Pacific Lamprey Larvae Life History, Habitat Utilization, and Distribution in the South Fork Clearwater River Drainage, Idaho

Technical Report
2000 - 2002

DOE/BP-00004039-3

April 2004

This Document should be cited as follows:

Claire, Christopher, "Pacific Lamprey Larvae Life History, Habitat Utilization, and Distribution in the South Fork Clearwater River Drainage, Idaho", 2000-2002 Technical Report, Project No. 200002800, 87 electronic pages, (BPA Report DOE/BP-00004039-3)

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

PACIFIC LAMPREY LARVAE LIFE HISTORY, HABITAT UTILIZATION, AND DISTRIBUTION IN THE SOUTH FORK CLEARWATER RIVER DRAINAGE, IDAHO

A Thesis

Presented November 2003 in Partial Fulfillment of the Requirements for the

Degree of Master of Science

with a

Major in Fishery Resources

in the

College of Graduate Studies

University of Idaho

by

Christopher W. Claire

Major Professor: George W. LaBar, Ph.D.

April 2004

AUTHORIZATION TO SUBMIT

THESIS

This thesis of Christopher W. Claire, submitted for the degree of Master of Science with a major in Fishery Resources and titled **"PACIFIC LAMPREY LARVAE LIFE HISTORY, DISTRIBUTION, AND HABITAT UTILIZATION IN THE SOUTH FORK CLEARWATER RIVER DRAINAGE, IDAHO,"** has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor ________________________________Date______________
George W. LaBar

Committee Members ________________________________Date______________
Tim Cochnauer

________________________________Date______________
James J. Nagler

Department Administrator ________________________________Date______________
George W. LaBar

College of Natural Resources Dean _________________________________Date______________
Steven B. Daley Laursen

Final Approval and Acceptance by the College of Graduate Studies

_________________________________Date______________
Margrit von Braun

ABSTRACT

Pacific lamprey *Lampetra tridentata* are a native Snake River basin fish species occupying a unique ecological niche. Pacific lamprey ammocoetes historically were an important food for Snake River white sturgeon *Acipenser transmontanus* populations and are thought to contribute to Snake River basin aquatic productivity. Recent decline of returning Pacific lamprey adults to the Snake River basin has focused attention on the species. Adult Pacific lamprey counted migrating upstream past Ice Harbor Dam fishway averaged 18,158 during 1962-69 and 352 during 1993-2001.

In 2000-2002 we employed trapping, electrofishing, and visual redd surveys to determine life history strategies, habitat utilization, distribution, and total number of Pacific lamprey ammocoetes (larvae) and macrothalmia (juveniles) in the Red River subbasin, South Fork Clearwater River drainage, ID. A total of 272, 488, and 526 Pacific lamprey were captured in 2000, 2001, and 2002 respectively. Downstream migration of ammocoetes and macrothalmia in Red River occurred predominantly (94.5%) in the April 1 – June 30 period, with a limited number (5.5%) from July 1 – October 31. Ammocoete average density was 25.7/100 m^2 in Red River lateral and straight scour pool habitat, 4.4/100 m^2 in riffle habitat, 2.1/100 m^2 in rapids habitat, and 253.3/100 m^2 in alcove habitat. Ammocoetes were found in water depths ranging from 1.0 cm to 1.0 m, however, the two greatest densities were observed in habitat units with maximum depths >0.50 m during July, August, and September. Pacific lamprey ammocoete density decreased in Red River (sampled units) with increasing stream habitat flow velocity, decreased with increasing coarse substrate, increased with increasing medium substrate, increased with increasing fine substrate, and increased with increasing stream riparian canopy (shade). Pacific lamprey were found in Red River with stream temperatures up to 26.7^{0}C, however, substrate temperatures averaged 2.2^{0}C less than stream temperatures. Pacific lamprey distribution was limited to Red River (rkm 7.5 to the mouth) and the South Fork Clearwater River. The Red River ammocoete and macrothalmia population was estimated to total 20,593 ± 82,359 (rkm 0.0-7.5).

Pacific lamprey may be nearing extinction in the Snake River basin. Key habitat and distribution information in the Columbia River basin and Snake River subbasin is limited. Determining Pacific lamprey habitat requirements and maintaining adequate habitat are foundational for persistence of Snake River basin Pacific lamprey populations critically in decline.

ACKNOWLEDGEMENTS

It is necessary to express forward and firm appreciation to those who without their contribution, the project would have been greatly reduced in magnitude, scope and refinement. Idaho Department of Fish and Game provided the organizational framework for completion of field work and contributed logistical support. Tim Cochnauer (Idaho Department of Fish and Game, Sr. Fishery Research Biologist) envisioned the project from infancy with knowledge of wild fish ecology, which provided for the evolution of the project to a greater understanding of a little known species. Jody Brostrom (U. S. Fish and Wildlife Service) increased the initial foundational structure of the work with her collection of information and primary Pacific lamprey field data. The Bonneville Power Administration and Deborah Docherty worked faithfully to administer funding and to coordinate the interagency needs of Idaho Department of Fish and Game and the Bonneville Power Administration. It is strategically important to express thanks to the University of Idaho for contributing (indirect funding) to the Pacific lamprey study and to Dr. George LaBar (University of Idaho, Fish and Wildlife Resources Department Head) for steady understanding of work schedules, logistical complications, data manipulation menageries, and for infusing expert advice and funding. Dr. Dale Everson (University of Idaho, College of Statistics) essentially re-enlisted from retirement to manipulate data concerning a species which was perhaps unknown to him. Without his firm grasp of numerical relationships the project would have required a greatly increased effort to clarify the ecology of the species.

Four Idaho Department of Fish and Game biological aides likely impacted the Pacific lamprey project as much those mentioned thus far. Anne Peterson with her doggedly persistent data management increased the foundational scope of the project. Her consistent fieldwork skills and loyalty to the resource were forthright in establishing the project (thanks for cleaning the lunch box, (not the work one)). Rebecca Repp with her fascination of biological systems contributed daily to clean assessment of habitats and documenting of biological parameters. Kyle Steele worked in inclement and enjoyable conditions obtaining field information with persistence. Terry Douglas recognized the need for energy input into field habitat assessment and was always implementing that energy at work.

Special appreciation is expressed to Dr. D. H. Bennett for his ability to endure soul baring comments and maintain a personal connection. Dr. J. J. Nagler repeatedly worked with good humor in unscheduled meetings. Edwin Buettner is recognized for his support, his love of the truth, and respect for wild salmonids.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Pacific lamprey *Lampetra tridentata* are considered primitive and have an ancestry dating back 400+ million years (Bond 1996). Pacific lamprey are anadromous and parasitic during the ocean phase. They often migrate upstream in the night as well as during daylight hours. Pacific lamprey spawn and rear in coastal and inland streams from the coast of southern California to Alaska (Simpson and Wallace 1982). Pacific lamprey ammocoetes occupy freshwater stream substrates for four to seven years (Beamish and Levings 1991) where they filter-feed on plant and animal detrital (likely desmids, diatoms, and protozoa (Creaser and Hann 1929)) material (Richards and Beamish 1981). It is unknown if reaching critical size or age is required before Pacific lamprey ammocoetes (larvae) undergo transformation (Richards and Beamish 1981) into macrothalmia (juveniles) and migrate to the ocean to begin a parasitic phase. Transformation changes include restructuring of the mouth into an oral disk with rasping mouthparts, development of eyes, growth of teeth needed to attach to prey, and other structural alterations including expansion of the tail among others. Following an estimated one to two year period parasitically feeding in the ocean, Pacific lamprey return to spawn in fresh water (Beamish and Levings 1991). Pacific lamprey survive only a short time after semelparous spawning.

The Pacific lamprey was historically abundant in the Columbia River basin (Close et al. 1995), perhaps numbering in the millions. Two other species of lamprey, the river lamprey *L. ayresii* and western brook lamprey *L. richardsoni* coexist with Pacific lamprey in the Columbia River (Kan 1975). Western brook lamprey have been observed in Oregon and Washington streams (Jackson et al. 1997), however, neither river lamprey nor western brook lamprey have been found in Idaho streams (including the Snake River) (Jennifer Bayer, Columbia River Research Laboratory, personal communication).

Pacific lamprey provided food for and were culturally significant to Native American inhabitants of the Columbia River basin and Snake River subbasin before white settlement (Close et al. 1995). In addition to utilization as an energy source, Pacific lamprey also were used in ceremonies, and for medicinal purposes. Native Americans harvested Pacific lamprey at the mouth of the Snake River and at Wallula on the Columbia River near the mouth of the Walla Walla River (Close et al. 1995). Swindell (1941) documented testimony of Native American use of Pacific lamprey adults in the main Columbia River during the late 1800's and early 1900's. The Pacific lamprey is still significant in Native American Culture (Close et al. 1995) and they are harvested in the Willamette and Umpqua Rivers, in Oregon (David Close, Umatilla Tribal Fisheries, personal communication).

It is likely that Pacific lamprey ammocoetes and macrothalmia comprised a significant percentage of the aquatic predator diet historically in the Snake River (downstream of Shoshone Falls) and Columbia River corridors during spring period Pacific lamprey, salmon (*O. tshawytscha, O. nerka,* and *O. kisutch*), and steelhead trout *O. mykiss* downstream migrations (Close et al. 1995). Predator utilization of Pacific lamprey ammocoetes and macrothalmia potentially reduced predator dependence on salmon and steelhead trout outmigrating juveniles (Close et al. 1995). Pacific lamprey ammocoetes and macrothalmia provide food for white sturgeon *Acipenser transmontanus* (Galbreath 1979), northern pikeminnow *Ptychocheilus oregonensis* (Poe et al. 1991), and other Columbia River basin aquatic and avian predators. Pacific lamprey ammocoetes, macrothalmia, and adult brook lamprey accounted for (70.8%) of the contents in stomachs of gulls *Larus* spp. near McNary Dam in the main Columbia River (Merrell 1959). Limited returns of adult Pacific lamprey to the Columbia River basin and Snake River subbasin have potentially resulted in minimal recruitment of Pacific lamprey ammocoetes and macrothalmia in the basins and reduction in the number of outmigrants in the predator prey base.

Hydroelectric impacts and alteration of rearing habitat are considered to be two major factors contributing to Pacific lamprey decline in the Columbia River basin and Snake River subbasin (Jackson et al. 1996). Hydroelectric facilities are suspected to be the single greatest source of Pacific lamprey ammocoete and macrothalmia mortality in the Columbia River basin (upstream of Bonneville Dam) and the Snake River subbasin (Pacific lamprey Technical Workgroup, personal communication). Bypass and collection facilities at hydroelectric projects in the Columbia River basin and Snake River subbasin were constructed to facilitate collection and improve survival of salmon and steelhead trout downstream migrants (Idaho Chapter, American Fisheries Society 1992). It is likely, however, that pressure changes and contact with juvenile salmon and steelhead trout bypass systems at dams contribute to mortality of migrating Pacific lamprey ammocoetes and macrothalmia (Jackson et al. 1996). Impingement of ammocoetes on turbine bypass equipment commonly occurs (Larry Barrett, Idaho Dept. of Fish and Game, personal communication). Additionally Pacific lamprey adults experience difficulty navigating fish ladders at dams during upstream migration (Vella et al. 1997). As a result Pacific lamprey upstream migrant numbers diminish with upstream migration distance and immigration of spawners into tributary streams, but predominantly due to the number of hydroelectric projects Pacific lamprey attempt to navigate.

It is not clear how changes in ocean productivity affect ocean phase survival and subsequent Pacific lamprey adult returns to the Columbia River. It is commonly known that ocean productivity greatly impacts salmon and steelhead returns to the Columbia River. However, Pacific lamprey populations in the Columbia River basin have declined irrespective of ocean productivity cycles in the last 40 years (Close et al. 1995) (Figs. 1-4).

While Pacific lamprey outmigrant mortality and upstream adult passage problems at hydroelectric projects likely contribute to Pacific lamprey decline in the Snake River subbasin, significant habitat alteration to spawning and rearing streams since 1850 have potentially resulted in reduced Pacific lamprey production in the Columbia River basin and Snake River subbasin as well. Jackson et al. (1996) cited mining, logging, and several other land uses as having potential negative impacts affecting Pacific lamprey ammocoete rearing conditions. Close et al. (1995) suggested that elevated stream temperatures due to riparian canopy removal may be negatively impacting juvenile and larval Pacific lamprey populations in a significant number of Columbia River basin streams. Obtaining knowledge of the habitat requirements and preferences of the species is paramount to provide the foundational information to restore and maintain Columbia River basin and Snake River subbasin Pacific lamprey populations.

Little is known about Pacific lamprey rearing habitat requirements and utilization in the Columbia River basin. Hammond (1979), however, provides documentation of Pacific lamprey ammocoete habitat for selected sites in the Potlatch River in Idaho.

Pletcher (1963) provided extensive information on lamprey life history in the Salmon River, British Columbia, including documentation of selected stream habitats where Pacific lamprey ammocoetes were captured. The Clearwater River drainage (Selway River, Lochsa River, South Fork Clearwater River (SFCR)) and Red River subbasin in North Central Idaho currently support a population of Pacific lamprey. Outmigrating lamprey ammocoetes and macrothalmia caught at salmonid traps in the SFCR basin have been identified as Pacific lamprey using morphological assessment (Jennifer Bayer, Columbia River Research Laboratory, personal communication). Red River subbasin in the SFCR drainage, Idaho has considerable stream habitat variability. Determination of Pacific lamprey life history and habitat utilization requires extensive examination of the subbasin's stream habitats.

OBJECTIVES

1. Determine specific life history attributes (downstream migration timing, magnitude, transformation timing, length/weight relationship, and population structure) of Pacific lamprey ammocoetes in Red River, SFCR drainage, ID.
2. Determine the habitat utilization of Pacific lamprey ammocoetes in response to six stream parameters: habitat type, habitat unit flow velocity, depth, substrate (cover), temperature, and riparian canopy, in Red River, SFCR drainage, ID.
3. Determine the distribution of Pacific lamprey ammocoetes in the SFCR drainage, ID.
4. Determine the (minimum) population number of Pacific lamprey ammocoetes in Red River, SFCR drainage, ID.

HYPOTHESES

Pacific lamprey ammocoete habitat utilization in a stream potentially reflects several factors including substrate type, water velocity, and stream depth (Hammond 1979). It is suspected that several of these stream habitat factors will explain habitat utilization of Pacific lamprey ammocoetes in the Red River drainage**.** The following hypotheses directly relate to Red River Pacific lamprey larvae habitat utilization and preference.

Ho: Pacific lamprey larvae use of Red River stream habitat shows no relationship to the stream habitat parameters: Habitat type, stream velocity, stream depth, stream substrate, stream temperature, and stream riparian canopy cover.

Ha: Pacific lamprey larvae use of Red River stream habitat reflects relationship to the above listed stream habitat parameters.

PROJECT AREA HISTORY

The Clearwater River drainage in North Central Idaho encompasses approximately 2.5 million hectares. The SFCR, a major tributary to the Clearwater River, drains 300,440 hectares. Glaciation in the SFCR drainage (Figs. 5 and 6) occurred primarily in the John's Creek and Crooked River drainages as indicated by glacial lakes in the headwaters of these streams. Vegetation in the SFCR drainage is primarily coniferous in the upper reaches with grand fir *Abies grandis,* lodgepole pine *Pinus contorta,* Douglas fir *Pseudotsuga menziesii,* and spruce *Picea engelmanii* dominating the uplands. The stream riparian corridor tree species in the upper reaches are largely alder *Alnus* spp., willow *Salix* spp., Osier *Osier* spp., and spruce. Lower SFCR drainage upland vegetation is a mixture of ponderosa pine *Pinus ponderosa,* Douglas fir, and grasses, with alder, willow, and black cottonwood *Populus trichocarpa* in the stream corridors.

The current land ownership in the SFCR drainage is U.S. Forest Service (68%), private (28%), Bureau of Land Management (2%), Nez Perce Tribe (0.9%), and State of Idaho (0.7%). Land use in the SFCR drainage is predominantly forestry related in the upper SFCR basin with livestock production grazing in middle and lower reaches. Historically, mining was centered in the upper reaches. Wide-spread mining from the 1860's to the mid-1900's occurred in four SFCR tributaries Crooked River, Red River, American River, and Newsome Creek. Bucket dredge mining occurred in the early 1900's in the upper SFCR drainage and the Red River subbasin (USDA Forest Service 1998). Dredging impacted numerous stream reaches to a high degree, confining the channel, reducing habitat diversity, eliminating riparian canopy, and directly discharging sediment into Red River. Several kilometers of Red River today remain channelized or constricted by dredge tailings, resulting in little sinuosity and pool habitat. Mining in the watershed has impacted fish production in varying degrees through sedimentation, channel alteration, and riparian habitat degradation.

Information is limited pertaining to anadromous species populations in the SFCR drainage before 1900. Harpster Dam was constructed by Grangeville Electric Light and Power Company in 1910 at river kilometer (rkm) 32.0 on the main SFCR. In 1937 Avista Utilities (formerly Washington Water Power) acquired the dam. Pacific lamprey migration was likely possible, but restricted, over the dam from 1935 to 1949. High flows destroyed the fishway in 1949 eliminating adult salmonid passage until the dam was removed in 1963 (USDA Forest Service 1998). The impact to Pacific lamprey upstream migrants is unknown.

Red River joins American River 8.0 km west of Elk City, ID, to form the SFCR at SFCR rkm 83.0. The Red River watershed (41,824 hectares) contributes the single largest flow volume to the SFCR. The lower section of the river is tightly confined in a canyon with relatively steep walls rising 60 to 80 meters before leveling off to a gradually rising timbered main ridge on both sides of the river. Stream wetted width in the lower reach is generally 11.0-15.0 m during August and September. The middle section of Red River flows through a moderately confined conifer-vegetated canyon reach and two large meadow complexes. The river is confined by stream channel rock through several kilometers of the middle section with moderate sinuosity present in the meadows. Like the lower section, the August and September stream wetted width in the middle section is 10.0-15.0 m. The upper section of Red River flows through a timbered canyon and two small meadow complexes (~20 ha). The August and September stream wetted width in the upper section is generally <10.0 m.

Stream habitat geomorphology is widely diverse in the Red River subbasin. The lower section of the river is predominantly boulder confined, but contains pockets of finer substrates. The middle section is sandy substrate dominated providing usable quality habitat for Pacific lamprey ammocoetes even though the stream riparian community is grass and sedge dominated and stream shading is limited. The water temperatures in the upper basin are cooler in response to groundwater input and greater riparian shading, providing habitat refuge from temperature extremes encountered in the other sections.

The meadow complexes in the middle section (Siegal Creek to South Fork of Red River) of Red River have historically been subjected to heavy seasonal livestock grazing. Livestock historical use of the reach has degraded streambanks, contributed to widening of the stream, and reduced hardwood component of the riparian community to insignificant levels (USDA Forest Service 1998). The stream in this reach is shaded only by topography or dispersed conifers resulting in high solar input into the stream with limited shading of the water from the sun under stream banks. Protected reaches of the middle section of Red River have alder and willow hardwood regeneration, however, the recovery duration to climax may be decades, due to severe winter stream channel ice scour, limited summer growth period (June, July, and August), and wildlife utilization of shrubs. Several reaches (rkm 14.0, 15, and 16) of the middle section of Red River have been channelized, reducing the stream habitat complexity, altering bedload transport, decreasing channel stability, and impacting stream productivity. The mining in the middle section occurred mostly in the lower sections of the upper meadow and the canyon reach separating the meadows. Reworking of the stream and tailings piles following mining has made historical materials less visible, giving the appearance that stream channel stability is greater than actually exists. Excessive stream temperatures limit salmonid production in the section (USDA Forest Service 1998). The upper middle section of Red River (South Fork of Red River to Red River Campground) supports limited riparian hardwood vegetation 1.0 – 3.0 m in height. The riparian plant community has a high incidence of young plants with few mature, possibly as a result of recovery following historical livestock and wildlife grazing. Alder and willow regeneration is present throughout most of the section. Most of the streambanks in the upper middle section are vegetated with hardwoods, grasses, and sedges *Juncus* spp..

The Red River upper section (Red River Campground to Red River Hotsprings) meadow complex is entirely in private ownership. Historical grazing and stream channelization impacts are visible in the section. Currently outfitter packstock further degrade the riparian community or keep the hardwood component in early regenerative stages. The channel stability is, however, higher in this upper meadow complex reach than in the middle section. Smaller stream size in the reach results in reduced stream destabilizing process forces, i.e. the size of winter ice jams, debris, and substrate transported during winter or peak flow events. The headwater reach of the upper section of Red River runs through a timbered canyon and observations indicate high bank stability in the section.

Timber harvest and road building since the 1850's (largely since 1930) have elevated sediment input into Red River above background levels (USDA Forest Service 1998) potentially impacting chinook salmon, steelhead trout, and Pacific lamprey populations in the subbasin. The current Equivalent Clearcut Area of the Red River subbasin is (12%) which is greater than in other SFCR subbasins. The 947 km of road in the subbasin reduce runoff travel time in the drainage, potentially impacting hydrologic regimes and contributing to increased peak flows.

METHODS

We determined the 41 1-kilometer Red River sections on USGS 1:24,000 quadrangle maps from mouth to headwaters. In 2000-2002 one-hundred meter subsample stream reaches were randomly selected from 41 1-kilometer sections and the stream habitat was classified as pool, riffle, glide, etc., (Table 1) using a modified version of stream classification methodology utilized in Platts et al. (1983) and Overton et al. (1997). Stream habitat measurements taken in sampled habitat units included: wetted width, channel width, habitat unit length, maximum depth, average flow velocity, substrate (cover) size percent composition, stream temperature, and riparian canopy cover percent (shade). In 2001 and 2002 random sampling was restricted to Red River downstream of rkm 7.5 to in order to adjust to known Pacific lamprey distribution.

The substrates within habitat units (riffles, pools, etc.) were visually classified using Platts et al. (1983) size classification (Table 1). Substrate classification transects perpendicular to the thalweg of the stream channel at three points (25%, unit center, and 75% of the distance from the downstream to upstream boundary) in a habitat unit were used to augment and calibrate visual estimation in 2000. Water velocity measurements were taken with a mechanical flow meter 1.0 cm above substrate (Hammond 1979) and at 60% of depth above the substrate in a habitat unit; at 25% from left bank, stream center, and 25% from right bank. Habitat unit flow velocity measurements were also taken at 20% and 80% of depth (at the three locations) above the substrate if the depths were greater than two meters. Maximum depth was recorded in individual units. Individual water velocity and site depth measurements were taken over substrates where Pacific lamprey ammocoetes were captured on emergence. Individual site emergence flow velocity measurements for each unit were averaged. Substrates yielding Pacific lamprey ammocoetes were documented. Canopy cover (shade) values were obtained using a standard concave forestry densiometer with only 17 of the total 25 squares corner points uncovered. Readings at three locations left bank, right bank, and stream center were taken in a habitat unit at one-half the distance from downstream boundary to upstream boundary. The densiometer was held 30 cm above the water surface and 30 cm from the wetted edge while obtaining left bank, and right bank readings. Upstream and downstream (2 total) readings were taken at stream center 30 cm above the water surface. The total of counted densiometer squares for an individual location was multiplied by

1.5, (normal densiometer readings utilize 25 uncovered points, 17 x 1.5 = ~25 (25.5)) yielding a reading of one-quarter of the total stream shade. The four measurements were summed to obtain canopy cover in a unit.

The habitat types in the 100 m reaches were electroshocked systematically with an Engineering Technical Services ABP-2 electroshocker from the downstream habitat type, working upstream without repeating sampling in like habitat types. Stream habitat units were electroshocked from bank to bank working upstream from the lowermost point of the riffle, pool, glide, etc., being sampled to the upstream end to ensure complete coverage of the unit. Effective electrofisher settings were optimized, recorded, and repeated throughout units electrofished to standardize effort. Electroshocking elapsed times were recorded and electroshocking effort per unit of area was expressed as m^2 electroshocked/minute. Pacific lamprey abundance in a unit was expressed as ammocoetes/100 m^2.

Pacific lamprey ammocoete minimum population estimates in Red River were completed following Pajos and Weise (1994) and Morkert (1993) methodology, however, a one-pass effort was utilized to minimize impact to lamprey. The electroshocking catch per unit of area fished (lamprey/100 m^2) for individual habitat types was expanded for total habitat type area in a 100 m section. The Pacific lamprey densities were averaged for individual habitat types in a 100 m section and multiplied by the estimated stream habitat type area per kilometer of stream section. Minimum population estimates were determined for individual kilometers utilizing Pacific lamprey average density information obtained in corresponding kilometer reaches.

Non-random presence-absence electroshocking surveys were conducted on potential Pacific lamprey ammocoete habitat sites in the mainstem SFCR, SFCR tributaries, Red River, and the South Fork of Red River. Selection of sites was determined utilizing initial sampling information indicating Pacific lamprey ammocoete preferred habitat. Five sites were sampled in upper Red River upstream of rkm 24.0, six in the South Fork of Red River (rkm 1.5 to rkm 8.0), and 23 in the main SFCR (mouth to Red River) and tributaries (Fig. 6). Capture locations were recorded and mapped in order to assess distribution of Pacific lamprey ammocoetes in the SFCR basin and Red River subbasin.

Three downstream migrant traps currently operated by Idaho Department of Fish and Game (IDFG) in the SFCR drainage were used to monitor Pacific lamprey ammocoete and macrothalmia downstream movements and assist in determining SFCR drainage (Table 2) Pacific lamprey distribution. Traps were operated 24 hours and checked twice daily (a.m. and p.m.). The Crooked River scoop trap (rkm 1.0) was operated in 2000 and 2001. In 2002 a 1.50 m diameter rotary screen trap replaced the scoop trap on Crooked River. A 1.50 m diameter rotary screen trap on American River (rkm 3.0) and another 1.50 m diameter rotary screen trap on Red River (rkm 5.0) were operated in 2000, 2001, and 2002. Red River rotary screen trap historical records (1992-1999) were examined to augment Pacific lamprey 2000-2002 downstream migration information. Outmigrant estimates past traps were made using (Beamish and Levings 1991) trap-area fished methods.

Captured Pacific lamprey were anesthetized, enumerated, measured for total length, weighed, and released near the capture location following recovery in fresh water.

Pacific lamprey (>100 mm TL) captured while electroshocking were marked with injections of florescent orange elastomeric solution (0.5 cm in length) under the skin. Mark orientation and location was differentiated to distinguish between field seasons with marks in 2000 on the left side, posterior to the gill openings, and in 2001 on the right side, posterior to the gill openings. No Pacific lamprey ammocoetes were marked in 2002 due to the limited potential for recapture and the stress of marking to the individual ammocoetes.

Eight kilometers of Red River and its tributaries with suitable substrates (Red Horse Creek, South Fork of Red River) were visually surveyed for spawning adult Pacific lamprey from April 19 to July 7 in 2000 (Appendix A1). Seven kilometers of Red River and its tributaries were surveyed from April 30 to July 1 in 2001. In 2002, 0.3 km of Red River were surveyed once on June 7. In 2000 redd surveys were primarily upstream of Red River rkm 13.0. In 2001 redd surveys were expanded to include habitat in the Red River rkm 7.5 section and the lower reaches of Red Horse Creek. Redd surveys were reduced to one section in 2002 due to the suspected limited number of adult spawners (Fig. 3) in the subbasin.

Red River stream temperature information was obtained from the (IDFG) Red River trap (rkm 5.0) and plotted to determine maximum annual stream temperature in the subbasin. Stream temperature and substrate temperature were both measured at ten Red River sites on August 9, 2001. The substrate temperatures were obtained at 10.0 cm beneath the substrate surface in fine gravel-fine silt deposits.

Analysis

Pacific lamprey ammocoete habitat preferences were analyzed with Analysis of Variance (ANOVA). For analysis, Pacific lamprey density (ammocoetes/m^2) values for individual habitat types were utilized. The natural log average Pacific lamprey ammocoete density values for individual lateral scour pools, riffles, rapids, etc., were analyzed to determine if mean Pacific lamprey densities were different. The Pacific lamprey density values in lateral scour pool and straight scour pool habitats were analyzed as "lateral scour pool" (a single habitat type) average densities due to similarity in the structure of the two habitats. The riffle and riffles with pockets (pocket water) densities were combined and analyzed as "riffles" due to similarity in the structure of the two habitats. ANOVA requires an average value (of two or greater samples), therefore the single alcove habitat unit Pacific lamprey density was not included in ANOVA of the ammocoete density and habitat type relationship.

The Pacific lamprey ammocoete density relationship to stream habitat unit parameters (water velocity, maximum depth, canopy cover (shade), and substrate type) were assessed through linear regression and modeled with best fit step-wise multiple regression. To simplify analysis, Pacific lamprey ammocoetes/$\underline{m}^2$ natural log values rather than ammocoetes/$\underline{100\ m}^2$ were utilized. Linear and multiple regression F-tests (α = 0.05) were utilized to determine the strength of the relationship between ammocoete density and stream parameters. The Pacific lamprey ammocoete densities obtained in alcove habitat and one lateral scour pool were excluded from linear and multiple regression of the velocity, substrate, maximum depth, and canopy cover parameters.

Initial sampling in Red River indicated Pacific lamprey ammocoete density differences were minimal when comparing substrate size classes (fine sand, sand, coarse sand etc.). Therefore substrate classes (fine sand, coarse sand etc.) were combined into three classifications: "coarse" (large boulder, small boulder, cobble), "medium" (course gravel, medium gravel, fine gravel), and "fine" (course sand, fine sand, silt/organic) and analyzed in relationship to Pacific ammocoete densities in the corresponding units.

Severe difficulty was encountered visually identifying individual ammocoete emergence sites when multiple ammocoetes emerged simultaneously. As a result there were numerous occasions when accurate measurement and calculation of site of emergence stream velocities, depths, and canopy cover was not possible. The habitat unit average velocities, maximum depths, and canopy cover measurements (rather than individual site of emergence) for corresponding units were incorporated in order to analyze the Pacific lamprey ammocoete density in response to the parameters.

RESULTS

During 2000-2002, no Pacific lamprey ammocoetes or macrothalmia were captured in the Crooked River or American River traps. One-hundred ninety-two Pacific lamprey ammocoetes and 23 macrothalmia were captured in the Red River rotary screen trap (Table 3). The average total length of the ammocoetes and macrothalmia (combined) was 138.0 mm. No length was obtained for the one macrothalmia captured in 2001 (Fig. 7).

Based on trap-area fished, a total of 175 (n=25) ammocoetes and 14 (n=2) macrothalmia were estimated to have migrated past the Red River trap in 2000, compared to 307 (n=45) ammocoetes and seven (n=1) macrothalmia in 2001, and 875 (n=125) ammocoetes and 140 (n=20) macrothalmia in 2002. Downstream migration of ammocoetes and macrothalmia occurs predominantly at night from mid-March to May 31, with a limited number (<10%) captured in September and October (Fig. 8). Out of the total Pacific lamprey ammocoetes (n=693) captured April 1 to October 31, 1993-2001 87% occurred between April 1 and May 31. In 1996 trapping was initiated March 13 and a total of 25 Pacific lamprey ammocoetes was captured in the March 13 to March 31 period indicating an unknown portion of downstream migration may occur prior to the general April 1 – October 31 trapping period. The number of ammocoetes and macrothalmia estimated to have migrated past the Red River trap was a maximum of 1,357 in 1993 and minimum of 98 in 1994 (Fig. 9).

Because statolith banding examination for age determination requires sacrificing lamprey, age assessment was based on length frequency of Red River trapped and electroshocked ammocoetes and macrothalmia. Figures 7, 10, and 11 indicate there may be five or six age classes in the fish sampled based on growth rates in Scott and Crossman (1973). The maximum total length of the Pacific lamprey ammocoetes captured in Red River is greater than ammocoetes in the SFCR, however, it is unknown if growth rates or age distributions vary in the two streams.

In 2000, a total of 154 Pacific lamprey ammocoetes was captured by electroshocking in Red River (Table 3). Pacific lamprey ammocoetes were found in rkm's 1.0, 2.0, and 3.0 in 2000. No sections between rkm 3.0 and 8.0 were sampled in

2000 due to the randomness of selection. Eight total sites in Red River tributaries (Siegal Creek, Red Horse Creek, and South Fork of Red River) were sampled, but no Pacific lamprey were found. The largest Pacific lamprey electroshocked in the SFCR drainage measured 166 mm TL, while the smallest (found in SFCR) was 47 mm TL (Fig. 10). No macrothalmia were captured while electroshocking in 2000.

In 2001, a total of 185 Pacific lamprey ammocoetes and one macrothalmia was captured by electroshocking in Red River (Table 3). Pacific lamprey ammocoetes were found in seven sections of Red River up to rkm 7.0. No Pacific lamprey ammocoetes or macrothalmia were captured in Red River sample sites above rkm 8.0. The Red River tributaries, Siegal Creek, Red Horse Creek, and the South Fork of Red River were resampled in 2001, but no Pacific lamprey were found. The largest Pacific lamprey captured electroshocking in the SFCR drainage in 2001 was 169 mm (TL) and the smallest Pacific lamprey ammocoete captured measured 60 mm (TL). In 2001 three macrothalmia were captured electroshocking in the SFCR and one in Red River. The largest macrothalmia (158 mm TL) was captured in Red River. The smallest macrothalmia (140 mm TL) was electroshocked in the SFCR. The macrothalmia were captured in August and September. One of the macrothalmia captured in the SFCR was partially transformed, with partially formed eyes and macrothalmia mouth parts. Two Pacific lamprey ammocoetes marked at Red River rkm 3.4 in August, 2000, were recaptured within 40.0 m of the original capture location in August, 2001 (Table 4).

In 2002, a total of 274 Pacific lamprey ammocoetes was captured by electroshocking in Red River. Pacific lamprey ammocoetes were found in one previously unsampled section of Red River (rkm 7.0-7.5). Twelve sites were sampled in the

American River drainage in 2002, but no Pacific lamprey were found. One-hundred seven ammocoetes were captured in the SFCR in 2002 at two sites sampled in 2001. The largest Pacific lamprey captured electroshocking in the SFCR drainage in 2002 was 155 mm (TL) and the smallest measured 77 mm (TL). In 2002 no macrothalmia were captured electroshocking in the SFCR drainage.

Numerous potential spawning sites with suitable substrates were identified in SFCR drainage tributary streams in 2000-2002. However, no Pacific lamprey adults or redds were observed during 2000-2002 surveys (Appendix A1). Limited visibility water conditions inhibited counts in mainstem Red River in 2000. Counts in Red River (rkm 7.5 to mouth) were difficult in 2000-2002 due to depths predominantly greater than 0.5 m impact of visual assessment of substrates.

The length and weight relationship of Pacific lamprey ammocoetes captured in Red River and SFCR indicates that weight increases exponentially with length (Figs. 12 and 13). The majority of Pacific lamprey ammocoetes and macrothalmia captured in Red River were greater than 120 mm TL, however, ammocoetes and macrothalmia electroshocked in the SFCR were predominantly <120 mm TL (Fig. 13). The macrothalmia electroshocked in 2001 in Red River was 158 mm (TL) and 7.9 g, which is a greater weight for 158 mm (TL) than the majority of ammocoetes of similar length sampled, however, it is unknown if this represents a pattern.

Capture values (number captured/time) for different electroshocking rates were assessed in order to determine if different sample rates impacted the catch rate (Fig. 14) confounding the calculation of Pacific lamprey ammocoete individual habitat type densities. However, catch rates were similar irrespective of sample rates during Red

River habitat sampling and adjustment for varying sample rates between units sampled was determined unnecessary (Fig. 14).

Pacific lamprey ammocoetes were captured in the entire range of Red River habitat types sampled. The greatest density was seen in alcove habitat type (Table 5) and the greatest total number of ammocoetes was captured in lateral (lateral and straight combined) scour pools. The Pacific lamprey ammocoete density averaged 952% and 690% greater in lateral and straight scour pool habitat than in rapids with boulders and riffle habitats, respectively. The scour pool densities ranged from 0.8 to 152.3 (lamprey/100 m^2), riffle and riffle with pockets densities from 0.0 to 14.9, and the rapids with boulders from 0.0 to 3.3.

Pacific lamprey ammocoete densities in Red River habitats were similar for comparable velocity habitat types (Fig. 15). The Pacific lamprey ammocoete density in alcove habitat was greater than in other habitat types, however, alcove habitat is rare in Red River comprising an estimated 0.56% of total stream habitat from rkm 0.0 - 7.0. The single alcove sampled at rkm 0.9 yielded a greater Pacific lamprey ammocoete density (253.3/100m^2) than the other habitat types. Because only one alcove was sampled the alcove density was not included in the analysis of Pacific lamprey habitat utilization and response to stream habitat type and parameters.

Red River stream habitat unit average velocities ranged from 0.47 m/s in riffle habitat to 0.050 m/s in the alcove habitat unit (Table 6). Pacific lamprey ammocoete density decreased with increasing stream flow velocity in Red River habitat units sampled (R^2 = 0.477) (Fig. 16). Red River maximum depths for sampled units averaged from 0.77 m in lateral and straight scour pool habitat to 0.40 m in the alcove habitat. The relationship between Pacific lamprey ammocoete density and depth was not significant (Fig. 17). Coarse substrate averages ranged from 61.4% in scour pool habitats to 32.0% in alcove habitat. Medium substrate ranged from 29.3% in riffle habitat to 10.0% in alcove habitat. Fine substrate averaged from 58.0% in alcove habitat to 10.5% in rapids habitat. The greatest average canopy cover (shade), measured was 33.0% for the alcove habitat and the minimum was 9.8% in riffle habitat.

Red River substrates within the known Pacific lamprey ammocoete distribution (rkm 0.0 – 7.5) are largely boulder and cobble (Table 7). The Red River Pacific lamprey ammocoete density decreased with increasing coarse substrate (R^2 = 0.263), increased with increasing medium substrate (R^2 = 0.333), and increased with increasing fine substrate percentage (R^2 = 0.157) (Figs. 18, 19, and 20).

Red River drains in a northwesterly direction from approximately the mouth of Red Horse creek (rkm 9.0) to the mouth. The solar input reaching the riparian and upslope canopy in the Red River stream section rkm 0.0 – 7.5 is potentially comparable (rkm 1.0, 2.0 compared to 3.0, etc.) due to stream flow direction and similar upslope topography. Pacific lamprey ammocoete density in Red River increased with increasing habitat unit canopy cover (shade) percentage (Fig. 21).

Analysis of Variance (ANOVA) of Pacific lamprey densities in scour pool, riffle, and rapids habitat in Red River units was insignificant (P= 0.0854, $> \alpha 0.05$) (Table 7). However, analysis of the habitat unit (scour pool, riffle, and rapids with boulders) mean densities with Fisher's LSD indicated the scour pool mean (Table 5) was modestly different from the riffle mean (P= 0.0616), and the rapids with boulders mean.

Linear regression of the Pacific lamprey ammocoete density (by habitat unit) and average flow velocity relationship, yielded a significant response (P= 0.0007) (Table 8). Linear regression of stream Pacific lamprey ammocoete density and canopy cover (shade) was also significant (P= 0.0280). The coarse substrate and medium substrate ammocoete density responses were significant as well (P= 0.0208), (P= 0.0070) (Table 8). Multiple Regression of the Pacific lamprey habitat unit ammocoete density and stream parameters produced a best fit model with velocity, coarse substrate, and canopy cover (P= 0.0080, P= 0.0350, and P= 0.0400 respectively) (R^2= 0.631) (Table 9).

Red River stream temperature increased with distance from the source. However, Red River daily stream temperatures in the rkm 0.0 – 7.5 reach during August and September are comparable, with slightly higher temperatures near the mouth. Pacific lamprey ammocoete densities in the reach were representative of ammocoete densities in the temperatures present and the inability to isolate (sample and obtain density information) ammocoetes in another reach with different temperatures precluded analysis of the Pacific lamprey ammocoete and stream temperature relationship. Temperatures in Red River (Fig. 22) and the subbasin tributary streams commonly reach 20.0^0C or higher in the summer period. Maximum stream temperature obtained at the IDFG Red River trap (rkm 5.0) in 2000 was 26.7^0C. Substrate temperatures were an average of 2.2^0C (P<

0.05) cooler than stream temperatures when measured August 9, 2001, suggesting substrate temperatures remain cooler during the maximum stream temperature period of the day (Fig. 23).

No Pacific lamprey were found when we sampled upper Red River, the South Fork of Red River, or SFCR tributaries. Pacific lamprey distribution in the SFCR drainage was limited to the lower 7.5 km of Red River, and the SFCR (Fig. 6).

The Pacific lamprey ammocoete and macrothalmia population in Red River was estimated to total 20,395 ± 82,359. Pacific lamprey were estimated to reach the greatest average density of 88.9/100 m^2 for a total of 15,168 ammocoetes, in Red River kilometer 6.0-7.0 (Fig. 24). The greatest number of Pacific lamprey ammocoetes and macrothalmia were captured in scour pool habitats (Tables 6 and 10), however, Pacific lamprey were present in all habitats sampled in Red River. Pacific lamprey ammocoetes were estimated to average 2874 per km in Red River.

Red River contributes the single greatest flow volume to the SFCR and stream habitats in lower Red River and the SFCR are similar. The SFCR Pacific lamprey minimum population is estimated at 178,458 ± 720,639. The total SFCR occupied distance was adjusted from 83.0 km to 70.0 km to account for marginal habitats (extensive high velocity rapids with few pockets of finer substrates and cobble embedded riffles) in the Meadow Creek to Silver Creek and Stites to Kooskia reaches where Pacific lamprey ammocoete densities are estimated to approach zero.

DISCUSSION

Pacific lamprey adult upstream passage at Bonneville Dam and Ice Harbor Dam has declined since the 1960's. Ice Harbor Dam Pacific lamprey adult passage counts for 1995-2001 are a fraction of returns in the 1962-1969 period. Hydroelectric development in the Columbia River corridor and Snake River corridor is thus implicated as the predominant source of Pacific lamprey decline in the Columbia River basin and Snake River subbasin (Jackson et al. 1997). Pacific lamprey ammocoete and macrothalmia downstream migrant mortality and upstream adult migrant passage impediment are suspected as the primary hydroelectric factors contributing to Pacific lamprey decline. Lewiston Dam on the main Clearwater River, Lewiston, ID, (1927-1972) was a known obstruction to a number of upstream migrating species (White 1954), however, impacts to Pacific lamprey are unknown. Ocean decadal productivity regime shifts are suspected to impact ocean phase Pacific lamprey survival (Close et al. 1995) and resulting returns to the Columbia River and Snake River. However, Pacific lamprey adult returns to the Columbia River basin and Snake River subbasin have continued to decline despite Pacific ocean productivity regime shifts in the 1969-2001 period. Habitat alterations to Pacific lamprey spawning and rearing streams are implicated as contributing to declines as well (Close et al. 1995).

The Harpster Dam on the SFCR impacted anadromous species upstream passage for 15 consecutive years from 1949-1963. It is unknown if Pacific lamprey populations in the SFCR drainage upstream of Harpster Dam were eliminated and current populations are the result of recolonization following removal of the project. Several other minor dams were also present in the SFCR drainage in the early 1900's (USDA Forest Service

2001), however, it is not known if they blocked salmonid and Pacific lamprey passage. The Harpster Dam was a concrete sill structure with flow over the sill during peak flows or hydroelectric operation flow fluctuations. Thus it is possible adult Pacific lamprey were able to navigate over the Harpster Dam and other structures. Adult Pacific lamprey have been observed climbing considerable distances above the water surface on wetted concrete (Gretchen Starke, U.S. Army Corps of Engineers, personal communication). Pacific lamprey returns to the main Clearwater River in the period following removal of the SFCR Harpster Dam could have provided recolonization stock for the SFCR drainage, due to the colonizing nature of the species (David Close, Umatilla Tribal Fisheries, personal communication).

Assuming growth rates for Pacific lamprey ammocoetes in native habitat are similar to those noted by Scott and Crossman (1973), length frequency distribution data suggests there are five, possibly six age classes present in the SFCR drainage. However, varying growth rates between year classes in response to annual stream temperature, stream flow, and other variations in habitat factors decrease the accuracy of ageing. Population age structure estimation would potentially improve with additional sampling. Length frequency distribution information for both Red River and the SFCR indicates Pacific lamprey age –0 are either not present in the SFCR drainage or were not captured (based on Scott and Crossman 1973 growth rates). Younger age class ammocoetes are commonly undersampled with electrofishing (David Close, Umatilla Tribal Fisheries, personal communication). The minimum size of ammocoetes captured in the SFCR increased in 2001 while the total number of ammocoetes captured and sites sampled in 2001 increased. In 2002 the minimum length of ammocoetes captured in the SFCR drainage increased by 27 mm (Fig. 11). With greater sampling distribution and increased total number of Pacific lamprey captured in 2001-2002, an increase in minimum size of ammocoetes in the SFCR basin could indicate a lack of recruitment. Lower Granite Dam fish bypass generally captures ammocoetes and macrothalmia greater than 100 mm (TL) and determining Snake River basin Pacific lamprey ammocoete recruitment with information obtained from the project is difficult at best. The estimated outmigration numbers from the project are highly useful in determining lifestage proportions and general outmigration magnitude, but due to spill and varying hydroelectric operation flow regimes, downstream migrant passage routes through the project and the numbers of Pacific lamprey captured fluctuate irrespective of short-term population trends.

The length/weight relationship for Pacific lamprey ammocoetes captured in the SFCR drainage indicates ammocoete weight increases exponentially with length. Exponential weight increase with length increase is an expected response for Pacific lamprey in order to store energy needed for transformation and subsequent outmigration. The macrothalmia captured were greater in weight for a given length than ammocoetes, possibly indicating a biological requirement exists in order for transformation to occur. In sea lamprey *Petromyzon marinus* a minimum length and weight are required for ammocoete initiation of transformation (Youson et al. 1993). The length and weight relationship (Figs. 12 and 13) additionally indicates that the majority of Pacific lamprey ammocoetes in Red River are greater in length than the ammocoetes in the SFCR. Perhaps larger Pacific lamprey in the SFCR occupy water depths greater than were sampled, however, most of the Pacific lamprey captured in Red River were captured in stream habitat <0.3 m in depth. Deeper habitat was often present, but stream flow velocity and coarse substrates were often greater in deeper habitat locations. Substrate preference potentially impacts the size of Pacific lamprey occupying a location (Pletcher 1963). It is possible larger ammocoetes in the SFCR are in locations where the substrates are generally of coarse sand or fine gravel. The majority of sampled substrates in the SFCR 2000-2002 were fine sand-silt in size.

Downstream migration of ammocoetes and macrothalmia in Red River occurred primarily at night, similar to the findings of Beamish and Levings (1991) (Fraser River drainage Canada) from March 15 to May 31. In a tributary of the Fraser River Canada Beamish and Levings (1991) documented downstream migration of ammocoetes occurring primarily in the April-June period and macrothalmia April-May. Trapping in Red River was initiated March 13 in1996. Capture of Pacific lamprey in this period suggested that a significant percentage of ammocoete and macrothalmia downstream migration occurs before April 1. Operation of the three traps utilized to monitor chinook salmon, steelhead trout, and Pacific lamprey outmigrants in the SFCR basin is difficult in early March due to ice conditions. As a result, trapping operations generally are from April 1 to October 31 and information pertaining to the downstream migration of Pacific lamprey in the period before April 1 is limited. No information has been obtained documenting annual Pacific lamprey downstream migrations in Red River before March 13. Outmigration of Pacific lamprey ammocoetes and macrothalmia in the Red River subbasin is primarily during the March, April, and May peak flow period (IDFG unpublished 2002). Outmigration of anadromous species in peak spring flow periods is commonly considered an adaptive strategy utilized to conserve energy and it is likely Pacific lamprey have developed a similar strategy. The majority of Pacific lamprey captured at the Red River trap are ammocoetes. The ammocoetes migrating downstream in the Red River subbasin may be relocating to suitable habitat within the Red River subbasin, SFCR, Clearwater River, or Snake River rather than migrating to the estuary. The ratio of ammocoetes to macrothalmia (241:1 electroshocked, 8.5:1 trapped) in Red River and SFCR basin Pacific lamprey is considerably greater than the ratio at Lower Granite Dam (generally 3:1 - 1:7.6). This indicates that the transformation process (3-7 months in sea lamprey (Holmes and Youson 1998)) occurs in a number of Pacific lamprey downstream of the Red River trap. The length of lamprey electroshocked in the Red River subbasin ranged from 72 mm to166 mm (TL); it is unknown if a biologically mandatory size and weight (or meeting other unknown requirements) is needed to undergo transformation and migrate successfully.

Red River substrates (rkm 0.0 – 7.5) are predominantly boulder and cobble in the lower reach (Table 7), however, extensive areas of finer substrates are present. Random selection of samples excluded several 500+ m^2 (estimated) fine substrate dominated lateral scour pool habitat units from sampling. It is possible Pacific lamprey ammocoete densities in finer substrate-dominated reaches of Red River would differ from sampled sites. A lateral scour pool in rkm 6.0 yielded an ammocoete density of 152.3/100 m^2, which is 480% greater than the maximum lateral scour pool density obtained in 2000 and 2001. If Pacific lamprey ammocoete densities in unsampled reaches of Red River are considerably different from sampled reaches it is unlikely the habitat type preference analysis results would differ, however, population estimates might vary from those calculated.

Studies in the Salmon River of British Columbia and other river systems (Pletcher 1963; Close 1995) have indicated Pacific lamprey ammocoetes use reduced stream velocity habitat types. Pacific lamprey ammocoete densities in Red River were greater in lateral scour pool habitats compared to riffle and riffle with pockets and rapids habitats, supporting the findings of Pletcher (1963). However, the ANOVA of the Pacific lamprey ammocoete habitat type relationship was not significant (P= 0.0854) indicating that habitat type and Pacific lamprey ammocoete density in Red River are correlated, but due to data variability, numerical proof is difficult. The Pacific lamprey ammocoete densities in Red River lateral scour pool habitat ranged from 0.8/100 m^2 to 152.3/100 m^2. The ammocoete densities in other habitat types were also ranged widely. The density range within like habitat types reduced the potential to obtain significance. The stream parameter (substrate, canopy cover, flow velocity, and depth) differences for individual units and their influence on Pacific lamprey ammocoete habitat selection is the suspected reason habitat unit Pacific lamprey densities ranged widely. The range of habitats sampled included lateral scour and straight scour pools, riffles, riffles with pockets, rapids with boulders, and alcove habitats. Other habitat types (glides, rapids over bedrock, and dammed pools) are present in Red River, but are extremely rare.

Pletcher (1963) indicated the ability of all Pacific lamprey ammocoetes (age –0 to 2+) to burrow was impacted at velocities exceeding 31.0 cm/s and burrowing time of ammocoetes increased with increases in water velocity in the Salmon River, British Columbia. Youngest age class (age - 0) Pacific lamprey burrowing ability was reduced by small increases in velocity (15.0 cm/s) (Pletcher 1963). In response to reduced velocities Pacific lamprey ammocoetes are thought to seek pools after hatching (Pletcher

1963). Pacific lamprey ammocoete densities in Red River decreased with increasing flow velocity. Pacific lamprey were captured in stream habitats with greater velocity (riffles, rapids, etc.), however, lamprey in these habitats were found in margin pockets where velocity is reduced. Shoreline boulder-created calm water pockets in Red River commonly supported increased Pacific lamprey ammocoete densities.

Pletcher (1963) observed Pacific lamprey ammocoetes using deeper water in summer and shallower water in the winter in the Salmon River of British Columbia, Canada. Larger ammocoetes (age 2+) used deeper water in one river system in Canada (Pletcher 1963). Pacific lamprey ammocoete densities in Red River were greater in depths less than 0.3 m when habitats were sampled in August and September. Pacific lamprey winter ammocoete density and stream depth utilization relationships in Red River are unknown. Habitat sampling in Red River is restricted to minimum-flow, ice-free months (primarily July, August, and September). Larger ammocoetes (>120 mm TL) were captured in the range of Red River depths without noticeable pattern. Pacific lamprey ammocoete density and habitat unit maximum depth relationship in Red River is generally weak (R^2= 0.029), however, habitat unit maximum depth reflects the attributes of the entire habitat unit (occasionally only a specific location in a unit), not the specific locations ammocoetes occupy. The difficulty visually identifying individual ammocoete emergence sites precluded analysis of single ammocoete depth utilization in Red River.

Substrate preference of Pacific lamprey ammocoetes in the Salmon River, British Columbia, was predominantly mud and silt for age 1+ and 2+ ammocoetes (Pletcher 1963). Older ammocoetes were found predominantly in sand and leaf substrates. Hammond (1979) found most ammocoetes in sand, silt, or clay substrates in the Potlatch

River, ID. Beamish and Lowartz (1996) found that American brook lamprey *L . appendix* density was positively correlated with the amount of medium-fine sand and organic matter in the substrate. The substrates in the Red River drainage are predominantly gravels, boulders, and sand with lesser amounts of silt and organic material. Pacific lamprey ammocoete densities in Red River were inversely correlated to substrate size. Pacific lamprey ammocoete densities noticeably increased in sites with a greater percentage of finer substrates (sand, silt/organic), however, the regression (fine substrate) strength was impacted due to the influence of other stream habitat parameters (flow velocity, depth, canopy cover, etc.) on Pacific lamprey habitat selection. Pacific lamprey were captured in substrates of all size classes, but were captured in modest numbers from sites with large and small boulders dominating the substrate. Ammocoetes in Red River commonly emerged from substrate gaps in cobble and small boulder areas. Pletcher (1963) indicated Pacific lamprey ammocoete burrowing ability is impacted by substrate size. Generally finer substrates are considered the preferred Pacific lamprey ammocoete substrate (Close et al. 1995; Pletcher 1963; Hammond 1979). However, if concealment is provided with larger substrates and the spaces are sufficient for ammocoetes to penetrate, or finer substrate pockets exist in coarse substrate sites, it is likely they are adequate for limited rearing.

Pacific lamprey ammocoetes and macrothalmia were present historically in most streams used by salmon and steelhead trout in the Columbia River basin (Simpson and Wallace 1982). Ammocoetes would have been exposed to the same stream temperatures (when out of the substrate) as salmon and steelhead trout. Pacific lamprey ammocoete rearing temperature requirements are not fully known, but ammocoetes are generally found in cold waters (Close et al. 1995), however, tolerance may exceed 25^{0}C (Mallat 1983). Holmes and Youson (1998) found the percentage of sea lamprey ammocoetes that metamorphosed was maximized with water temperature of 21.0^{0}C and inhibited with greater temperatures. Red River stream temperatures are known to reach or exceed 26.7^{0}C. Temperature monitoring in the Red River subbasin infers Pacific lamprey ammocoetes and macrothalmia are capable of surviving with stream temperatures in excess of 20.0^{0}C, however, the time period Pacific lamprey ammocoetes are able to survive stream temperatures greater than salmon and steelhead trout lethal limits is unknown. Red River substrate temperatures commonly exceed sea lamprey metamorphosis temperature preferendum of 21^{0}C for a limited time period in July and August, however, it is unknown if Pacific lamprey ammocoetes are negatively impacted. Substrate temperatures were cooler than stream temperatures sampled, but it is unclear whether Pacific lamprey benefit.

Limited riparian canopy cover is often cited as a factor impacting stream production (Jackson et al. 1996) (due to decreases in channel stability, shade, etc.). Elevated stream temperature due to removal of riparian canopy in cold-water species watersheds results in limited production of a number of native aquatic species (USDA Forest Service 1998), however, it is unclear if temperature extremes in Red River impact Pacific lamprey population productivity. Pacific lamprey ammocoetes are adeptly capable of detecting light. Pacific lamprey movements predominantly occurred at night (presumably due to light or predator avoidance) in the Salmon River in British Columbia (Pletcher 1963). Ammocoetes are predominantly captured from dusk to sunrise (at night) in the Red River rotary screen trap. Maximum stream temperature tolerances likely limit

Pacific lamprey production in watersheds where human removal of riparian canopy results in excessive insolarization of streams (Close et al. 1995; Jackson et al. 1996; Jackson et al. 1997). Low-angle shading was identified as an important parameter for Australian lamprey *Geotria australis* ammocoetes (Potter et al. 1986). The Pacific lamprey ammocoete density and riparian canopy relationship in Red River was stronger ($R^2 = 0.251$) than compared to the maximum depth ($R^2 = 0.029$) and fine substrate relationships ($R^2 = 0.157$). Pacific lamprey ammocoetes were captured in greater numbers repeatedly under overhanging hardwood riparian vegetation, however, whether the increased densities were in response to decreased (microhabitat) temperatures or light intensity is unknown.

We developed a theoretical model predicting Pacific lamprey abundance with Red River ammocoete density = HAB - VEL – SUBC + SHD. Where in the model: HAB = the average density in a habitat type (Table 5). VEL = the habitat unit average flow velocity (at substrate) effects on ammocoete density (regression slope coefficient, Fig. 16). SUBC = the habitat unit percentage coarse substrate effects (regression slope coefficient, Fig. 17) and SHD = the habitat unit percentage canopy cover impacts (regression slope coefficient Fig. 21).

No Pacific lamprey ammocoetes were found in potential habitat in Red River rkm's 7.5-41.0, Red River tributaries, the South Fork of Red River, and SFCR tributaries. Presence-absence sampling in 2000-2002 in 13 SFCR tributaries contributing the greatest flow volume to the SFCR indicates distribution of Pacific lamprey in the basin is limited. Suitable habitat remains in Red River above rkm 7.5, in Newsome Creek, American River, and Crooked River, but is currently devoid of Pacific lamprey. A minimum of approximately 60.0 km of currently unoccupied stream habitat in SFCR tributaries would potentially support Pacific lamprey. Work to date suggests population numbers are minimal and distribution restricted to the remaining preferred habitat in the SFCR basin. It is likely that presently unoccupied habitats in Red River, Newsome Creek, Crooked River, and American River contained Pacific lamprey during historical periods of greater spawner escapement into the SFCR drainage.

The Pacific lamprey ammocoete and macrothalmia minimum population estimate in Red River is likely representative of occupied habitat in the subbasin. A considerable amount of suitable ammocoete habitat exists in Red River in the rkm 0.0-7.5 reach which was unsampled or undersampled due to random sampling, however, sites were sampled in rkm's 1.0-7.5 (known distribution) and it is unknown if further work in the subbasin would augment current population estimates. The Pacific lamprey population in Red River is potentially modestly greater than the estimated size in part due to one-pass sampling. The SFCR Pacific lamprey ammocoete and macrothalmia estimate is considered conservative considering stream size and suitable substrate quantity. The number of ammocoetes per kilometer in Red River is a function of the stream width and habitat type composition. The SFCR stream size is considerably larger (twice the width of Red River) and the number of pools with suitable habitat greater. One lateral scour pool sampled in 2000 in the SFCR was estimated to possess 500+ ammocoetes. It is possible the SFCR Pacific lamprey ammocoete and macrothalmia population is greater than the estimated 178,458 based on Red River ammocoete densities.

It is not known, if however, Pacific lamprey densities observed in 2000-02 potentially reflect overall low population numbers in the SFCR drainage. The number of spawning adults in the SFCR basin is suspected to have been fewer than 50 Pacific lamprey annually during 1998-2001. The SFCR estimated spawning adult escapement is based on Lower Granite Dam passage of less than 320 adults annually in the 1998-2001 period and assumption of even distribution of Pacific lamprey adults into the Grande Ronde, Imnaha, Salmon, and Clearwater Rivers with one-half of Clearwater River drainage spawners returning to the SFCR. Increasing minimum size of Pacific lamprey ammocoetes in the SFCR and low SFCR basin densities would be expected following several years of limited spawning.

Pacific lamprey are a species critically linked to the ecological function of the Snake River drainage and SFCR drainage biological communities. The decline of Pacific lamprey adult upstream migrants to the Snake River basin is undoubtedly in part a function of instream migration corridor mortality, hydroelectric upstream passage impediments, and rearing stream habitat degradation (Close et al. 1995; Jackson 1996; Vella et al. 1997). Pacific lamprey persistence in the SFCR drainage following the installation of Harpster Dam indicates the resilient and enduring character of the species. Knowledge of Columbia River basin Pacific lamprey population ecology, subbasin distributions, and species habitat requirements is currently limited. Increase in Pacific lamprey habitat requirement information will further augment the potential to intensively manage the species. Habitat utilization sampling in the SFCR drainage suggests maintenance of remaining preferred habitats in Red River, the SFCR, and SFCR basin tributaries is necessary to ensure rearing conditions are adequate for the species to continue to inhabit the drainage.

Table 1. Habitat and substrate classification for sampling sites in the South Fork Clearwater River drainage, ID, (Platts et al.1983).

Habitat Units	Code	Substrate Classification	
Falls	FLL	Substrate Type (mm)	
Cascades		Large Boulder	>512
		Small Boulder	256-512
Rapids		Cobble	64-256
Typical	RRR	Coarse Gravel	16-64
Boulders	RBB	Medium Gravel	8-16
Bedrock	RBD	Fine Gravel	2-8
		Course Sand	0.5-2
Riffles		Fine Sand	0.062-0.50
Typical	RIF	Silt/Organic	0.004-0.062
Pocket water	RIP		
Glide	GLD		
Pools			
Lateral Scour Pool	LSP		
Straight Scour Pool	SCP		
Plunge Pool	PPP		
Dammed Pool	DMP		
Alcove	ALC		

Table 2. Downstream migrant traps location, type, and operation dates, South Fork Clearwater River drainage, ID, 2000-02.

Stream	Trap	Location	Year	Operation Dates
Red River				
	Rotary Screen	RKM 6.0*	2000	03/23 - 10/31
	Rotary Screen	RKM 6.0*	2001	03/29 - 10/31
	Rotary Screen (1.5 m diameter)	RKM 6.0*	2002	04/10 - 10/31
American River				
	Rotary Screen	RKM 3.0*	2000	03/26 - 10/31
	Rotary Screen	RKM 3.0*	2001	04/01 - 10/31
	Rotary Screen (1.5 m diameter)	RKM 3.0*	2002	04/12 - 10/31
Crooked River				
	Scoop	RKM 1.0*	2000	03/26 - 10/31
	Scoop	RKM 1.0*	2001	03/23 - 10/31
	Rotary Screen (1.5 m diameter)	RKM 1.0*	2002	04/04 - 10/31

*RKM: River Kilometer

Table 3. Stream sampled, method of capture, and number of Pacific lamprey captured in the South Fork Clearwater River drainage, ID, 2000-02.

Stream	Year	Method of Capture	Number Measured	Lamprey length ave. (mm)
Red River		Rotary Screen Trap		
	2000		27	133.3 (± 32.5)
	2001		23	128.2 (± 17.8)
	2002		130	137.0 (± 18.9)
Red River		Electroshocking		
	2000		151	139.5 (± 42.0)
	2001		186	134.7 (± 33.8)
	2002		269	121.7 (± 30.7)
S.F. Clearwater River		Electroshocking		
	2000		91	81.0 (± 37.8)
	2001		253	103.2 (± 39.8)
	2002		107	109.9 (± 30.9)

(95% confidence intervals)

Table 4. Non-random presence-absence and recapture surveys of Pacific lamprey ammocoetes in the South Fork Clearwater River drainage, ID, 2001.

	Total Lamprey Captured	Total Area Fished m^2	Total Time Fished (min)	Density (Lamprey/100m^2)	C.P.U.E. (Lamprey/min)
Red River (4 sites)	100	22.5	49	444.4	2.04
Recapture Survey (Red R.) (1 site)	69 Recapture (2)	--	102	--	0.68
S.F. Clearwater River (15 sites)	256	116.2	187	220.3	1.37
Totals	425	138.7	338	--	--

Table 5. Habitat utilization of Pacific lamprey ammocoetes in randomly sampled units, Red River and selected units in the South Fork Clearwater River, ID, 2000-02.

Red River					
Habitat Type	**Total Lamprey Captured**	**Total Area Fished m^2**	**Total Time Fished (min)**	**Density (Lamprey/100m^2)**	**C.P.U.E. (Lamprey/min)**
Lateral & Straight Scour Pools (n=9)	342	1283.4	1461	25.7 (± 87.7)	0.20 (± 0.65)
Riffle (n=4)	15	603.5	726	4.3 (± 11.3)	0.05 (± 0.13)
Riffle with Pockets (n=5)	57	1269.8	825	4.5 (± 12.2)	0.06 (± 0.15)
Rapids with Boulders (n=3)	10	357.3	305	2.1 (± 3.6)	0.03 (± 0.04)
Alcove (non random) (n=1)	19	7.5	20	253.3 (na)	0.95 (na)
TOTALS:	443	3521.5	3337	--	--
Average				12.6	0.13
S.F. Clearwater River (2000-01)					
Lateral Scour (margin) (n=15)	349	127.2	207	274.3	1.68
(95% confidence intervals)					

Table 6. Pacific lamprey ammocoete density and habitat unit parameter averages, Red River, South Fork Clearwater River drainage, ID, 2000-02.

Habitat Unit	Density (Lamprey/100m^2)	Velocity @ Substrate (m/s)	Max. Depth (m)	Substrate (%)			Riparian Canopy (%)
				Coarse	Medium	Fine	
Lateral & Straight Scour Pools (n=9)	25.7 (± 87.7)	0.26 (± 0.17)	0.77 (± 0.30)	61.4 (± 20.5)	22.6 (± 15.4)	17.5 (± 12.3)	21.3 (± 26.2)
Riffle (n=4)	4.3 (± 11.3)	0.47 (± 0.41)	0.60 (± 0.37)	53.4 (± 17.8)	29.3 (± 14.4)	17.4 (± 9.2)	9.8 (± 12.4)
Riffle with Pockets (n=5)	4.5 (± 12.2)	0.29 (± 0.24)	0.70 (± 0.29)	46.4 (± 58.3)	21.2 (± 10.1)	13.7 (± 6.0)	16.1 (± 26.2)
Rapids with Boulders (n=3)	2.1 (± 3.6)	0.41 (± 0.28)	0.62 (± 0.29)	69.5 (± 10.4)	20.0 (± 9.0)	10.5 (± 8.7)	20.3 (± 32.4)
Alcove (non random) (n=1)	253.3 (na)	0.05 (na)	0.40 (na)	32.0 (na)	10.0 (na)	58.0 (na)	33.0 (na)
(95% confidence intervals)							

Table 7. Analysis of variance (ANOVA) of electroshocked Pacific lamprey habitat type average ammocoete densities (natural log), Red River, South Fork Clearwater River drainage, ID, 2000-02 (lateral and straight scour pools, riffles and riffles with pockets and rapids).

Dependent Variable: ln density	DF	Sum of Squares	Mean Square	F Value	P Value
Model	2	15.1777036	7.5888518	2.83	0.0854
Error	18	48.2748641	2.6819369		
Corrected Total	20	63.4525678			

ln density = ln (density/m^2 x 1000 + 1)

Table 8. Linear regression of Pacific lamprey habitat unit ammocoete densities (natural log) and stream habitat parameters, Red River, South Fork Clearwater River drainage, ID, 2000-02.

Source	DF	Type III SS	Mean Square	F Value	P Value	R-square
Velocity	1	22.84545	22.84545	16.48	0.0007	0.4779
Substrate Crse.	1	12.57106	12.57106	6.42	0.0208	0.2630
Substrate Med.	1	15.94397	15.94397	9.01	0.0070	0.3335
Canopy Cover	1	9.18372	9.18372	5.71	0.0280	0.2515

ln density = ln (density/m^2 x 1000 + 1)

Table 9. Stepwise multiple regression of Pacific lamprey habitat unit ammocoete densities (natural log) and stream habitat parameters, Red River, South Fork Clearwater River drainage, ID, 2000-02.

Source	DF	Type III SS	Mean Square	F/t Value	P >F/t	R-square
Model	3	23.06964	7.68988	8.58	0.0015	0.6319
Error	15	13.44007	0.89600			
Corrected Total	18	36.50972				
Velocity	1			3.01*	0.0080*	-
Substrate Coarse	1			2.30*	0.0350*	-
Canopy Cover	1			2.25*	0.0400*	-

ln density = ln (density/m^2 x 1000 + 1)

* t value

Table 10. Pacific lamprey ammocoete and macrothalmia estimates, Red River (rkm 0.0 – 7.5), South Fork Clearwater River drainage, ID, 2000-02.

Habitat Units	Estimated Number of Lamprey	Total Habitat Area (m^2)	Electrofished Area (m^2)
Lateral & Straight Scour Pools	18,389	47,403.5	1,283.5
Riffles	274	13,428.7	603.5
Riffles with Pockets	1,471	30,902.8	1,269.8
Rapids with Boulders	307	11,879.7	357.0
Alcove	152	598.4	7.5
Totals	20,593	104,213.1	3,521.3

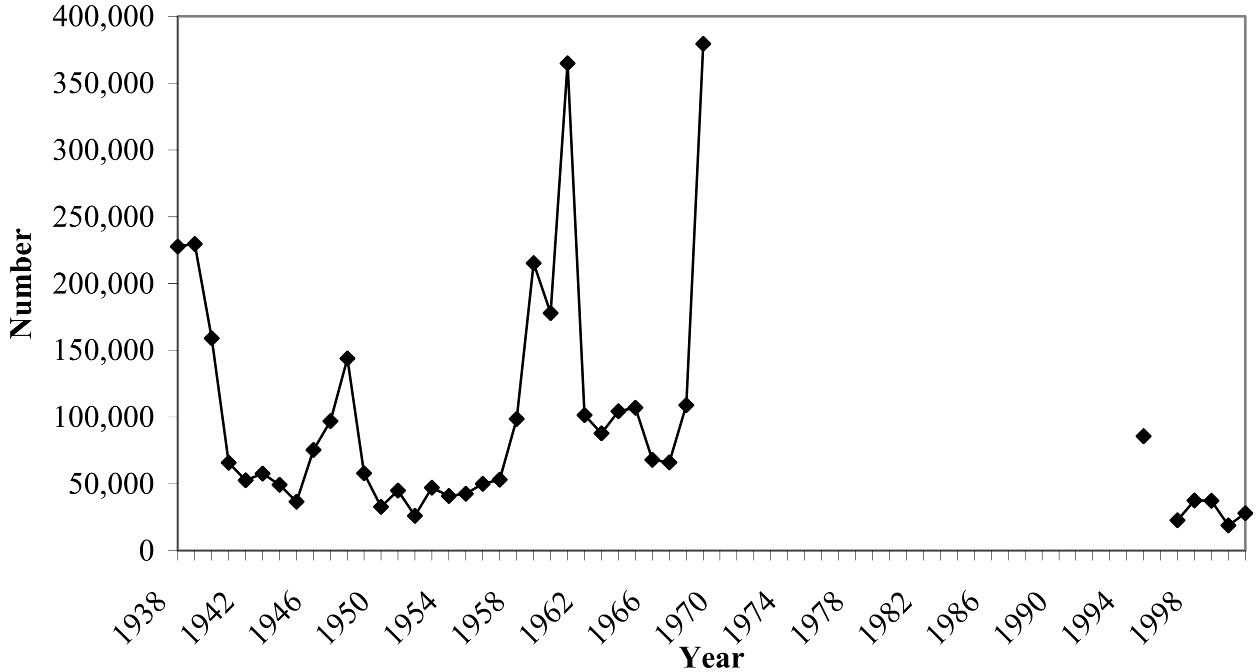

Figure 1. Annual day counts of Pacific lamprey adult passage Bonneville Dam, OR, 1938 – 2001.

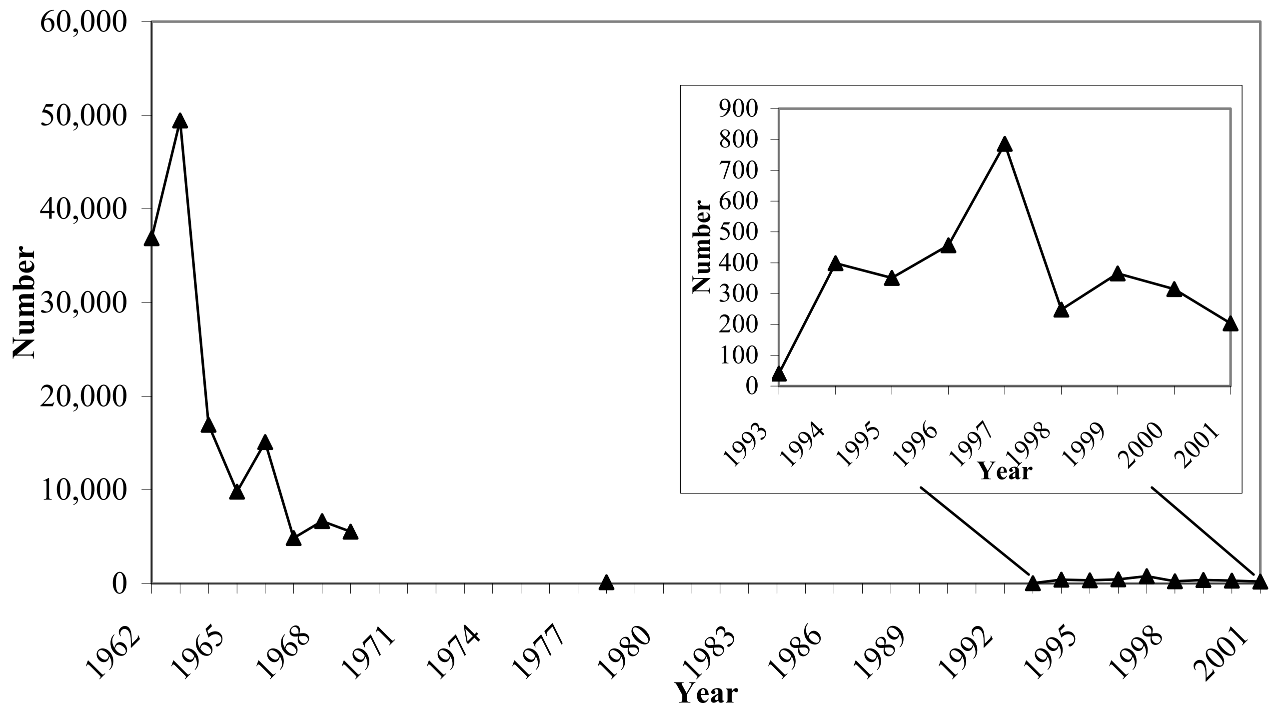

Figure 2. Annual day counts of Pacific lamprey adult passage Ice Harbor Dam, WA, 1962-2001.

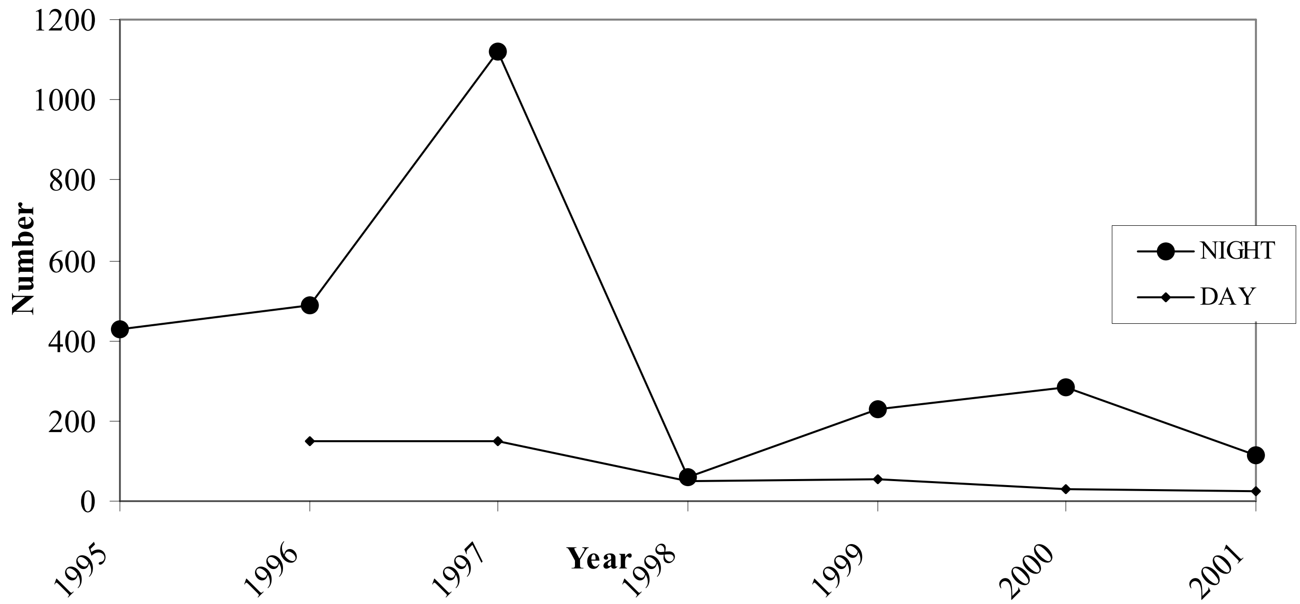

Figure 3. Annual Pacific lamprey adult passage at Lower Granite Dam, WA, 1995-2001.

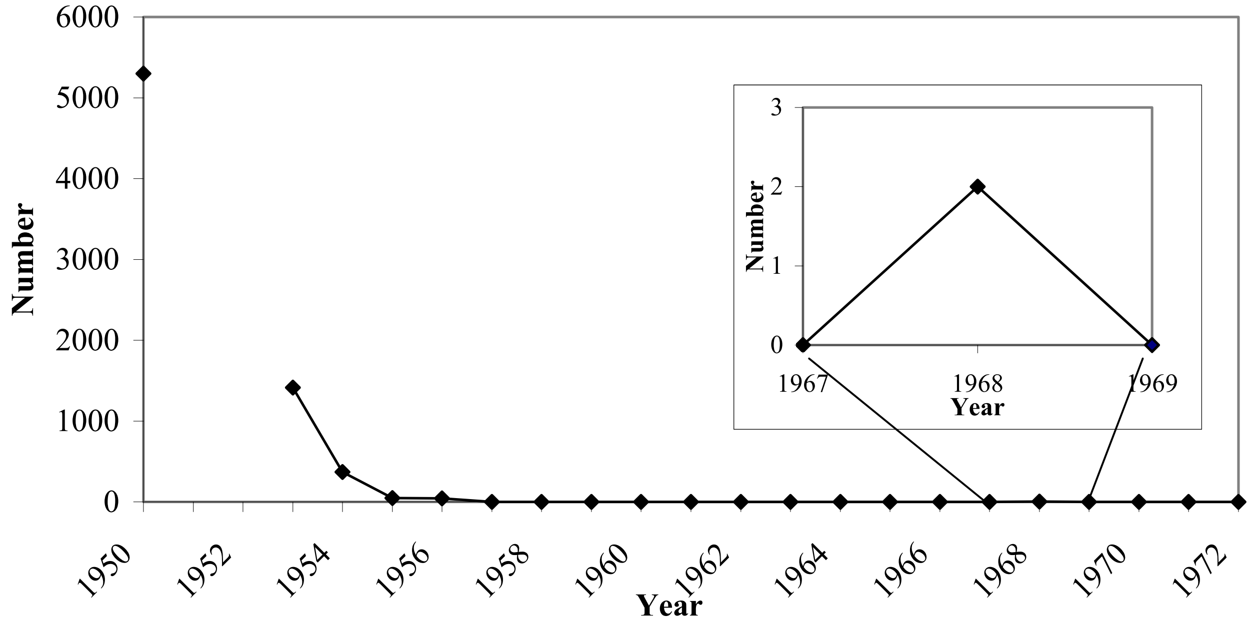

Figure 4. Annual upstream passage of adult Pacific lamprey at Lewiston Dam, ID, 1950-1972.

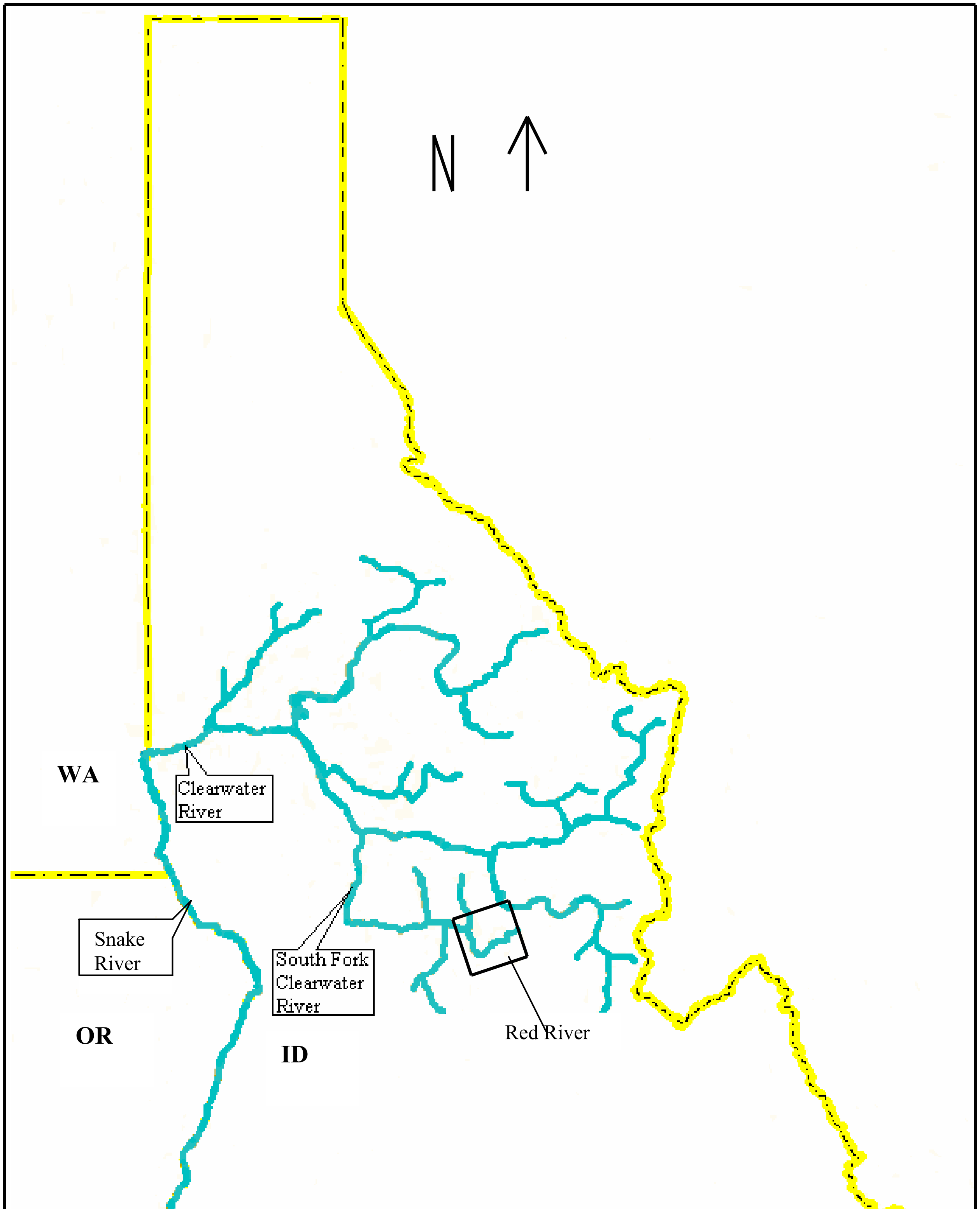

Figure 5. Location of Pacific lamprey investigations, Clearwater River drainage, ID, 2000-02.

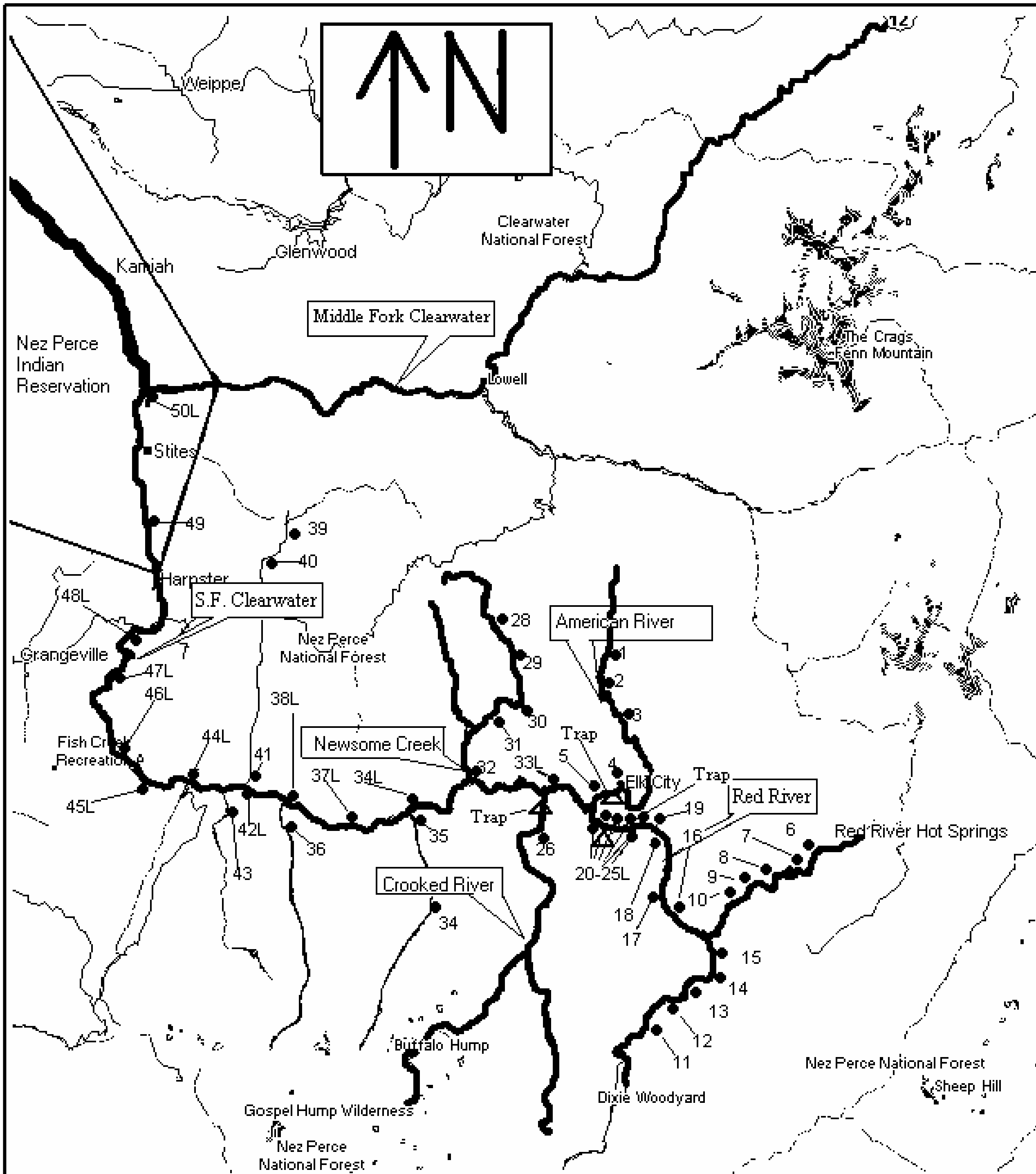

Figure 6. Geographic location of Pacific lamprey sample and collection sites in the South Fork Clearwater River drainage, ID, 2000-02. • = Sample sites, L = lamprey captured.

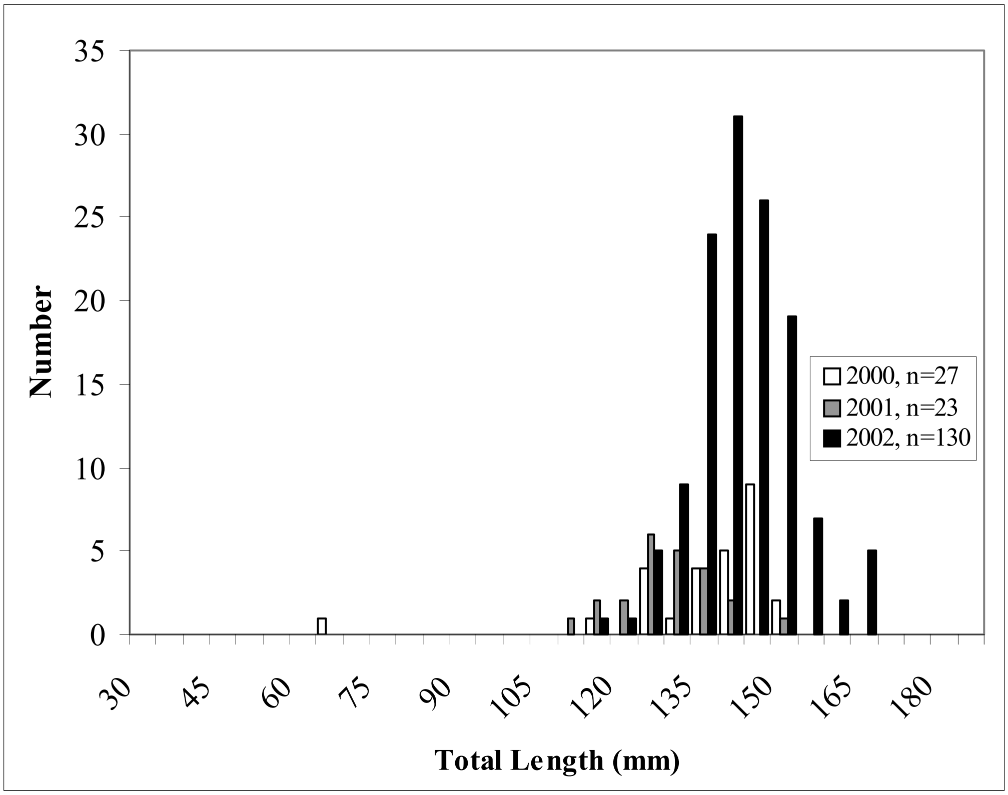

Figure 7. Length frequency of Pacific lamprey ammocoetes and macrothalmia captured in the Red River migrant trap, South Fork Clearwater River drainage, ID, 2000-2002.

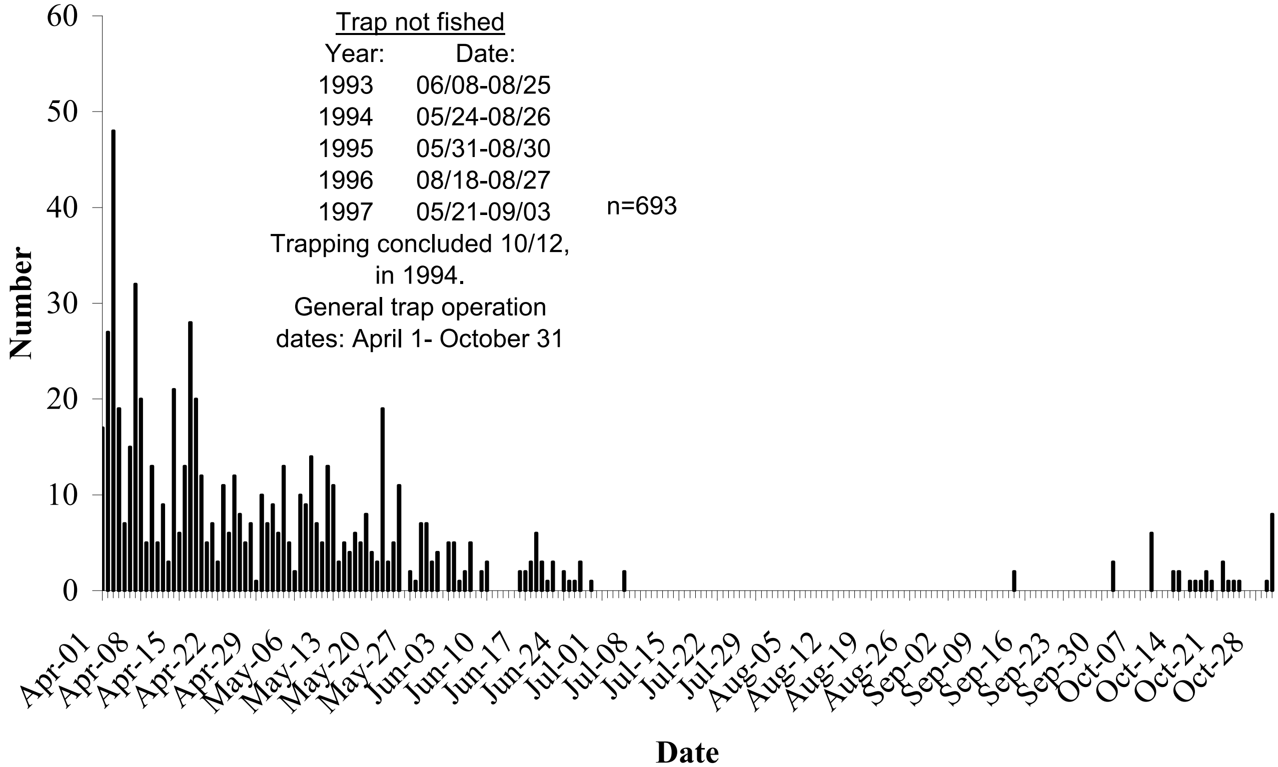

Figure 8. Pacific lamprey ammocoetes and macrothalmia captured in rotary screen trap (rkm 5.0) April 1 to October 31, 1993-2001 (earliest trap operation date March 13, 1996). Red River, ID.

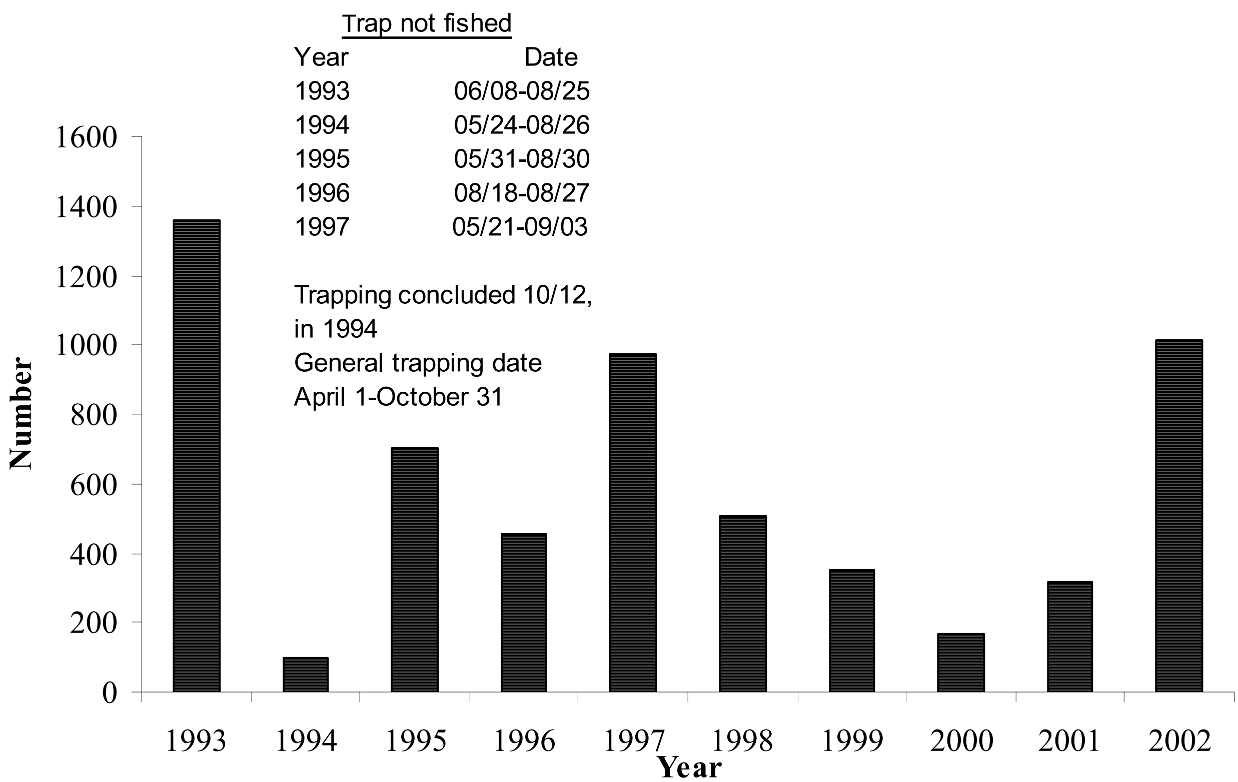

Figure 9. Pacific lamprey ammocoete and macrothalmia downstream migration estimates at Red River trap (rkm 5.0), April 1 to October 31, 1993-2002, ID. Estimates are expanded from numbers captured utilizing trap area fished.

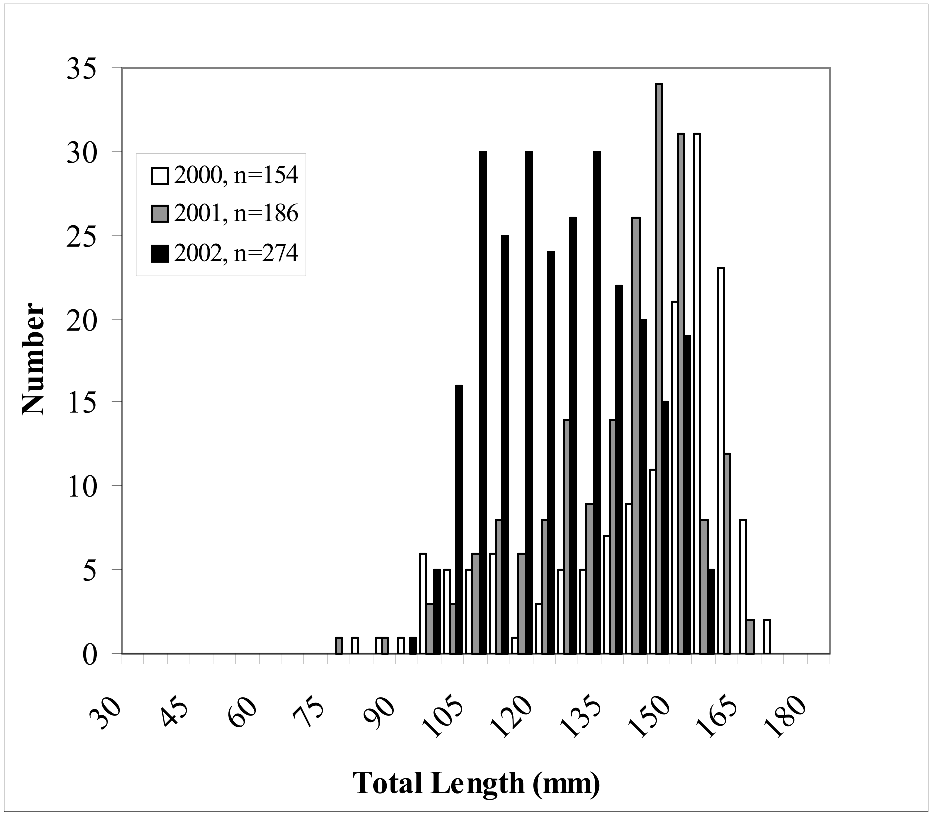

Figure 10. Length frequency of Pacific lamprey ammocoetes and macrothalmia captured by electroshocking in Red River, ID, 2000-02.

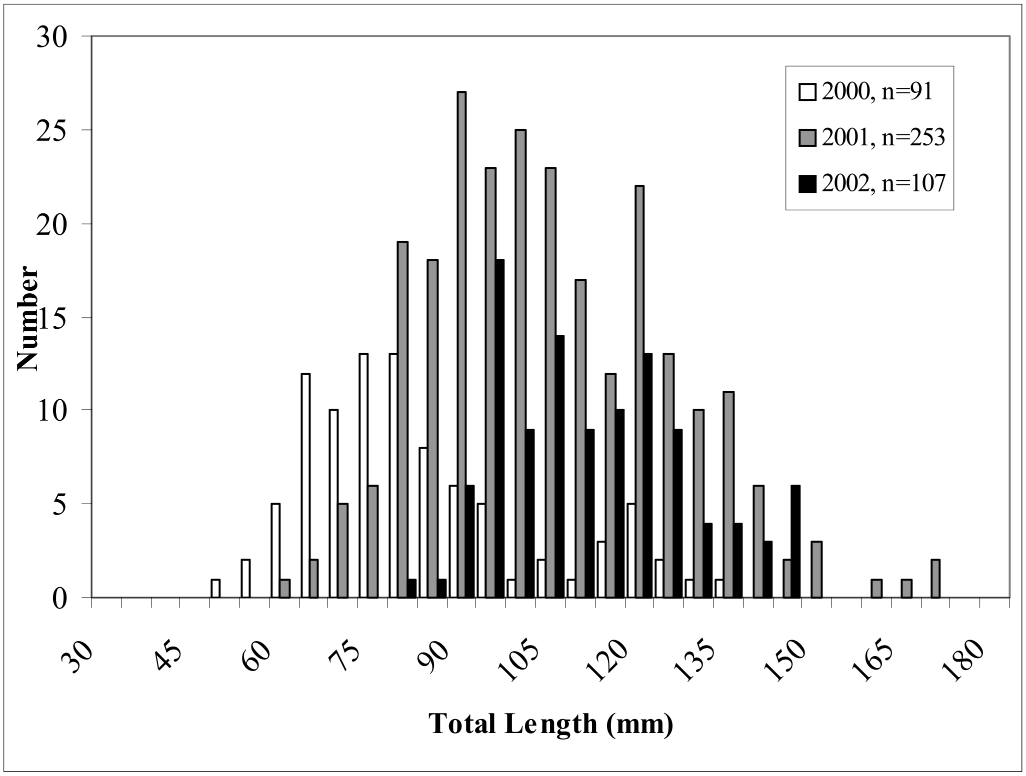

Figure 11. Length frequency of Pacific lamprey ammocoetes and macrothalmia captured by electroshocking in the South Fork Clearwater River, ID, 2000-02.

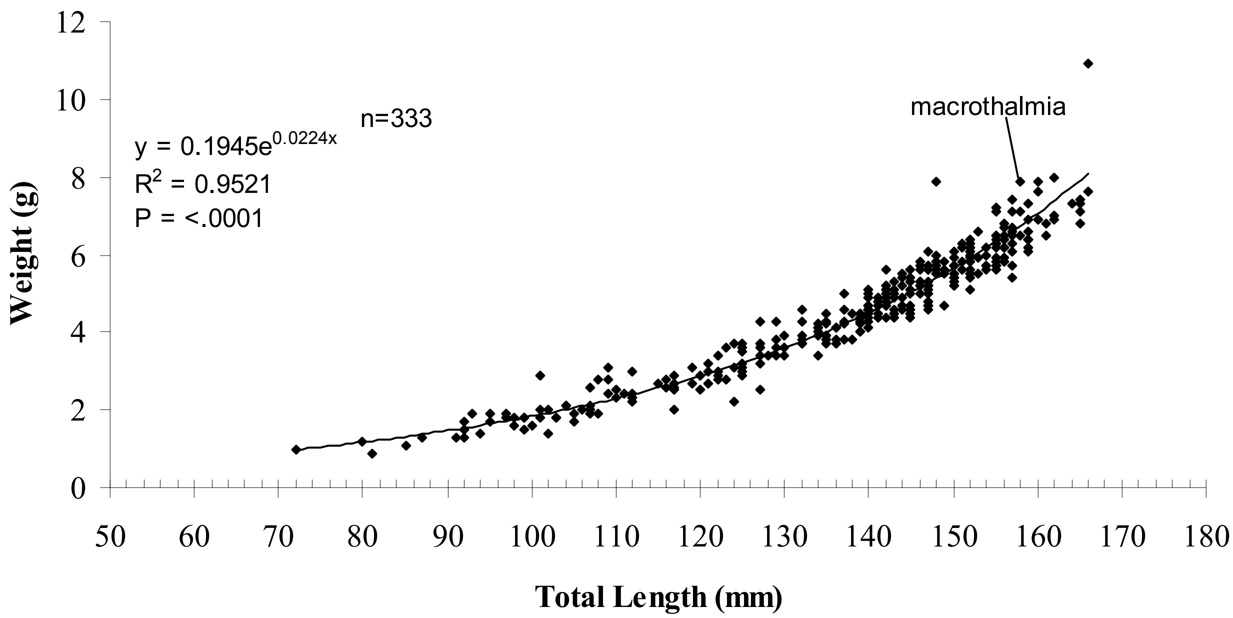

Figure 12. Pacific lamprey (electroshocked) ammocoete and macrothalmia length and weight relationship, Red River, ID, 2000-01.

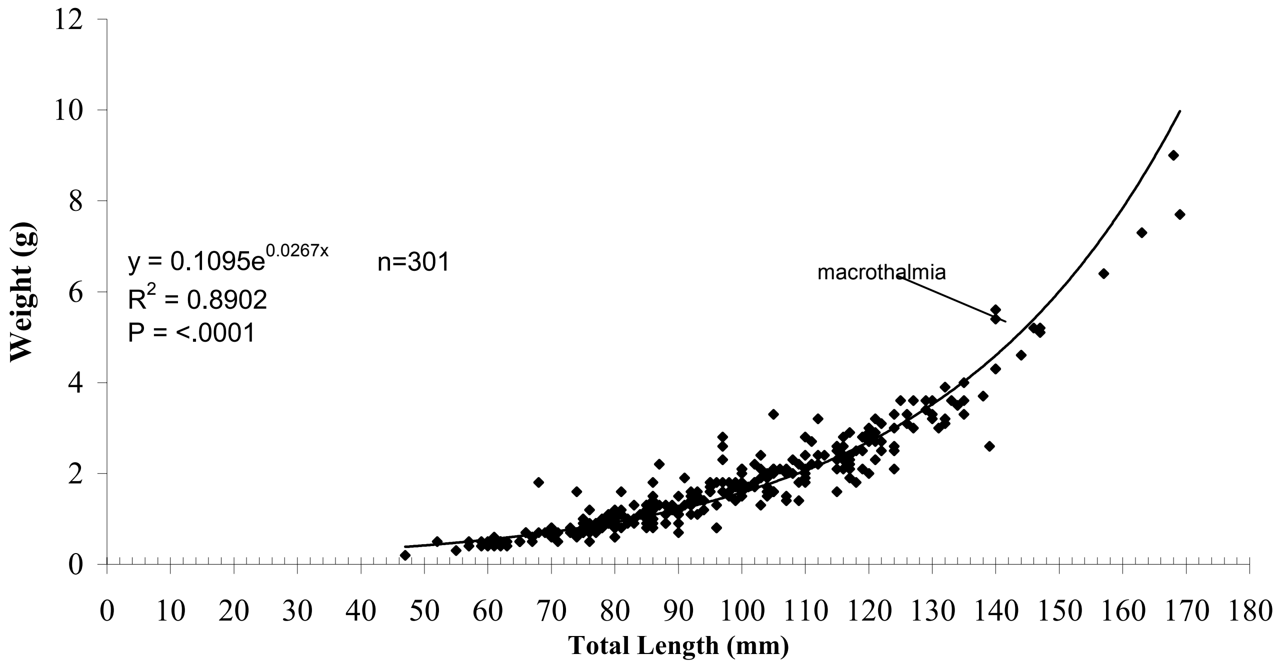

Figure 13. Pacific lamprey (electroshocked) ammocoete and macrothalmia length and weight relationship, South Fork Clearwater River, ID, 2000-01.

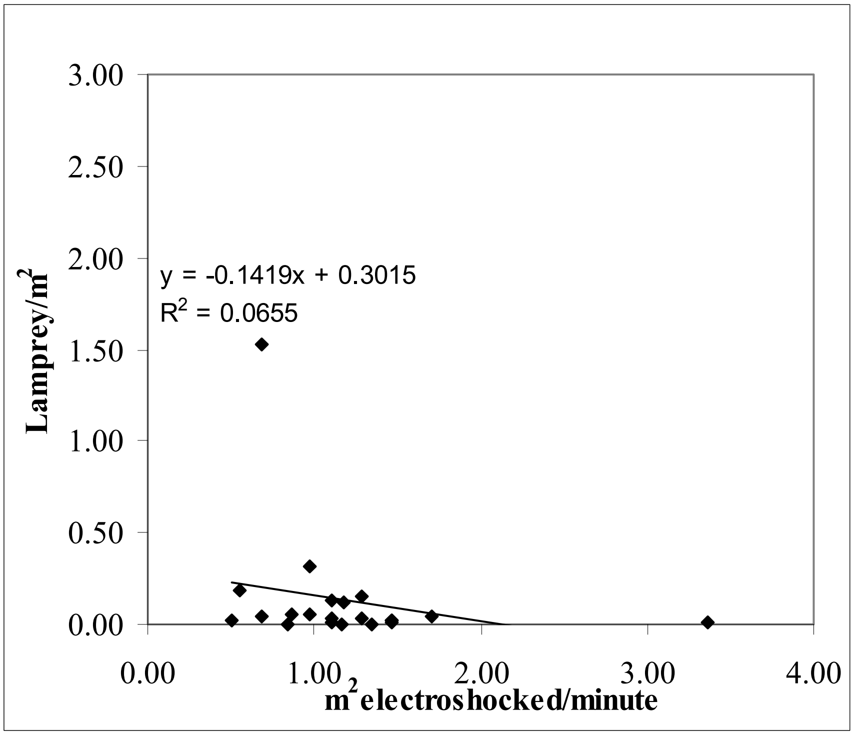

Figure 14. Relationship between capture rate (lamprey/m^2) and sampling rate (m^2 electroshocked/min.) relationship Red River, ID, 2000-02.

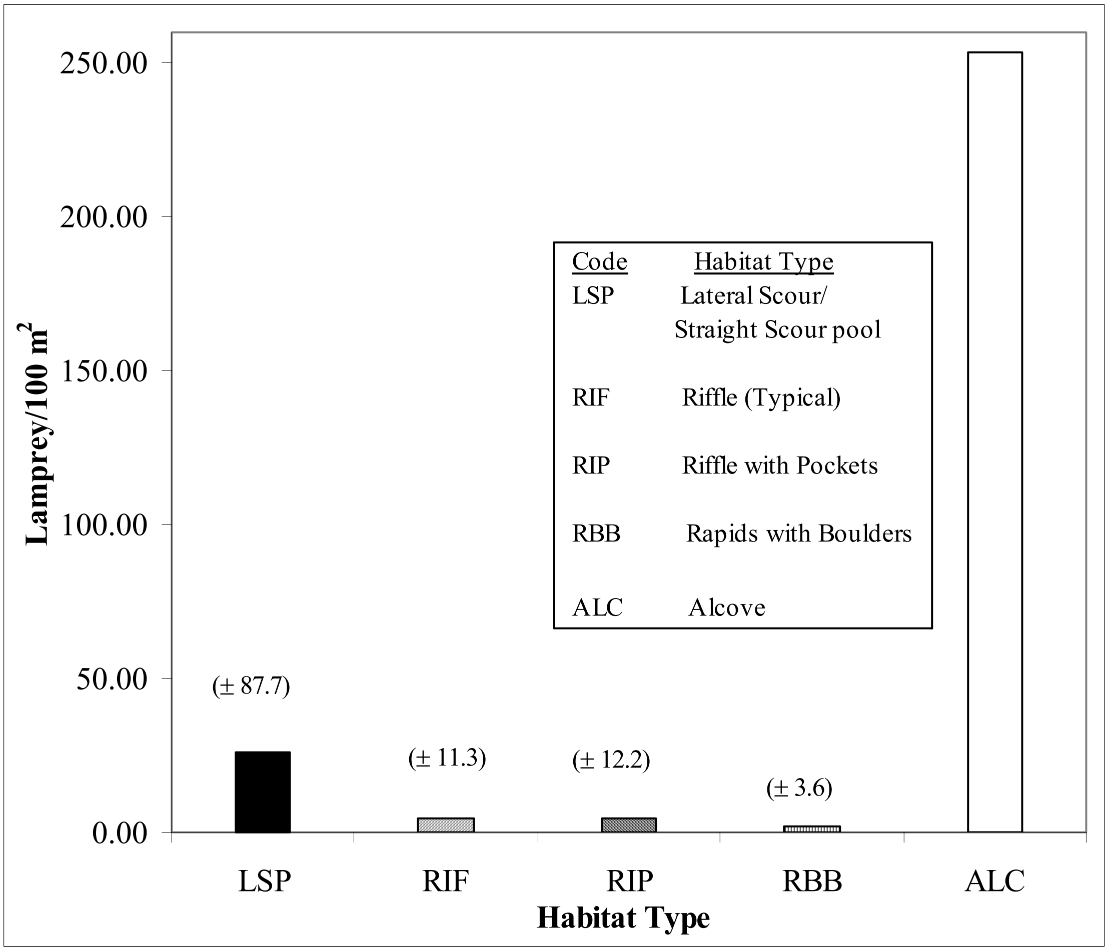

Figure 15. Pacific lamprey ammocoete average densities, in Red River, ID, 2000-02 (Alcove n=1).

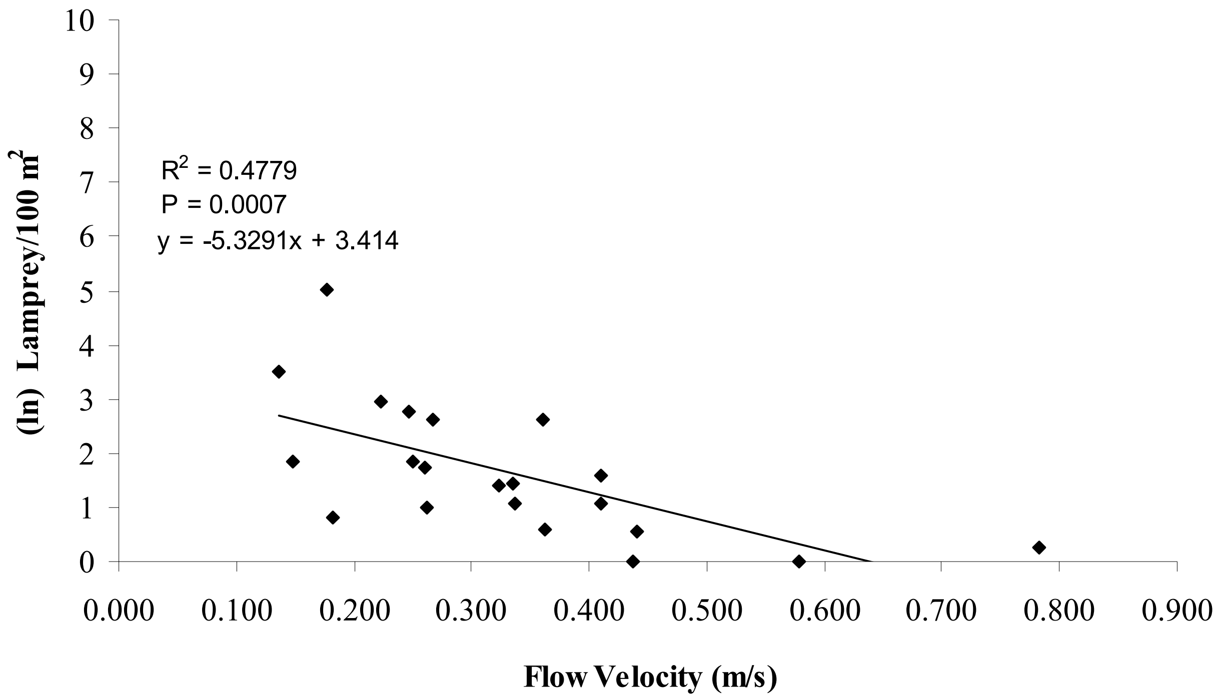

Figure 16. Natural logarithm of Pacific lamprey habitat unit ammocoete densities and average habitat unit flow velocity, Red River, ID, 2000-02.

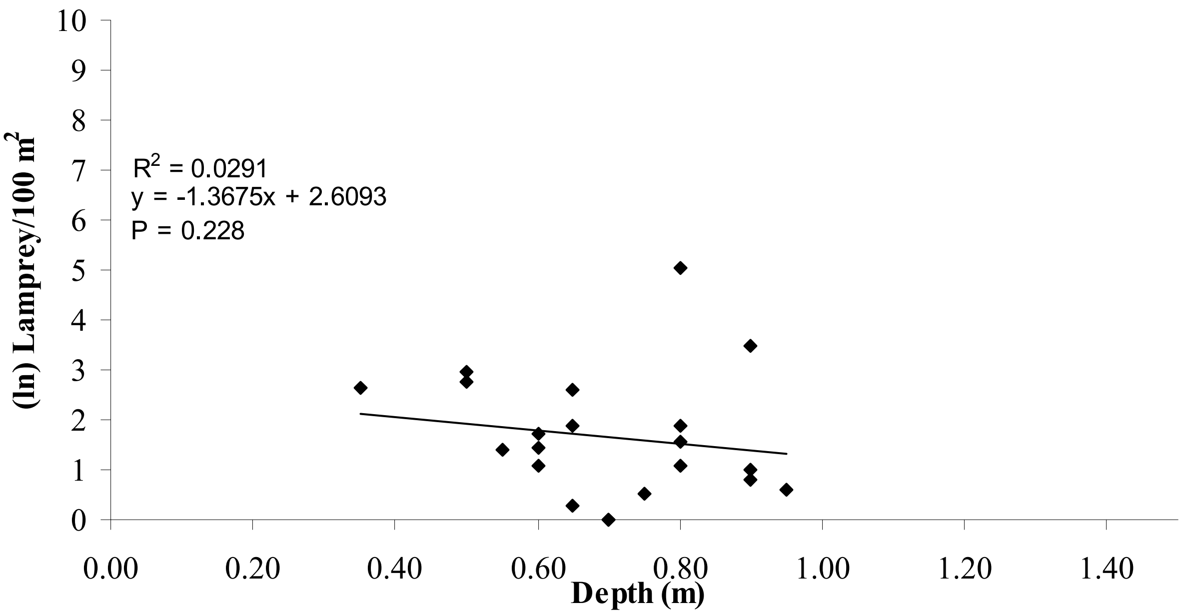

Figure 17. Natural logarithm of Pacific lamprey ammocoete densities and habitat unit maximum depth, Red River, ID, 2000-02.

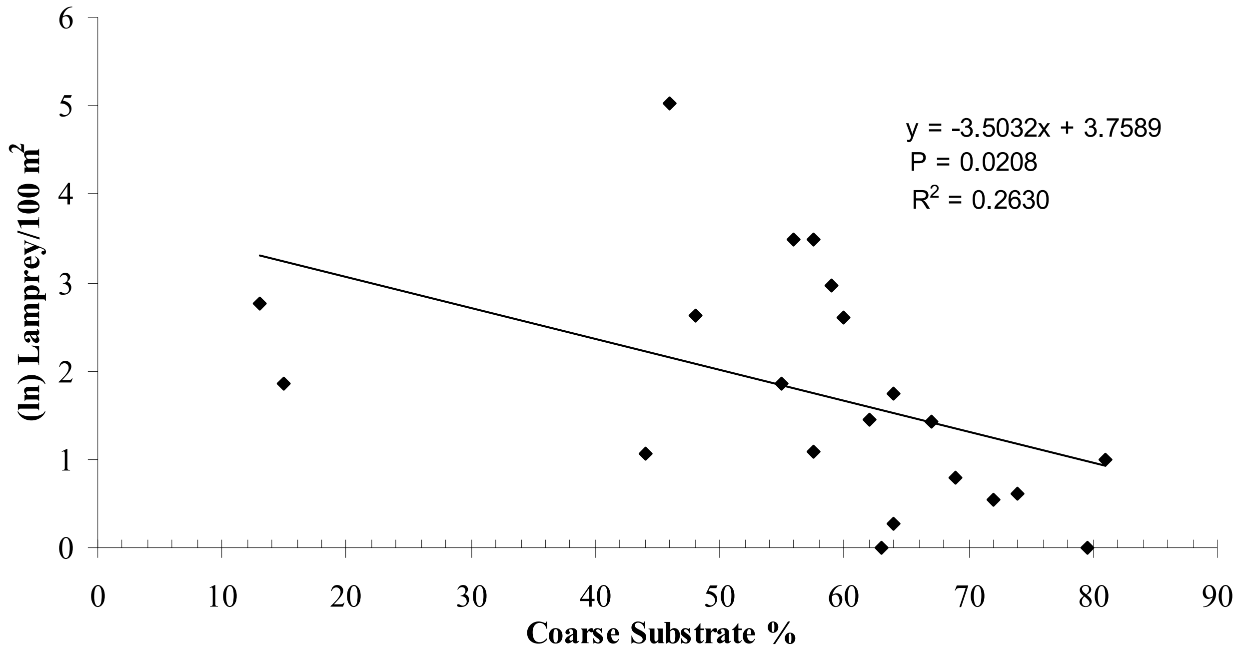

Figure 18. Natural logarithm of Pacific lamprey ammocoete densities and percentage of stream habitat unit coarse substrate (large boulder, small boulder, and cobble). Red River, ID, 2000-02.

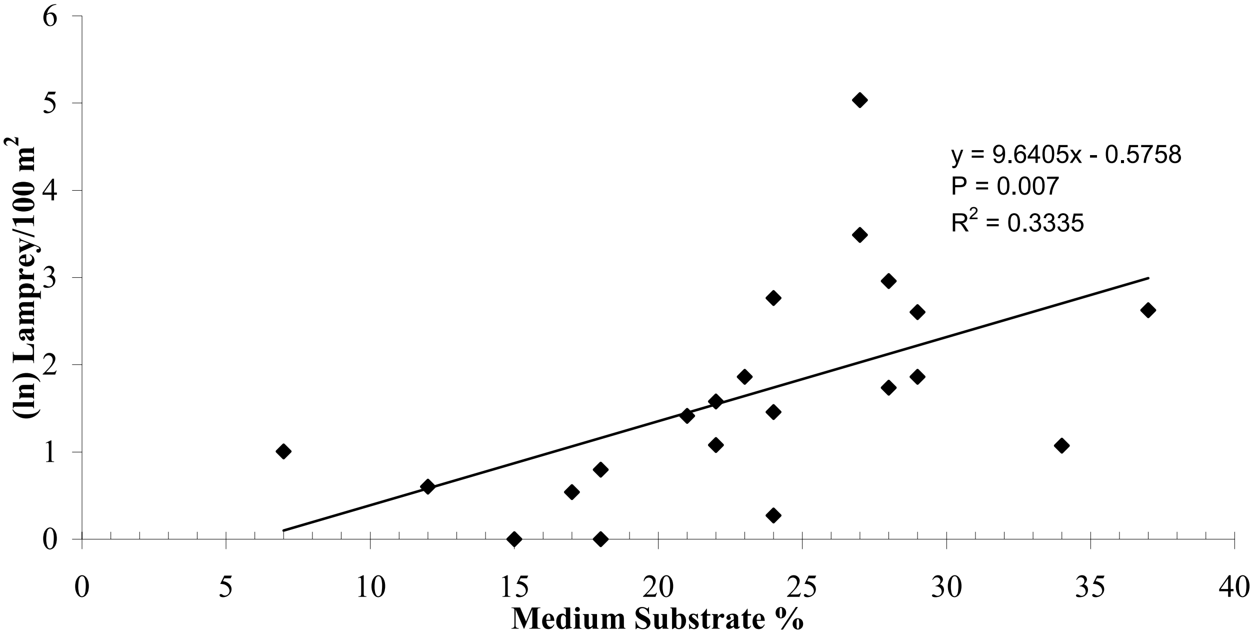

Figure 19. Natural logarithm of Pacific lamprey ammocoete densities and percentage of stream habitat unit medium substrate (coarse gravel, medium gravel, and fine gravel). Red River, ID, 2000-02.

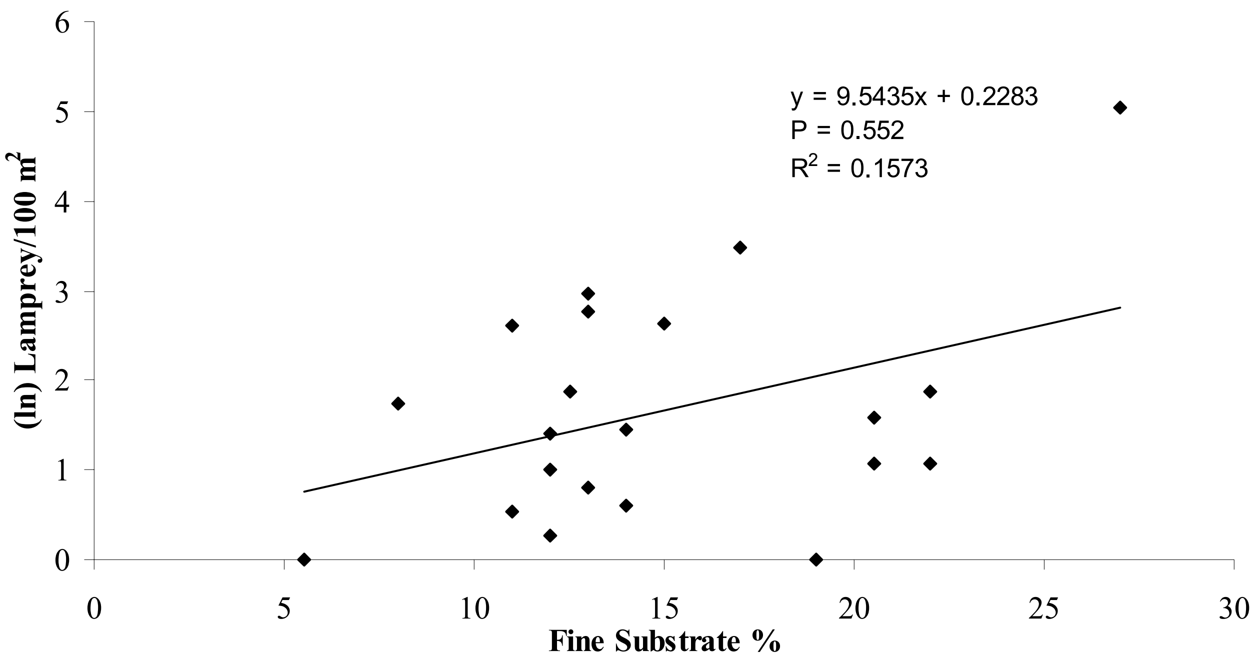

Figure 20. Natural logarithm of Pacific lamprey ammocoete densities and percentage of stream habitat unit fine substrate (coarse sand, fine sand, silt/organic). Red River, ID, 2000-02.

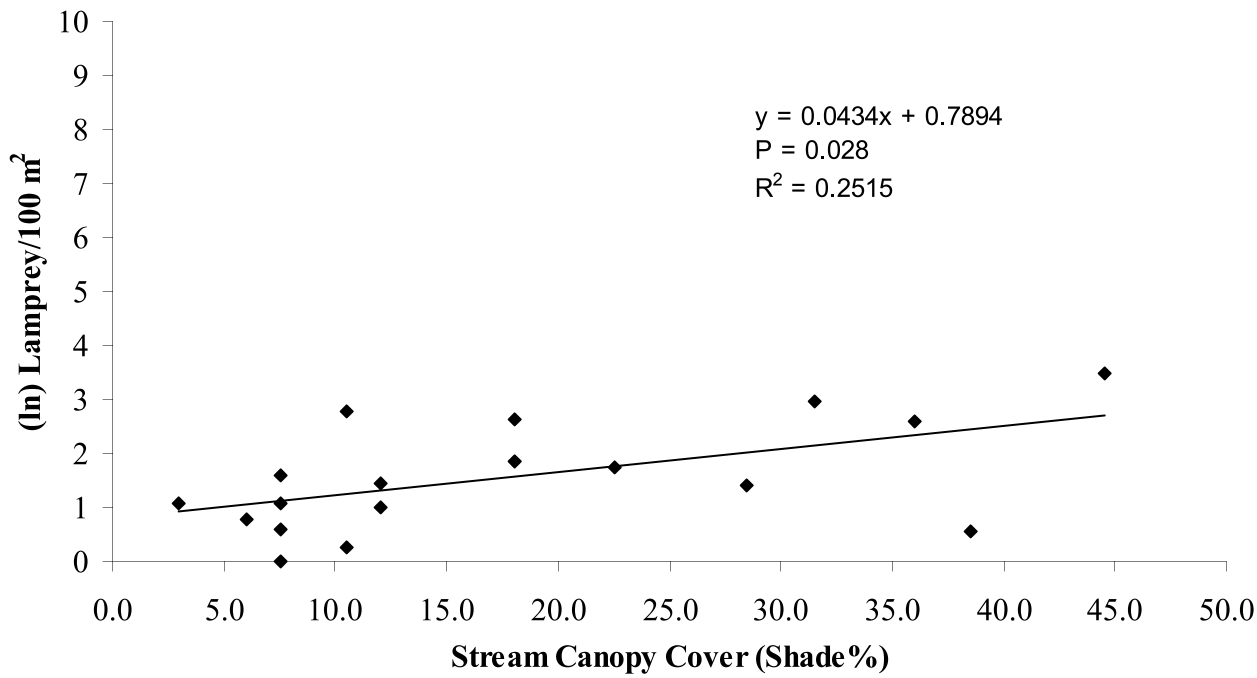

Figure 21. Natural logarithm of Pacific lamprey ammocoete densities and percentage of stream habitat unit riparian canopy cover. Red River, ID, 2000-02.

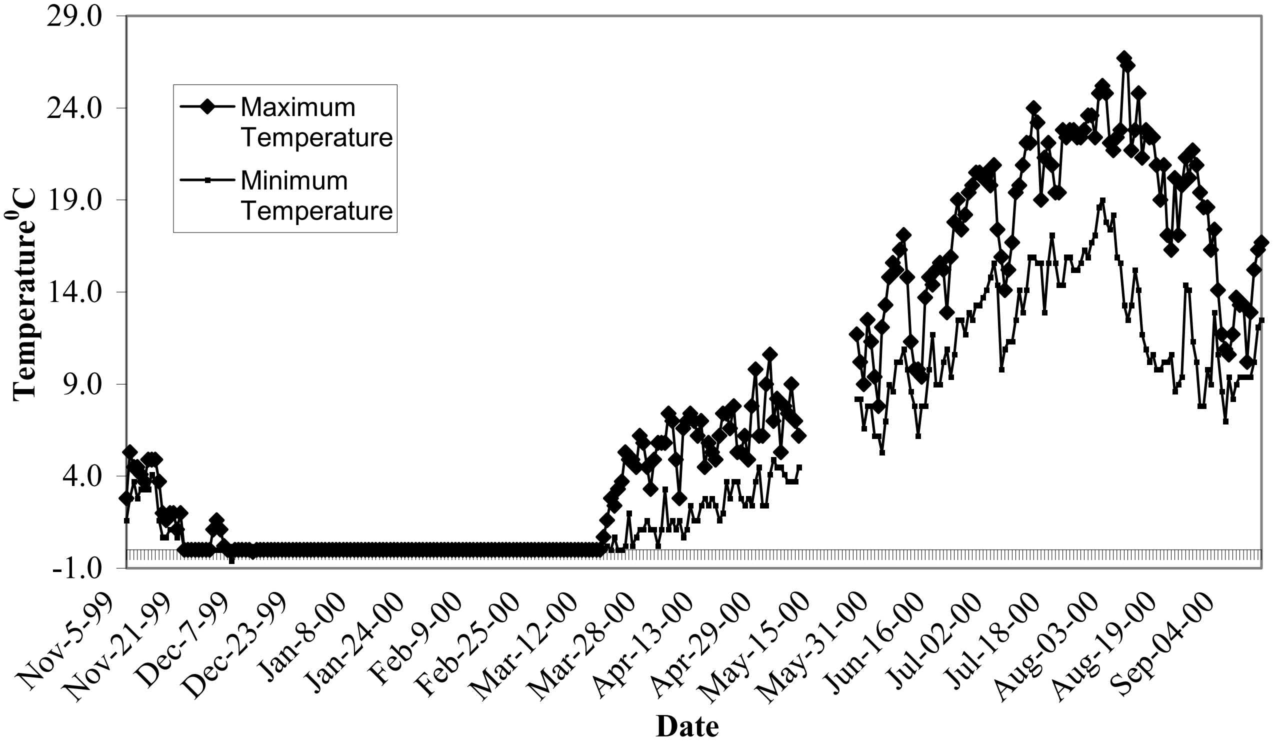

Figure 22. Daily maximum/minimum stream temperature (rkm 5.0) November 1999-September 2000, Red River, ID.

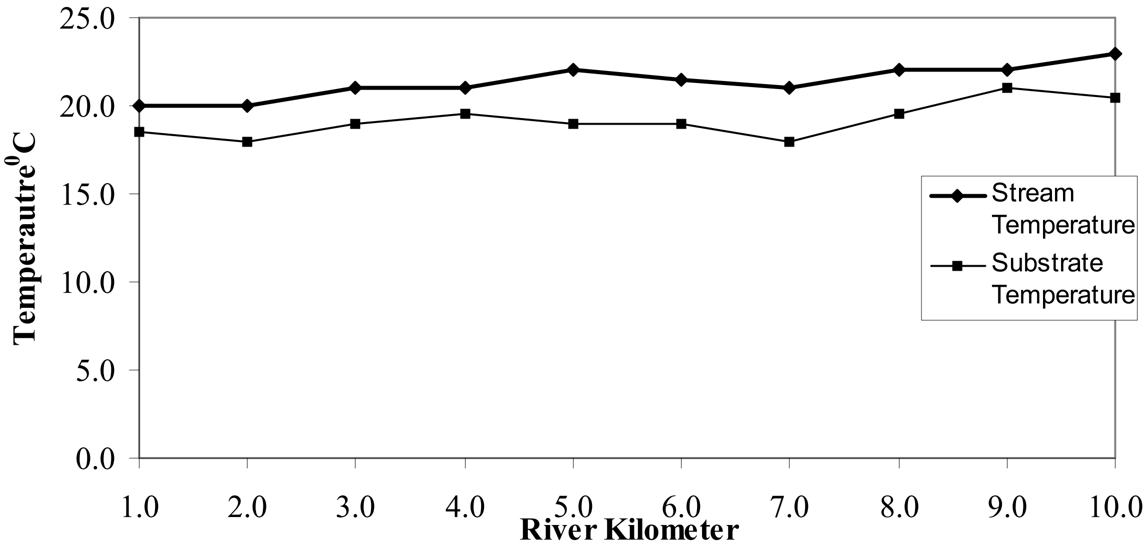

Figure 23. Stream surface and substrate temperatures at 10.0 cm in depth (rkm 1.0 to 10.0) 1545 to 1800 hours on August 9, 2001, Red River, ID.

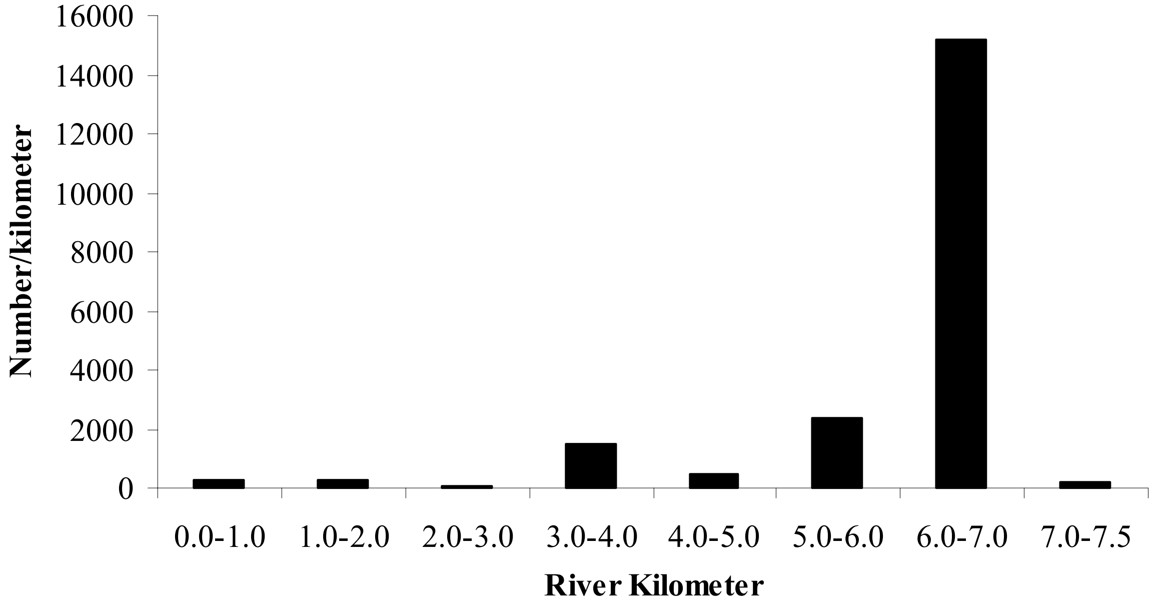

Figure 24. Pacific lamprey ammocoete and macrothalmia estimated totals, Red River (rkm 0.0 – 7.5), ID, 2000-02.

LITERATURE CITED

Beamish, R. J., and C. D.Levings. 1991. Abundance and Freshwater Migrations of the Anadromous Parasitic Lamprey *Lampetra tridentata*, in a Tributary of the Fraser River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 48:1250-1263.

Beamish, F. W. H., and T. E. Medland. 1988. Age Determination for Lampreys. Transactions of the American Fisheries Society 117:63-71.

Beamish, F. W. H., and S. Lowartz. 1996. Larval Habitat of American Brook Lamprey. Canadian Journal of Fisheries and Aquatic Sciences. 53:693-700

Bond, C. E. 1996. Biology of Fishes 2nd edition. Saunders College Publishing 1996:6.

Close, D. A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status Report of The Pacific Lamprey *Lampetra tridentata* in The Columbia River Basin. U.S. Dept. of Energy. Bonneville Power Administration. 1995:35.

Creaser, C. W., and C. S. Hann. 1929. The Food of Larval Lampreys. Michigan Academy of Sciences. 10:433-437.

Galbreath, J. 1979. Columbia River Colossus, the White Sturgeon. Oregon Wildlife, March 1979:3-8.

Hammond, R. J. 1979. Larval Biology of the Pacific Lamprey, *Entosphenus tridentata* (*Gairdner*), of the Potlatch River, Idaho. University of Idaho M. S. Thesis. 1979:40.

Holmes, J. A., and J. H. Youson. 1998. Extreme and Optimal Temperatures For Metamorphosis in Sea Lampreys. Transactions of the American Fisheries Society. 127:206-211.

Idaho Chapter of the American Fisheries Society. 1992. Passage and Survival of Juvenile Chinook Salmon Migrating from the Snake River Basin. Proceedings of a Technical Workshop. University of Idaho, February 26-28, 1992:242.

Idaho Department of Fish and Game. 2000. Washington Water Power Dam Counts on the Clearwater River at Lewiston, Unpublished file data. Idaho Department of Fish and Game. Lewiston , ID.

Idaho Department of Fish and Game. 2002. South Fork Clearwater River drainage, Idaho Supplementation Study, Unpublished file data. Idaho Department of Fish and Game. Lewiston, ID.

Jackson, A. D., P. D. Kissner, D. R. Hatch, B. L Parker, M. S. Fitzpatrick, D. A. Close, and H. Li. 1996. Pacific Lamprey Research and Restoration Annual Report 1996. U. S. Department of Energy. Bonneville Power Administration. 1996:66.

Jackson, A. D., D. R. Hatch, B. L. Parker, D. A. Close, M. S. Fitzpatrick, and H. Li. 1997. Research and Restoration Annual Report 1997. U. S. Department of Energy. Bonneville Power Administration. 1997:91.

Kan, T. T. 1975. Systematics, Variation, Distribution, and Biology of Lampreys of the Genus *Lampetra* in Oregon. Doctoral Dissertation, Oregon State University. Corvallis, OR. 1975:194.

Mallat, J. 1983. Laboratory Growth of Larval Lampreys *Lampetra entosphenus tridentata Richardson* at Different Food Concentrations and Animal Densities. Journal of Fisheries Biology. 22:293-301.

Mattson, C. R. 1949. The Lamprey Fishery at Willamette Falls, OR. Research Briefs, Fish Commission of Oregon. 2(2):23-27.

Merrell, T. R. 1959. Gull Food Habits on the Columbia River. Research Briefs, Fish Commission of Oregon. 7(1):82.

Morkert, S. B. 1993. A Habitat Evaluation and Population Estimate for Larval Sea Lampreys *Petromyzon marinus* In Jordan River, Michigan. Ludington Biological Station Internal Report. 1993:93-97.

Overton, K. C., S. P. Wollrab, B. C. Roberts, and M. A. Radko. 1997. R1/R4 (Northern Intermountain Regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. USDA Forest Service. General Technical Report INT-GTR-346.

Pajos, T. A., and J. G. Weise. 1994. Estimating Populations of Larval Sea Lamprey with Electrofishing Sampling Methods. North American Journal of Fisheries Management. 14:580 –587.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for Evaluating Stream Riparian and Biotic Conditions. USDA Forest Service General Technical Report INT-138.

Pletcher, T. F. 1963. The Life History and Distribution of Lampreys in the Salmon and Certain other Rivers in British Columbia, Canada. M. S. Thesis, University of British Columbia, Canada . 1963:190.

Poe, T. P., H. C. Hamsel, S. Viggs, D. E. Palmer, and L. A. Prendergast. 1991. Feeding of Predaceous Fishes on Outmigrating Juvenile Salmonids in John Day Reservoir, Columbia River. Transaction of the American Fisheries Society. 120:405-418.

Potter, I. C., R. W. Hilliard, J. S. Bradley, and R. J. McKay. 1986. The Influence of Environmental Variables on the Density of Larval Lampreys in Different Seasons. Oecologica. 70:443-440.

Richards, J. E., and F. W. H. Beamish. 1981. Initiation of Feeding and Salinity Tolerance in The Pacific Lamprey *Lampetra tridentata*. Marine Biology. 63:73-77.

Scott, W. B., and E. J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada Bulletin. 184:42-45.

Simpson, J. C., and R. L. Wallace. 1982. Fishes of Idaho. University of Idaho Press. Moscow, Idaho. 1982:46

Swindell, Edgar. 1941. Report on Source, Nature, and Extent of Fishing, Hunting, and Miscellaneous Rights of Certain Indian Tribes in Washington and Oregon. U. S. Department of Indian Affairs. 1941:483.

USDA Forest Service. 1998. South Fork Clearwater River Landscape Assessment. USDA Forest Service. Nez Perce National Forest. 1998:I:210.

USDA Forest Service. 2001. South Fork Clearwater River drainage historical information. USDA Forest Service Unpublished file data. Nez Perce National Forest.

Vella, J. J., L. C. Stuehrenberg, and T. C. Bjornn. 1997. Migration Patterns of Pacific Lamprey *Lampetra tridentata* In the Lower Columbia River 1997. Annual Report of Research. U. S. Army Corps of Engineers.

Weisser, J. W., and G. T. Klar. 1990. Electrofishing for Sea Lampreys *Petromyzon marinus* in the Great Lakes Region of North America. In Cowx 1990, Developments in Electrofishing. Fishing News Books 1990.

White, C. R. 1954. The Age, Growth, and Migration of Steelhead Trout in the Clearwater River, ID. University of Idaho, M. S. Thesis. 1954:65.

Youson, J. H., and seven coauthors. 1993. Importance of Condition Factor and the Influence of Water Temperature and Photoperiod on Metamorphosis of the Lamprey, *Petromyzon marinus*. Canadian Journal of Fisheries and Aquatic Sciences. 50:2448-2456.

APPENDIX

A 1. Pacific lamprey visual spawning survey stream sections, Red River, ID, 2000-01.

Date	Stream/Section	RKM/Location	Redds Counted	Distance sampled (km)
2000				
19-May-00	R. River/(upper)	43.0	0	0.33
15-Jun-00	R. River/(upper)	43.0	0	0.33
23-Jun-00	R. River/(upper)	43.0	0	0.33
30-Jun-00	R. River/(upper)	43.0	0	0.75
7-Jul-00	R. River/(upper)	43.0	0	0.50
19-May-00	R. River/(campground)	32.0	0	0.80
22-Jun-00	R. River/(campground)	32.0	0	0.80
29-Jun-00	R. River/(campground)	32.0	0	0.80
16-Jun-00	R. River/(Dawson Creek)	17.0	0	0.80
23-Jun-00	R. River/(Dawson Creek)	17.0	0	0.80
7-Jul-00	R. River/(Dawson Creek)	17.0	0	0.80
30-Jun-00	R.River/(WMA)	15.0	0	0.80
Total				7.84
2001				
1-Jun-01	R. River/(upper)	43.0	0	0.33
15-Jun-01	R. River/(upper)	43.0	0	0.33
22-Jun-01	R. River/(upper)	43.0	0	0.33
29-Jun-01	R. River/(upper)	43.0	0	0.33
1-Jun-01	Red Horse Creek/(lower)	1.0	0	0.10
15-Jun-01	Red Horse Creek/(lower)	1.0	0	0.10
23-Jun-01	Red Horse Creek/(lower)	1.0	0	0.10
1-Jun-01	Red River (lower)	7.5	0	0.75
16-Jun-01	Red River (lower)	7.5	0	0.75
22-Jun-01	Red River (lower)	7.5	0	0.75
15-Jun-01	R. River/(Dawson Creek)	17.0	0	0.75
6-Jul-01	R. River (campground)	32.0	0	0.75
6-Jul-01	R. River/(Dawson Creek)	17.0	0	0.75
7-Jul-01	Johns Creek/(lower)	1.0	0	0.75
Total				6.87