. General passage trends combined with life phase characterizations will be the primary data collected from these sites, although previously collected data from other studies maybe used to extrapolate abundance and diel passage behavoirs.

Adult Lamprey Investigations

Abundance Estimates

Monthly fish ladder passage counts at Bonneville, Ice Harbor, Lower Granite, Rock Island, Rocky Reach and Wells dams for 1995 and 1996 are presented in Tables (1 and 2). Except for Rocky Reach Dam, all counts were conducted 24 h per day.

Lamprey counts at upstream projects (Wells and Ice Harbor dams) early in the year were similar to counts at Bonneville Dam. Nearly as many lamprey were counted in April at Wells and Ice Harbor dams than at Bonneville Dam. Also the projects located upstream, had relatively high lamprey counts late in the year. Hydroelectric projects located upstream had 3 or more times the number of lamprey in 1996 than in 1995. Counts at Rock Island Dam increased by more than an order of magnitude in 1996 compared to 1995.

Counts of lamprey at Bonneville Dam varied greatly between 1995 and 1996 (Table 3 and 4). Lamprey passage estimates at the Washington Shore Count Station were much higher than estimates at the Bradford Island Count Station in both 1995 and 1996. The estimate for 1996 was actually -37,127 lamprey. This certainly raises questions regarding the value of this index of abundance. These findings are consistent with Starky and Dalen (1995), whom also calculated net negative passage estimates based on observations at the fish count stations.

Table 1. Estimated total adult Pacific lamprey passage by month at Bonneville, Ice Harbor, Lower Granite, Rock Island, Rocky Reach and Wells dams in 1995.

	Bonneville	Ice Harbor	Lower Granite	Rock Island	Rocky Reach	Wells
January	-	-	-	-	-	-
February	-	-	-	-	-	-
March	-	-	-	-	-	-
April	20	3	0	-	-	23
May	15,286	14	4	-	-	23
June	35,873	11	2	-	-	6
July	34,557	164	55	6	-	27
August	-	380	74	38	-	95
September	-	99	123	65	-	182
October	-	9	6	2	-	1
November	-	-	0	-	-	5
December	-	-	0	-	-	0
Total	85,736	680	264	111		362

Table 2. Estimated total adult Pacific lamprey passage by month at Bonneville, Ice Harbor, Lower Granite, Rock Island, Rocky Reach and Wells dams in 1996.

	Bonneville	Ice Harbor	Lower Granite	Rock Island	Rocky Reach	Wells
January	-	-	-	-	-	-
February	-	-	-	-	-	-
March	-	-	-	-	-	-
April	0	4	0	-	-	4
May	-2,565	13	0	-	-	0
June	-24,213	12	-1	5	1	0
July	6,438	178	31	33	5	14
August	-10,061	650	388	1,235	416	206
September	-5,488	232	214	722	144	488
October	-1,238	65	7	126	27	216
November	-	-	-	-	-	51
December	-	-	-	-	-	-
Total	-37,127	1,154	639	2,121	593	979

Table 3. Adult Pacific lamprey passage estimates (upstream and downstream) and related statistics made from videotapes recorded at Bonneville Dam in 1995.

	Bradford Island Upstream	Bradford Island Downstream	Washington Shore Upstream	Washington Shore Downstream
#days	122	122	122	122
Days counted	17	17	17	17
Total count	20,754	19,136	69,047	59,129
mean count	1,157	1,162	4,740	4,062
Passage estimate	141,110	13,1325	530,912	454,961
Bound	48,805	55,696	159,051	93,626

Table 4. Adult Pacific lamprey passage estimates (upstream and downstream) and related statistics made from videotapes recorded at Bonneville Dam in 1996.

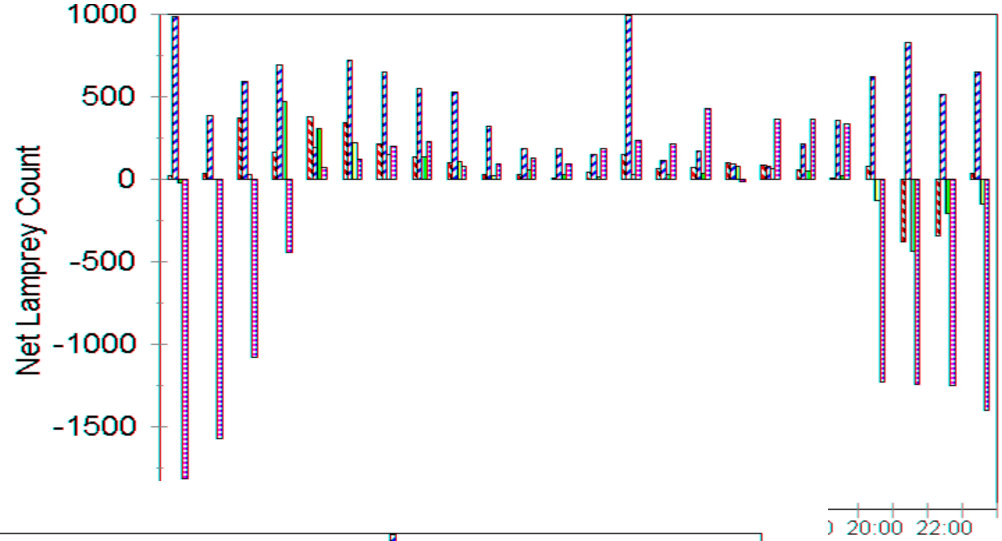
	Bradford Island Upstream	Bradford Island Downstream	Washington Shore Upstream	Washington Shore Downstream
#days	183	183	183	183
Days counted	26	26	26	26
Total count	19,555	18,635	86,525	93,241
mean count	716	681	3,374	3,612
Passage estimate	131,079	124,684	617,488	661,009
Bound	46,041	61,574	126,443	131,382

The lamprey passage estimates calculated from the 10-minute counts, made from Bonneville Dam video records, were all within 5% of the total enumeration, and seven of the 12 estimates were within 1% of the total enumeration (Table 5).

Table 5. Adult Pacific lamprey counts derived from completely reviewing 7 days of time-lapse recorded videotape and by systematically reviewing 10min intervals from each hour of recording and expanding to estimate lamprey passage. The % deviation is the difference between the estimated count and the complete count.

	Upstream Moving lamprey			Downstream Moving lamprey		
10min Interval	Expanded interval count	Complete count	% Deviation	Expanded interval count	Complete count	% Deviation
1	38,094	37,662	1.01	33,930	32,859	1.03
2	37,482	37,662	1.00	33,114	32,859	1.01
3	36,528	37,662	0.97	31,314	32,859	0.95
4	37,806	37,662	1.00	32,838	32,859	1.00
5	37,878	37,662	1.01	32,256	32,859	0.98
6	38,184	37,662	1.01	33,702	32,859	1.03

Lamprey activity in the windows of the fish count stations seemed to be least between 0600 and 1900 hrs, although it did vary between years and count stations (Figure 2). The greatest activity was between 2000 and 0300 hrs and the greatest net upstream passage generally occurred during dusk and dawn periods. Daytime periods generally involved net upstream movements, while nighttime periods involved downstream movement.



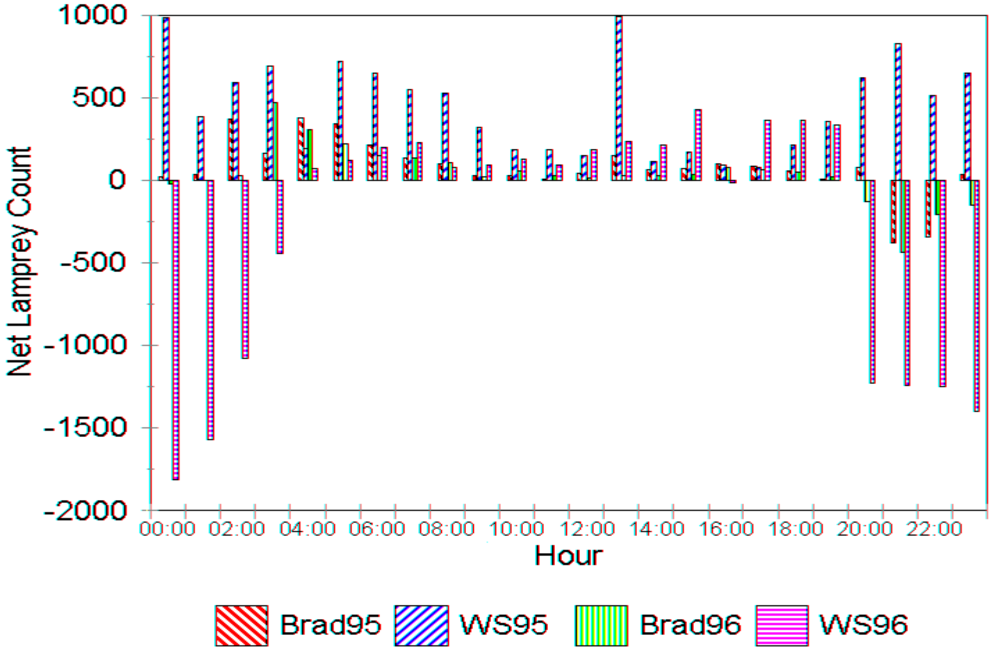


Figure 2. Adult Pacific lamprey passage estimates from Bonneville Dam in 1995 and 1996 as a function of hour of the day.

Length Frequency Estimates

A total of 395 lamprey images were measured from video recordings, 192 from Ice Harbor, 60 from Lower Granite, and 143 from Wells dam recordings. The relative frequency of these data was computed and plotted as a function of one-inch length classes (Figure 3). The modes from the Wells Dam and Ice Harbor Dam data were very close. The mode for the Lower Granite Dam data was at 21 inches approximately 2 inches less than the data from Wells and Ice Harbor dams.

We participated in a lamprey salvage operation at John Day Dam on 1/8/97. These fish were trapped in the fish ladder during dewatering. Prior to releasing these fish upstream, we anesthetized and measured 120 of them. The length frequency plot from these data is presented in Figure (4). The mode was 24 inches resulting in a frequency that was very similar to those from Wells and Ice Harbor dams.

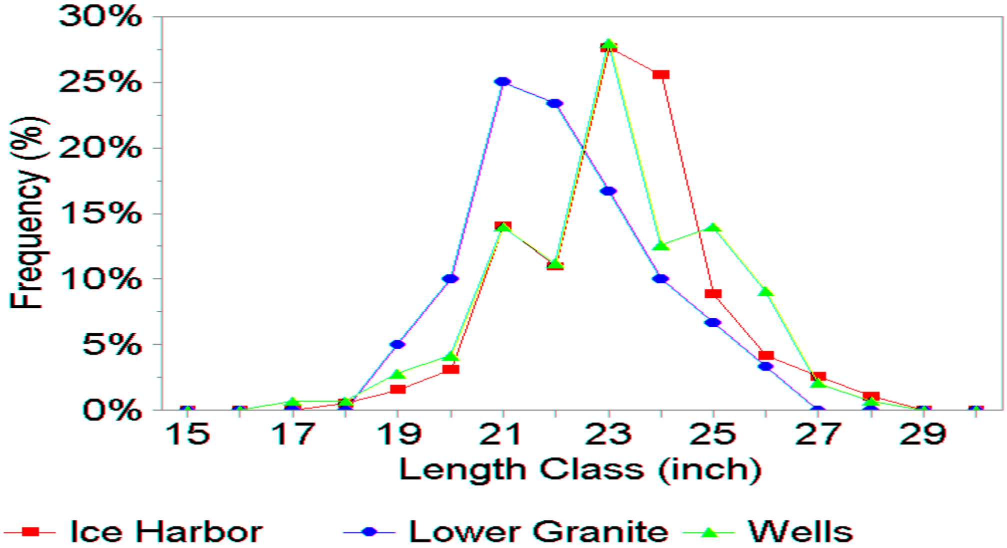


Figure 3. Plot of adult Pacific lamprey length frequency estimated from measuring images recorded on videotape at Ice Harbor, Lower Granite, and Wells dams in 1996.

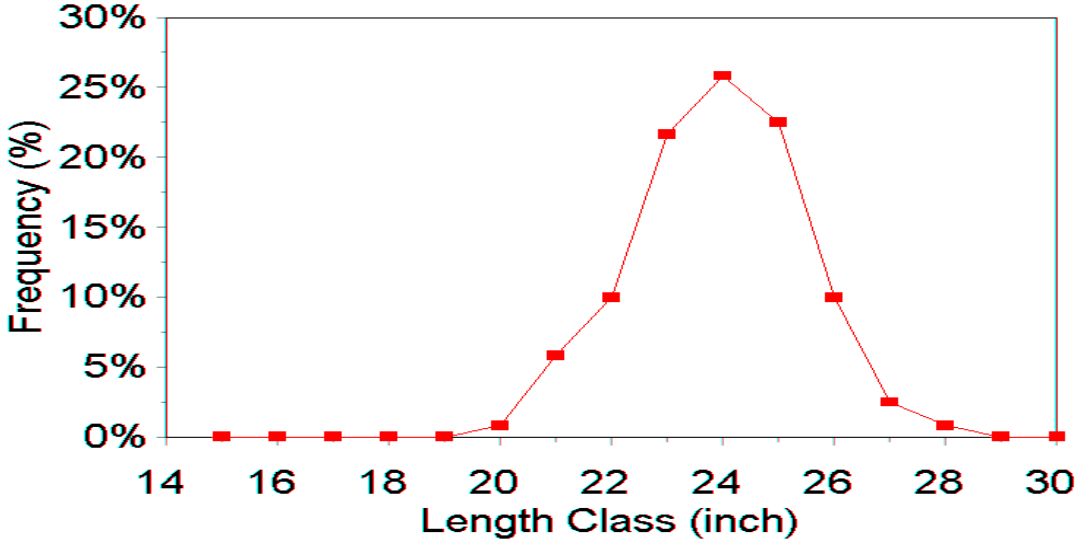


Figure 4. Plot of adult Pacific lamprey length frequency collected at the John Day Dam fish ladder on 1/8/97.

Discussion

Juvenile Lamprey Investigations

The literature review illustrates the need for additional data collection that more clearly defines juvenile passage and migration needs. Fyke net studies document substantial variation in juvenile lamprey passage within a few days time. This information combined with continued uncertainties regarding impacts from juvenile salmonid bypass illustrate the need to more clearly define lamprey passage and migrational trends to reduce potential impacts during the juvenile outmigration. Increased coordination with other juvenile anadromous fish (e.g. salmonids) studies, particularly those assessing predation and river operation impacts on juvenile salmonids, should be encouraged to gather additional information on juvenile lamprey.

Finally, ongoing and proposed juvenile salmonid collection and transportation operations must factor in the passage and migration aspects of juvenile lamprey. The current uncertainty regarding the impacts of fixed bar screens needs to be quantitified, not dismissed due to a lack of substantive data. The existing system of cleaning fixed bar screens at regular intervals supplemented by periodic video assessment will likely confirm the existing premise that juvenile lamprey are not impacted, since they are infrequently collected and mortalities would be scrubbed from the screens and washed downstream to be eaten by predators, not documented and reported.

Adult Lamprey Investigations

Interpreting and discussing lamprey count data is very problematic because of the lack of data collection for many years, the behavior of lamprey in the count stations, and the ability of lamprey to bypass count station windows.

Pacific lampreys were initially counted at all eight-mainstem Columbia and Snake river projects. Depending upon the year of initial operations, the data set may be extensive (e.g. Bonneville Dam) or fairly brief (e.g. Little Goose) (Close et al. 1995). Regardless of inception, the Corp of Engineers ceased to count lamprey on a regular basis beginning in 1969 through 1993 or later, depending upon the specific project. During this time period, escapement of Pacific lamprey into the Columbia river declined by orders of magnitude (Close et al. 1995). This lack of action combined with a plethora of counting techniques and methodologies, many of which did not include night counting, has created a complex data set that often cannot be used for direct comparisons. Regardless, trend analysis clearly shows widespread declines of Pacific lamprey both in the Columbia Basin and elsewhere (e.g. Oregon coastal rivers) (Close et al. 1995).

Counting lamprey can be very difficult particularly at Bonneville Dam. Upstream and downstream movement can be tremendous during high passage times. Tracking and counting individual lamprey can be very difficult on time-lapse videotape recordings. In 1997, we plan to use high-density, time-lapse recorders that will record three times more records using the same time-lapse mode. We hope that this will make tracking and counting individual fish easier.

Lamprey movement near the bottom of the fish counting chamber is very difficult to detect because of the lack of contrast between the fish and the background. This fact may have biased our counts at Bonneville Dam. Many lamprey swimming upstream near the bottom may not have been detected by counters, therefore, underestimating the upstream count. Conversely, lamprey moving downstream generally passed higher in the water column where detection is much easier and counting more precise. In 1997, we plan to further investigate these issues by occasionally stationing individuals on-site to exclusively count lamprey and comparing counts with those derived from video.

Lamprey can and do bypass count station windows by traveling behind the picketed leads at the crowder (Starky and Dalen 1995). Several radio tagged lamprey passed Bonneville Dam undetected but were detected at upstream dams in 1996 (Personal Communication John Vella, NMFS) indicating that lamprey may exit ladders in places that are not monitored. The magnitude of this movement is probably site and time specific but could have extraordinary impacts on enumeration programs. At Bonneville Dam additional uncounted lamprey may be exiting the Washington Shore fish ladder system at the old Cascade Island Count Station. This count station is not operated and fish are excluded from the area with picketed leads. Lamprey may be passing through these leads and exiting the system. This may have a big impact on Bonneville Dam lamprey counts since lamprey appear to use the Washington Shore ladder more than the Bradford Island facility. It would be interesting to monitor this exit during the lamprey radio tracking study conducted by NMFS. Other migration avenues through the dams probably are available for lamprey since they can move through pickets and course screens.

Besides at Bonneville Dam, lamprey may be passing other dams undetected. In 1996, lamprey counts at Rock Island Dam were 2,121 this number dropped to 593 at Rocky Reach the next dam upstream, leading one to believe that lamprey may have turned off in the Wenatchee River for spawning, however 979 lamprey were counted upstream at Wells Dam. This suggests that 1) a sizeable population may be spawning in the Wenatchee River, however, we have recorded fish passage at Tumwater Dam (RM 32) on the Wenatchee River for about 10 years and have not seen any lamprey. The lower Wenatchee River should probably be sampled in the future to assess lamprey. These data also suggest that 2) many lamprey may be passing Rocky Reach undetected. In the Snake River, a similar pattern was present with lamprey counts at Ice Harbor and Lower Granite dams where 1995 and 1996 counts were reduced by 62% and 55%, respectively. Lamprey assessments should be carried out in that reach of the Snake River to identify potential production areas.

Recommendations

Juvenile Lamprey Investigations

1. Require comprehensive testing of fixed bar screens to determine impingement rates of juvenile lamprey prior to system-wide implementation of this guidance equipment.

2. Maintain data collection (e.g. length, weight, maturation level, condition, etc.) on juvenile lamprey at all juvenile salmonid collection facilities.

3. Attempt the development of passage indices for lamprey at selected projects using existing data.

4. Attempt to quantify the survival curves for juvenile lamprey using pressure chamber tests to simulate draft tube pressure extremes.

Adult Lamprey Investigations

1. Continue to review videotapes to estimate lamprey passage and length frequency at Bonneville, Ice Harbor, Lower Granite, Rock Island, and Wells dams.

2. Ground truth lamprey passage estimates with on-site counting at Bonneville Dam.

3. Modify fish counting stations to improve lamprey-counting precision.

4. Identify lamprey migration routes through dams that enable them to bypass count station windows.

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for

Pacific Lamprey Research and Restoration Project

Part (C) Adult Passage Research

by

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Abstract

To study the potential impact of dam passage on the reproductive success of adult Pacific lamprey (Lampetra tridentata), methods such as radio-tracking are being used by biologists in the Columbia River Basin. However, the key assumption in studies that employ radio tags is that tagged animals are representative in performance of untagged animals. To test this assumption, radio tagged adult Pacific lampreys were assessed for physiological recovery from the stress of the tagging procedure. Plasma levels of glucose (an indicator of stress) in lampreys implanted with 10 g tags were elevated compared to those in untagged controls at 4 months after the surgical procedure. However, glucose concentrations in lampreys implanted with smaller tags (3 g) were similar to controls. These results suggest that tagging methodology must be evaluated carefully before implementation in field studies.

Table of Contents

List of Figures

Introduction

The reasons for the decline of Pacific lamprey populations throughout the Columbia River Basin are unknown. One possible contributor to this precipitous fall may be migratory failure resulting from the inability of lampreys to negotiate passage around the dams within the Columbia River Basin. In order to determine if migration of adult lampreys is impaired by hydroelectric projects, methods for examining the behavior of adult lampreys around dams must be developed. Currently, NMFS biologists are using radiotelemetry to follow the movement of adult lampreys around Columbia River dams. One of the assumptions of radiotelemetry studies is that the radio tagged animals behave like untagged' animals; however, this assumption must be verified. One part of the verification process is to examine if radio tagged adult lampreys have recovered from the stress of the radio tagging procedure. Another step in the verification process is to assess the swimming performance of radio tagged individuals. Finally, even if adult lampreys successfully negotiate passage, it is important to estimate the physiological condition of lampreys to determine if passage constitutes an excessive metabolic cost that reduces the likelihood of successful further migration. The objectives undertaken in the first year of study by Oregon State University, were 1) to develop clinical indicators of stress for adult lampreys; and 2) to use these indicators to assess whether and when radio tagged lampreys recover from the procedure.

Methods

Animals. Adult Pacific lamprey were collected at the fish passage facility at Willamette Falls (near West Linn OR) and transported by truck to the Fish Performance and Genetics Laboratory at Corvallis, OR. The animals were treated with salt (at 7 ppt) during transport and subsequently with formalin (at 167 ppm) once per week for 4 weeks to prevent fungal infection. Fish were also treated with oxytetracycline (0.05-0.10 ml) to combat bacterial infection. Fish were maintained in flow-through 0.9 m diameter tanks supplied by well water at a temperature of 12-13 C. Adult lampreys do not feed during the freshwater phase, therefore, the animals were not fed during the study.

Experimental Design. The first set of experiments, were designed to assess the utility of several classical physiological indicators of stress for use in Pacific lampreys. In experiment 1A, adult lampreys (n=6) were stressed by placing them in a dewatered bucket for 5 min and then returning them to their original tank. After 1 hour, the fish were sampled for blood. In experiment 1B, adult lampreys were distributed into 0.9 m diameter tanks (n=5/tank). Each tank was randomly assigned a sampling time (i.e. no individual fish was sampled more than once). After two weeks of acclimation, the fish were sampled before the stress (controls; time = 0) or stressed by placing them in a dewatered 20 L bucket for 5 minutes and then returning them to their original tank. At each sampling time (0, 0.5, 1, 4, 24, or 48 hours after the stress), one tank of lampreys was sampled (see below). This sampling design was repeated 5 weeks later with different fish. In experiment 1B, adult lampreys were distributed among tanks (n = 5/tank; 2 tanks/sampling time), acclimated, and stressed as before; however, the replicate tanks were sampled at 0 (controls), 1, 24, 72, or 168 hours (7 days) after stress.

The second experiment was designed to examine the effects of surgical implantation of radio tags on adult lampreys. In experiment 2A, adult lampreys (n = 5 fish/treatment) were anesthetized in MS-222 and then implanted with a 3 gram tag. Control fish were treated the same as tagged fish, but no tag or sutures were used. At 1, 6, 24, hours after completion of surgery, the fish were anesthetized and sampled for blood. In experiment 2B, adult lampreys (n = 4 fish/tank; 3 tanks/replicate treatment) were either implanted with a 3 gram tag (tagged), put through implantation surgery but without tag implantation (sham), or anesthetized but otherwise left intact (control). In addition, other lampreys (n = 6 fish/treatment) were implanted with either a 10 gram tag (10 gram tagged) or left intact (10 gram control) by John Vella at the National Marine Fisheries Service in Pasco Washington, and then transported back to Oregon State University four weeks after surgery. Fish were sampled for blood at 4 months after completion of surgery.

Physiological Sampling. Lampreys were anesthetized in tricaine methansulfonate (MS-222; 600 mg/L for lethal sampling; 200 mg/L for non-lethal sampling) buffered with sodium bicarbonate and then a blood sample was collected from the caudal vein with a vacutainer needle. The plasma was separated by centrifugation and stored for analysis at –80 C. In those instances in which muscle lactate was to be determined (experiment 1B), the fish were lethally sampled. After sampling for blood, a small (approximately 1.5 g) piece of muscle was removed with a scalpel from just below the first dorsal fin, snap frozen in liquid nitrogen, and then stored at -80°C.

Plasma samples were analyzed for cortisol by radioimmunoassay (Redding et al. 1984), for glucose by colorometric assay (Wedemeyer and Yasutake 1977), and for lactate by colormetric assay (Pasonneau 1974); plasma chloride levels were determined by Bill LaVoie at the Idaho Cooperative Fishery Research Unit.

Statistical analysis. Plasma levels of glucose and chloride were compared by ANOVA followed by multiple range testing using Duncan's LSD method. The significance level was set at $p^{2}0.05$.

Results

In experiment 1A, all six lampreys subjected to 5 minutes of dewatering had non-detectable levels of plasma cortisol. In experiment 1B, lampreys stressed similarly increased plasma glucose from 47.8 mg/dl (mean) at time 0 to 57.3 mg/dl (mean) within 30 minutes of stress (Fig. 1). Glucose peaked at 4 hours (mean = 65.9 mg/dl) and remained elevated for 48 hours (mean = 60.8 mg/dl). Mean plasma levels of lactate increased from 17.5 mg/dl before stress to 48.3 mg/dl at 30 minutes; however, due to large variation in plasma levels at 30 minutes, this increase was not statistically signficant. Muscle lactate varied widely after stress. Resting level of plasma chloride decreased significantly from 97.7 mEq/L to 93.0 mEq/L by 4 hours, but returned to resting levels (99.2 mEq/L) by 8 hours; however at 24 hours, levels again were significantly lower (91.4 mEq/L) before returning to resting levels at 48 hours (97.9 mEq/L).

In experiment 1C, stressed lampreys increased plasma glucose levels significantly from a mean resting level of 45.4 mg/dl to 59.0 mg/dl within 1 hour of a 5 minute dewatering stress (Fig. 1). The mean level of glucose at 24 hours (52.1 mg/dl) was not significantly different from the mean at time 0; however, mean glucose at 72 hours (59.8 mg/dl) was significantly higher than the mean at time 0. At 168 hours (7 days), mean glucose (46.5 mg/dl) was not significantly different from that at time 0.

In experiment 2A, plasma glucose levels at 1, 6, 24 hours did not differ significantly between control and tagged adult lamprey (Fig. 2). In experiment 2B, plasma glucose levels at 4 months post-surgery were significantly higher in lampreys that had been implanted with 10 gram tags in comparison to 10 gram controls; however, fish implanted with 3 gram tags had glucose levels similar to both sham and control lampreys (Fig. 3).

Discussion

The steroid hormone cortisol becomes elevated after stress in many species of fish, such as salmon; however, the first experiment indicated that stressed Pacific lampreys do not have detectable levels of cortisol. In addition, plasma lactate, muscle lactate, and chloride varied widely after stress. Thus, cortisol, lactate, and chloride may not be good indicators of stress in Pacific lampreys. However, adult lampreys respond to a five-minute dewatering stress by elevating plasma glucose within 30 minutes to a peak at one to four hours after stress. Therefore, the use of glucose as a clinical indicator of stress has been confirmed for Pacific lamprey. Glucose levels remain higher than resting levels for up to three days and do not return to pre-stress levels until seven days. These results suggest that adult Pacific lamprey may require holding for some time after radio tagging before physiological recovery from the stress of surgery.

Plasma glucose levels did not differ significantly between untagged lampreys and lampreys with 3 gram tags. Adult lamprey with 10 gram tags exhibited significantly higher glucose levels than controls. These results suggest that 3 gram tags have less of an impact on Pacific lampreys and are recommended for use. In those cases inwhich heavier tags are required, caution should be excercised in generalizing the results to natural populations of lampreys.

Future studies at Oregon State will focus on the swimming performance of radio tagged adult Pacific lampreys in comparison to untagged lamprey. In addition, further studies on the use of physiological indices of stress and exhaustion will be conducted to determine if fish passage facilities are perceived as stressful to adult lampreys and if the metabolic cost of negotiating such fishways is excessive and therefore, impairing survival.

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