Evaluate Habitat Use and Population Dynamics of Lamprey in Cedar Creek

BPA Project #2000-014-00

Annual Report for 2005 Sampling Season

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Abstract

Pacific lamprey (*Lampetra tridentata*) populations in the Columbia River basin have declined and the status of the Western brook lamprey (*L. richardsoni)* and river lamprey (*L. ayresi*) is unknown. Identifying the biological and ecological factors limiting lamprey populations is critical to their recovery. This ongoing, multi-year study examines lamprey in Cedar Creek, Washington, a third-order tributary to the Lewis River. This annual report describes the activities and results of the sixth year of this project. Adult (n = 140), macropthalmia (n = 146), and ammocoete (n = 272) stages of Pacific and Western brook lamprey were examined in 2005. The ladder was most productive in capturing adults. There was a small peak in adult capture in early summer and another in the fall. Thirty-three spawning ground surveys were conducted during which 291 Pacific lamprey and 10 Western brook lamprey nests were identified. Accuracy of nest enumeration showed that the number of nests may have been overestimated; however, most nests were old upon first observation. Ammocoete movement was positively correlated with high flows and appeared to be passive while macropthalmia movement was not associated with discharge. The ability to detect presence of larval lamprey with an electroshocker was assessed relative to larval size and larval density. Higher densities increased the probability of detection. Capture efficiency was higher for smaller fish.

Introduction

Three lamprey species (*Lampetra tridentata*, *L. richardsoni, and L. ayresi*) include the Columbia River basin (CRB) within their geographic ranges (Kan 1975). Pacific lamprey (*L. tridentata*) in the CRB have declined to only a remnant of their pre-1940s populations (Close et al. 1995) and the status of Western brook lamprey (*L. richardsoni*) and river lamprey (*L. ayresi*) is unknown. The ecological, economic, and cultural significance of these species, especially the Pacific lamprey, is grossly underestimated (Kan 1975, Close et al. 1995). Although biological and ecological information for these species is available (e. g. Pletcher 1963, Beamish 1980, Richards 1980, Beamish and Levings 1991), few studies have been conducted within the CRB (Kan 1975, Hammond 1979, Close 2001). Actions are currently being considered for the conservation of Pacific lamprey populations in the CRB (CRB Lamprey Technical Workgroup 2003, Close et al. 1995).

Identifying the biological and physical factors that are limiting lamprey in the CRB is critical for their conservation. Availability and accessibility of suitable spawning and rearing habitat may affect the amount of recruitment that occurs within a basin (Houde 1987, Potter et al. 1986). Factors such as food base, disease, competition, and predation also need to be examined.

Studying lamprey population dynamics is essential for developing and evaluating management plans (Van Den Avyle 1993). Population assessments allow one to describe fluctuations in abundance and measure responses to environmental disturbances. Such knowledge is necessary to assess population trends and status.

The United States Fish and Wildlife Service (USFWS) Columbia River Fisheries Program Office (CRFPO) has been collecting quantitative baseline data for Pacific lamprey and Western brook lamprey in Cedar Creek, Washington since 2000. Data collected during 2000, 2001, 2002, 2003 and 2004 are summarized in five annual reports (Stone et al. 2001, Stone et al. 2002, Pirtle et al. 2003 and Lê et al. 2004, Luzier and Silver 2005). This annual report summarizes results of research and analytical activities conducted during 2005. The objectives of this research are to: 1. Estimate abundance, measure biological characteristics, determine migration timing of adult Pacific lamprey; 2. Evaluate spawning habitat requirements of adult lamprey; 3. Determine outmigration timing and estimate the abundance of recently metamorphosed lamprey (macropthalmia) and ammocoetes; and 4. Determine larval lamprey distribution, habitat use, and biological characteristics.

Life History

The Pacific lamprey ranges from Baja California to Alaska and is parasitic and anadromous (Scott and Crossman 1973). Adults enter freshwater from July to October and spawning takes place the following spring when water temperatures are 10 - 15 °C (Beamish 1980, Beamish and Levings 1991). Both sexes construct nests in gravel that are approximately 40 - 60 cm in diameter and less than 1 m in depth (Close et al. 1995). Females deposit between 10,000 - 200,000 eggs and both sexes die within 3 - 36 days of spawning (Kan 1975, Pletcher 1963). Larvae, known as ammocoetes, hatch after approximately 19 days at 15 °C (Pletcher 1963). Ammocoetes reside in fine sediment for 4 - 6 years and filter feed on diatoms, algae, and detritus by pumping water through their branchial chamber (Beamish and Levings 1991). Pacific lamprey transform from ammocoetes to macropthalmia between July and October (Richards and Beamish 1981). The macropthalmia migrate to the ocean between late fall and spring (van de Wetering 1998). They spend 1 - 4 years as adults, reaching lengths of 700 mm, feeding as external parasites on marine fish before returning to freshwater to spawn (Beamish 1980).

The Western brook lamprey ranges from southern California to British Columbia (Scott and Crossman 1973). They are non-parasitic and complete their entire life cycle in freshwater, obtaining lengths of 200 mm (Close et al. 1995, R. Horal personal communication). Spawning occurs from late April to early July when temperatures range from 7.8 - 20 °C. Nests are commonly constructed by males in gravel 16 - 100 mm and are 100 - 125 mm in diameter and 50 mm in depth (Scott and Crossman 1973). A nest may contain a group of up to 30 spawning adults and can be occupied by several different groups over a 10 - 14 day period (Scott and Crossman 1973). Eggs hatch in 10 days at 10 - 15.5 °C. After hatching, ammocoetes move to areas with low flow and high organic matter. Ammocoetes remain in the sediment nursery areas for 3 - 6 years and feed similarly to Pacific lamprey ammocoetes (Pletcher 1963). Mature ammocoetes metamorphose into adults from August to November and over-winter without feeding (Pletcher 1963). Adults become sexually mature in March and die shortly after spawning (Pletcher 1963).

Study Area

This study was conducted in Cedar Creek, a third-order tributary to the Lewis River (Figure 1). The Lewis River enters the Columbia River at river kilometer 139. The Cedar Creek drainage is 89.3 km^2 and includes diverse stream types and habitat conditions. Cedar Creek contains five major tributaries (Chelatchie, Pup, Bitter, Brush, and John Creeks), and is inhabited by Pacific, Western brook, and possibly river lamprey (Dan Rawding, Washington Department of Fish and Wildlife, Vancouver, WA, personal communication). Access for fish into Cedar Creek is uninhibited by dams or by the effects of mainstem Columbia River hydropower development.

Abiotic conditions in Cedar Creek and adjacent waters are recorded throughout the year by various agencies. The United States Geological Service (USGS) records discharge on the East Fork of the Lewis River at the Heisson Station (Figure 2). Washington Department of Ecology records discharge on Cedar Creek at a station located at the Grist Mill bridge (approximately 3.9 km upstream from the mouth) (Figure 2). The USFWS records temperature at three locations along Cedar Creek (Figure 1) and rainfall is measured at the Grist Mill (Figure 3).

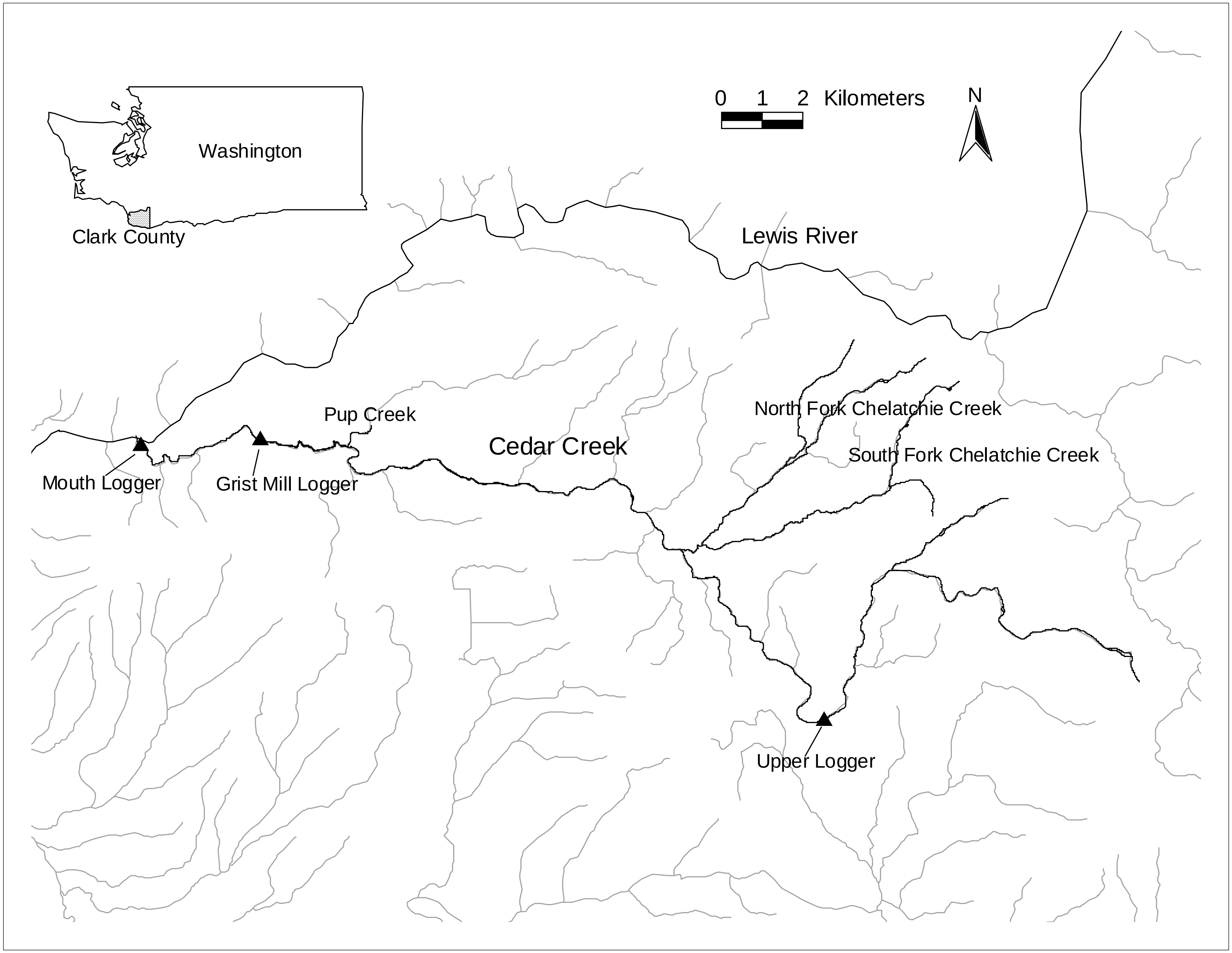

Figure 1. Cedar Creek in Clark County, Washington depicting the location of USFWS temperature loggers, 2005.

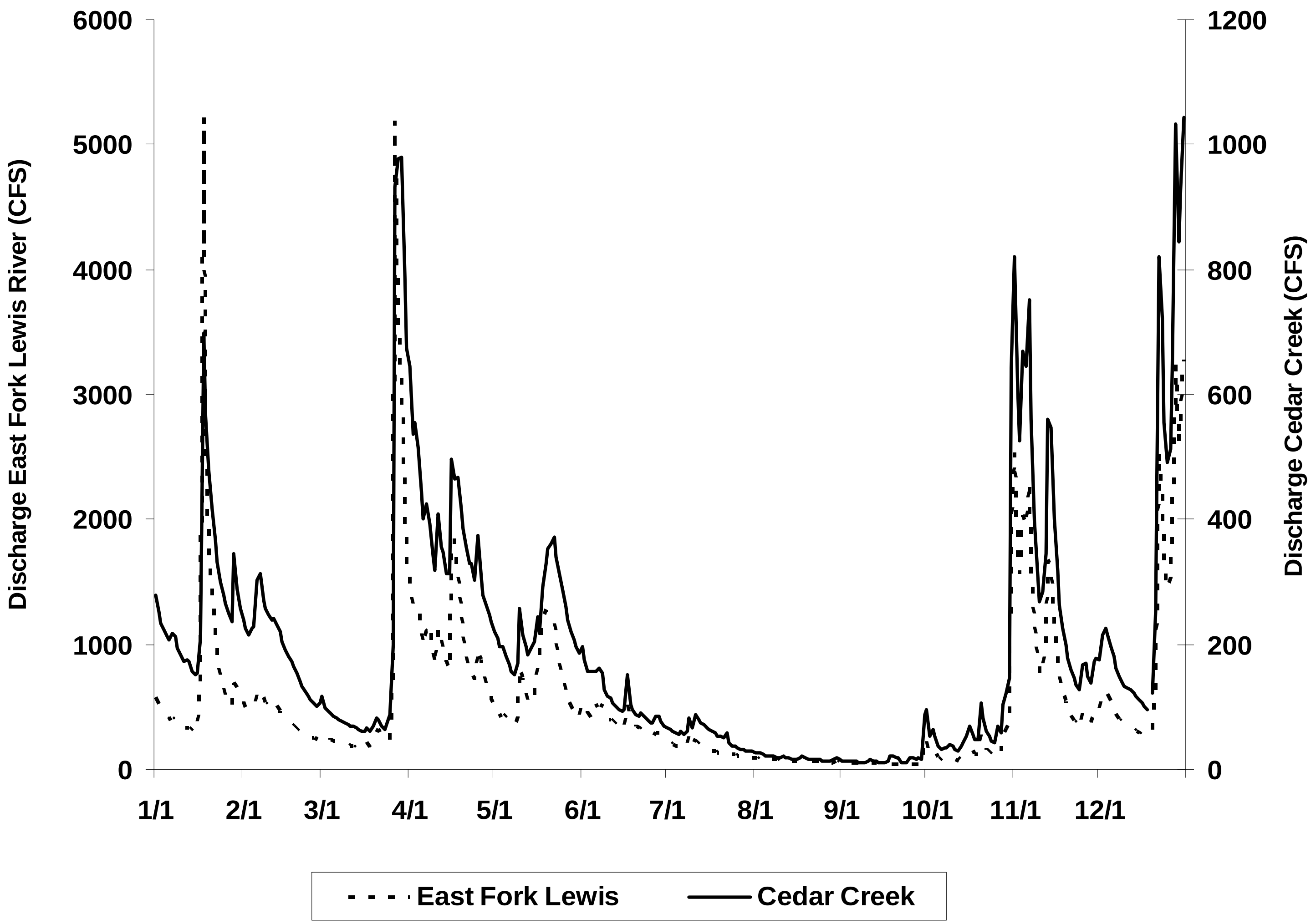

Figure 2. Mean Daily discharge for East Fork Lewis River, Heisson Station (USGS) and Cedar Creek (Washington Department of Ecology), 2005.

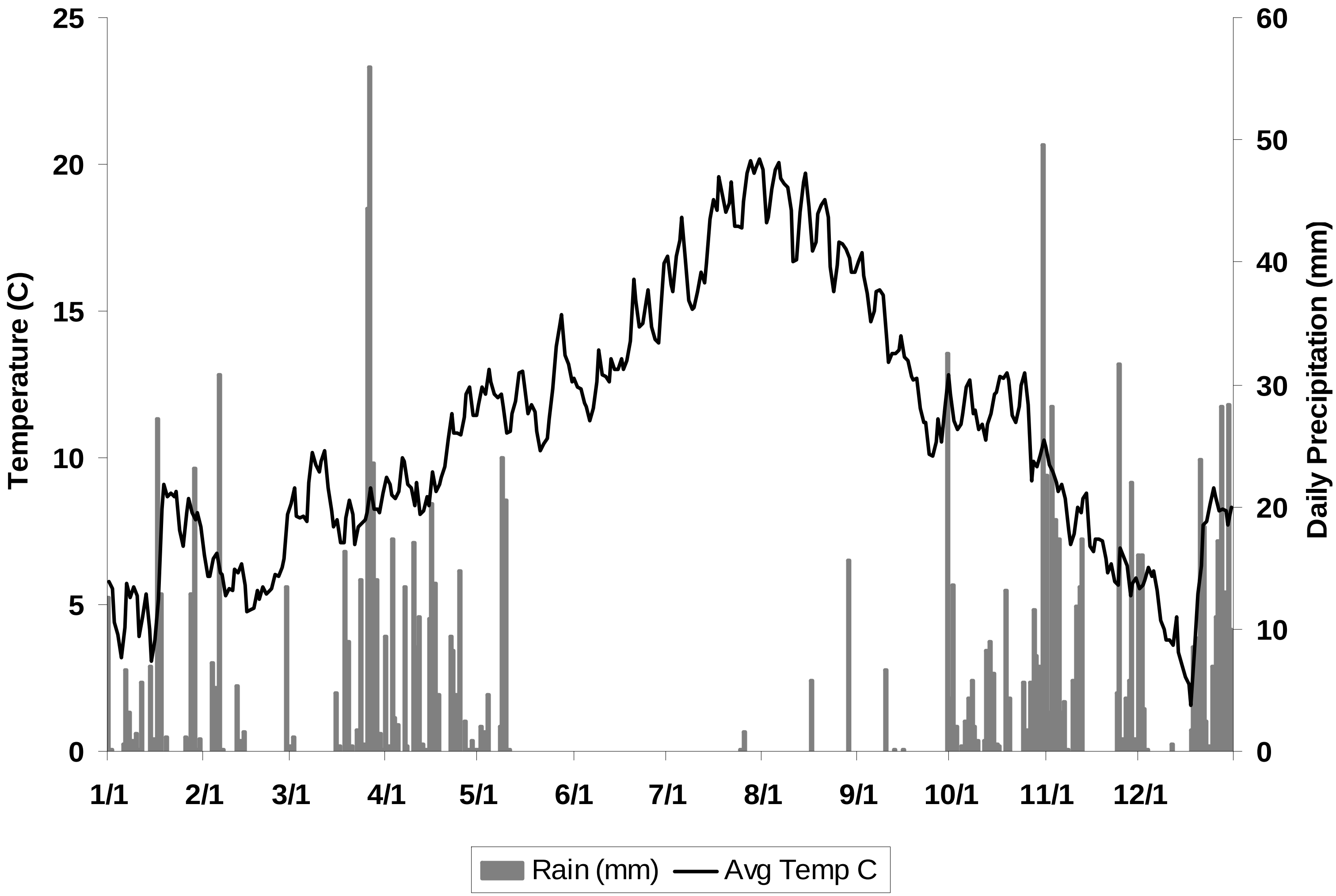

Figure 3. Water temperatures and precipitation recorded on Cedar Creek at the Grist Mill, 2005.

Methods

Adult Pacific Lamprey

Adult Pacific lamprey were captured in the Washington Department of Fish and Wildlife adult ladder operated for salmon at the Grist Mill falls and in lamprey pot traps (Luzier and Silver 2005) deployed in various locations. Two pot traps in the fish ladder fished from January 5 until December 21. Three pot traps at the Grist Mill falls were deployed on March 23 and fished until December 21 with the exception of two short periods of inoperability, the first week of April and two weeks in early November, due to high flows. A pot trap line at the mouth of Cedar Creek was launched on June 14 and fished until October 31. Another pot trap line was deployed just downstream of the Grist Mill on July 25 and fished until October 31. One additional single pot trap was deployed in the pool adjacent to the adult ladder. This pot was fished from July 15 until October 31. The effectiveness of individual capture methods (i.e., pots at mouth, pots at mill, pots in adult ladder, ladder alone) was tracked.

When fishing, lamprey pot traps and the adult fish ladder were checked daily. Captured lamprey were anesthetized with MS-222, measured for length and weight, and marked with a PIT tag and a dorsal fin clip. Fin clips were saved in 100% ethanol for future genetic analysis. Sex was determined by the presence of an anal lobe seen in females just prior to spawning and in the post spawn condition. Presence of the anal lobe in females along with an extended abdomen and shortened body length in both females and males indicated that spawning was imminent. Post spawn individuals had shortened body length, soft hollow abdomens, skin discoloration and in several cases cloudy eyes. First-time captures were released approximately 100 m downstream of their capture site and recaptured individuals were released approximately 100 m upstream of their capture site.

A trap retention study was initiated in 2005 to test the retention rates of two different pot trap designs: 1) single funnels on both ends; 2) single funnel on the downstream end, internal funnel and perforated wood closure on the upstream end. The pot traps were bolted together and deployed as a single unit downstream of the Grist Mill (Figure 4). One PIT tagged fish was placed in each pot before deployment. The pots were retrieved after 24 hours and lamprey were removed and scanned for PIT tags.

Spawning

Pacific and Western brook Lamprey nests were identified by foot surveys during the spawning period. Surveys began May 3rd and continued until August 8th. To accomplish a census survey of nest occurrence, Cedar Creek was surveyed in its entirety in 2005 (all index, non-index and exploratory reaches identified in Le et al. 2004 and Luzier and Silver 2005 were surveyed). When possible, the location of each nest was recorded with GPS. As Western brook nests can look similar to animal hoof prints, only those nests containing adults were counted. Presence of adults on all nests was noted as well as number and sex of fish.

The length of the lamprey spawning season was determined by surveying seven 100 meter reaches throughout Cedar Creek. The date of the first nest activity in each reach was recorded as well as the last nest activity in the reach.

Nest longevity was determined by marking seven nests in three different reaches in Cedar Creek with weighted flagging. Each of the three reaches was visited every seven days and the flagged nests were recorded as visible or not visible.

Accuracy of Pacific lamprey nest enumeration was determined by excavating 5% of all nests and sampling for viable embryos. Rocks were gently removed from a presumed nest to a depth of approximately two inches or until eggs/embryos appeared. When observed, the embryos were collected for determination of viability with a microscope.

Emigrants

Emigrating lamprey were captured by a rotary screw trap with a five-foot diameter cone placed in a pool upstream of Grist Mill falls in Cedar Creek. The trap was deployed and operational from January 5 through December 21 with periods of non-operation due to high or insufficiently low flow. On July 28 during low flow conditions, the trap was removed. It was redeployed again on November 28 and operated until December 21 when it was pulled for the remainder of 2005.

When fishing, the trap was checked daily. Trap efficiency was estimated through recapture of marked lamprey juveniles (Thedinga et al. 1994). Captured lamprey were removed from the trap livebox, anesthetized with MS-222, identified to species, and measured for length and weight. Length and weight measurements were taken as biological characteristics as well as for the calculation of condition factor (Holmes and Youson 1994). Ammocoetes were marked using red, yellow, and green elastomer injections in the left or right and anterior or posterior areas of the body. Captured macropthalmia and Western brook adults were marked with fin clips removed from the upper or lower caudal fin. Fin clips were saved in 100% ethanol for future genetic analysis. Elastomer marks in ammocoetes and fin clips in macropthalmia were made according to a pre-determined marking schedule. First-time captures were released upstream of the trap (ammocoetes approximately 50 m and macropthalmia and Western brook adults approximately 2 km) and recaptured individuals were released approximately 50 m downstream of the trap. Lamprey measuring less than 60 mm and all wounded lamprey were released downstream without a mark.

Larval Lamprey

In 2005 the controlled electrofishing experiments were continued to address the questions revealed by the field study in 2004 (Lê et al. 2004).

Specifically, the effect of density and size on detecting presence and capture efficiency of larval lamprey was studied.

Ten one cubic meter net pens (Luzier and Silver 2005) having 0.4 mm mesh were filled to a depth of 15.2 cm with fine substrate excavated from the banks of Cedar Creek and placed in Cedar Creek. Lamprey were collected from several locations in Cedar Creek and kept in buckets with sediment and a flow through screen. To test the effect of size and density, five net pens per trial were seeded with five different densities (1, 2, 4, 8, 16) of larval lamprey from one of three size categories: 1) small = 50-70 mm; 2) medium = 80-100 mm; and 3) large = 110-130 mm. Three replicates of each size were performed. For example, one trial may have tested the small size category and pen 1 was seeded with one fish, pen 2 with two fish, pen 3 with four fish, pen 4 with eight fish and pen 5 with sixteen fish. The order of size replicates and the density assigned to each pen were randomly selected. Lamprey were seeded in the pens and allowed to acclimate for 48 hours before sampling occurred. Abiotic parameters such as water temperature, conductivity, and visibility inside and outside of the net pens, were recorded before each trial. In addition, the current emitted from the electroshocker was measured inside and outside the net pens.

Each net pen was sampled with a two-person crew (one person netting, one backpack electrofisher operator). Field personnel were kept consistent throughout the duration of the study. An ABP-2 backpack electrofisher (Engineering Technical Services, University of Wisconsin, Madison, Wisconsin) was used to remove lamprey from net pen enclosures. The electrofishing unit delivered 3 pulses/second (125 volts DC) at 25% duty cycle, with a 3:1 burst pulse train (three pulses on, one pulse off) to remove larvae from the substrate (Weisser and Klar 1990). If larvae emerged, 30 pulses/second was applied to stun them so they could be netted. Only the electrofisher operator knew the densities of the ammocoetes seeded in the net pen.

During each trial, each pen was shocked with five, 60 second passes. There was a fifteen minute break between each pass. The ability to detect presence (probability of detection) was tested first. As soon as one lamprey was detected, the pass number was noted when the detection occurred and the focus shifted to capture efficiency for the remaining passes. Total numbers of lamprey caught per pass were recorded for calculating capture efficiency.

Figure 4. Pot traps used for retention study of Pacific lamprey adults in Cedar Creek, WA, 2005.

Results

Adult Pacific Lamprey

One hundred forty adult Pacific lamprey were captured in Cedar Creek in 2005 (Figure 5). Adults were captured between April 28 and December 21. Lamprey pot traps deployed at the mouth captured 12 lamprey (9% of total catch) and near the Grist Mill captured 29 adults (21%). Twenty-one adult Pacific lamprey were captured free swimming in the ladder (15%) and 72 were captured in two pots placed inside the ladder (52%). Six were captured in the screw trap (4%). All but seven adult lamprey captured were in pre-spawning condition. Lamprey caught per day (CPUE) averaged 0.04 (95% CI 0.02 – 0.09) fish per day for pots at the mouth and Grist Mill. CPUE for the ladder was 0.29 (95% CI 0.25 – 0.34).

Of the 140 adults captured, 130 received PIT tags. Thirty-two marked fish were later recaptured. Capture efficiency for adults was 23% for all methods combined. A population estimate was calculated to be 493±118 for Pacific lamprey adults in Cedar Creek.

Adults were captured from April through December with one small peak in capture occurring in late June. Captures occurred during periods of low discharge and precipitation (Figure 5).

Maximum, mean, and minimum Pacific lamprey adult lengths were 681, 563, and 400 mm, respectively. Maximum, mean, and minimum Pacific lamprey adult weights were 482, 310, and 106 g, respectively. The length to weight relationship can be described by length = 1.2122weight - 374.16 and $R^2 = 0.77$.

Fourteen pot retention trials were conducted in 2005. The internal funnel pot retention rate was 93% (95% CI 68-100) while the single funnel pot retention rate was 43 (95% CI 21-68).

Spawning

Thirty-three spawning ground surveys were conducted during the survey period (May 3 through August 8). A total of 291 Pacific lamprey nests and 10 Western brook lamprey nests were identified and locations were assigned coordinates with GPS (Figure 6). Sixty-four Pacific lamprey nests were observed at the mouth of Cedar Creek (22% of total nests). Pacific lamprey nests were most abundant upstream of the adult fish ladder. Western brook lamprey nests were only seen on the Chelatchie Creek forks. Water temperatures during this time ranged between 9.5 and 21.0 °C

The length of the lamprey spawning season and nest longevity were not determined because we were not able to identify any nests within a few days of completion and observe them through the time when they were no longer discernable. All nests were old at the time of observation.

Approximately 5% of structures identified as Pacific lamprey nests were sampled for viable embryos. No eggs or embryos were seen in any of the sampled nests. Therefore we estimated that 0% (95% CI 0–50) of structures called nests were actually nests.

Emigrants

The rotary screw trap fished for 187 days during sampling year 2005. There were periods of inoperability due to high flows (March and November) and insufficient flows (July to mid-October). A total of 272 Pacific lamprey ammocoetes, 146 Pacific lamprey macropthalmia, 9 Western brook lamprey ammocoetes, and 7 Western brook lamprey adults were captured via the rotary screw trap. Trap efficiency marks were given to 236 and 127 Pacific lamprey ammocoetes and macropthalmia, respectively. Marks were given to 6 and 4 Western brook lamprey ammocoetes and adults, respectively. Four Pacific lamprey ammocoetes, 4 macropthalmia, and one Western brook ammocoete were subsequently recaptured. Average trap efficiencies were estimated to be 2% (95%CI 0.8 – 4.9) for Pacific lamprey ammocoetes, 3% (95% CI 1.0 – 7.5) for Pacific lamprey macropthalmia and 2% (95% CI 0.9 – 59) for Western brook lamprey ammocoetes. No Western brook lamprey adults were recaptured.

Emigrant capture data were divided based on pre- and post-summer screw trap operation (Table 1). There were no significant differences in pre- and post-summer Pacific lamprey ammocoete length, weight or condition factor (ANOVA $P>0.05$). Pre-summer macropthalmia were significantly longer and heavier than post-summer macropthalmia (ANOVA $P <0.05$); however, their condition factor was significantly lower than the post-summer individuals (ANOVA $P <0.05$). No Western brook ammocoetes or adults were captured during the post-summer period.

Population estimates were not calculated in 2005 for any life history stage of either species since trap efficiency was low and did not provide sufficient information required for reliable estimates.

Ammocoetes were captured during all months the trap was fishing. Peak ammocoete captures occurred in March, April and June (Figure 7). Ammocoete movement during April and June appears as if it was associated with discharge (Figure 7). Peaks in macropthalmia captures occurred in May and June (Figure 8). Peak macropthalmia capture was not associated with discharge (Figure 8).

Larval Lamprey

The third phase of the controlled field study to examine the efficiency of the backpack electrofisher was conducted from September 2 to October 5, 2005. A total of 10 trials were completed. Temperature and conductivity were consistent between trials and throughout the study period. Average temperature inside and outside of the net pens was 13.4°C and 13.8°C, respectively. Average conductivity inside and outside of the net pens was 94.4 µs. The electric current reading inside the net pen was 1.39 volts and decreased to 0.05

volts at one meter outside the net pen and 0.03 and 0.02 volts at two and three meters respectively outside the net pen.

The probability of detection increased as density increased for all sizes of ammocoetes (Figure 9) (small: $y = 0.1924Ln(x)+0.5333$, $R^2 = 0.22$; medium: $y = 0.2404Ln(x)+0.4667$, $R^2 = 0.3472$; large: $y = 0.3366Ln(x)+0.2$, $R^2 = 0.49$; all sizes combined: $y = 0.2565Ln(x) + 0.4$, $R^2 = 0.3422$). The probability of detection decreased as size increased for densities 1 and 2 and stayed constant as size increased for densities 4, 8 and 16 (Figure 10) (density 1: $y = -0.2707Ln(x)+0.3839$, $R^2 = 0.0873$; density 2: $y = -0.3225Ln(x)+0.9704$, $R^2 = 0.1238$; density 4: $y = 0.0518Ln(x)+0.7468$, $R^2 = 0.0032$; densities 8 and 16: $y = 1$). Cumulative capture efficiency (defined as the number of fish caught divided by the total number of fish present in the pen) increased as density increased for all sizes (Figure 11) (small: $y = 0.1563Ln(x)+0.4708$, $R^2 = 0.236$; medium: $y = 0.1202Ln(x)+0.4083$, $R^2 = 0.1624$; large: $y = 0.0721Ln(x)+0.5083$, $R^2 = 0.0557$; all sizes combined: $y = 0.1162Ln(x)+0.4625$, $R^2 = 0.1383$). Cumulative capture efficiency was highest for small ammocoetes (Figure 11). Cumulative capture efficiency stayed fairly constant at lower densities (1, 2 and 4) for all sizes and decreased as size increased for densities 8 and 16 (Figure 12) (density 1: $y = -2E\text{-}16Ln(x) + 0.3333$, $R^2 = 4E\text{-}32$; density 2: $y = -0.0263Ln(x) + 0.6268$, $R^2 = 0.0033$; density 4: $y = -0.0259Ln(x) + 0.7932$, $R^2 = 0.0041$; density 8: $y = -0.1757Ln(x) + 0.8133$, $R^2 = 0.2613$; density 16: $y = -0.1814Ln(x) + 0.7959$, $R^2 = 0.26$.

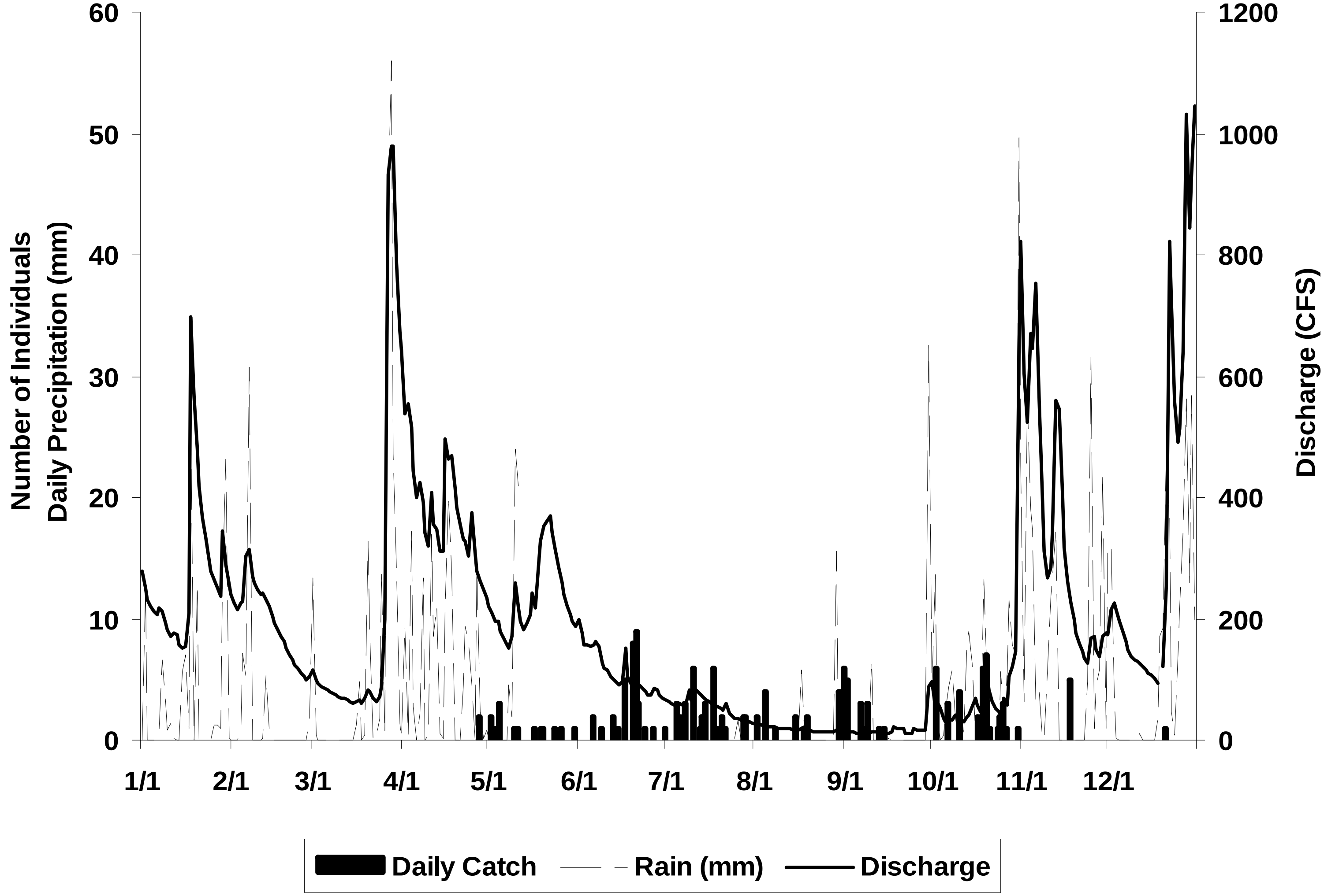

Figure 5. Pacific lamprey adult captures with daily precipitation and discharge on Cedar Creek, WA 2005.

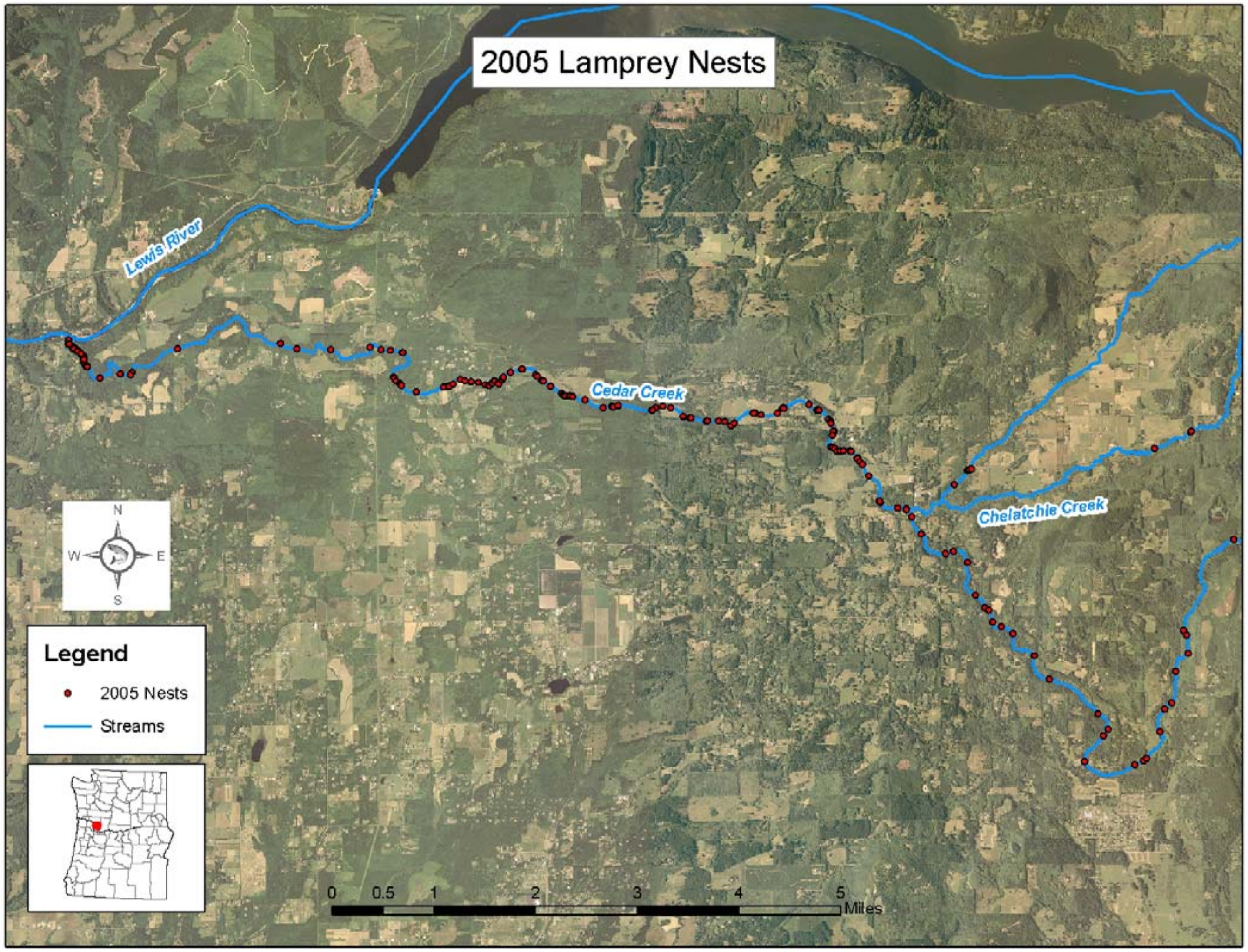

Figure 6. Locations of Pacific and Western brook lamprey nests on Cedar and Chelatchie Creeks, WA 2005. Pacific lamprey nests occurred on Cedar Creek, Western brook lamprey nests occurred on Chelatchie Creek.

Table 1. Data collected from juvenile lamprey captured in the rotary screw trap, Cedar Creek, WA 2005.

Pre-Summer January 6 - July 28, 2005

	Pacific Lamprey		Western Brook Lamprey	
	Ammocoete	**Macropthalmia**	**Ammocoete**	**Adult**
Minimum Length (mm)	41.0	100.0	108.0	104.0
Average Length (mm)	97.4	136.5	125.2	112.9
Maximum Length (mm)	140.0	172.0	145.0	124.0
Minimum Weight (g)	0.1	1.7	1.8	2.4
Average Weight (g)	1.6	3.6	3.4	3.6
Maximum Weight (g)	4.7	6.9	4.7	4.6
Minimum Condition Factor	0.42	1.18	1.43	1.98
Average Condition Factor	1.62	1.39	1.56	2.46
Maximum Condition Factor	4.35	1.99	1.91	3.11
Total Captured	259	125	9	7
Trap Efficiency Marks	224	112	6	4
Number Recaptured	4	4	1	0
Average Trap Efficiency (%)	1.8	3.6	1.7	NA

Post-Summer November 30 - December 21

	Pacific Lamprey		Western Brook Lamprey	
	Ammocoete	**Macropthalmia**	**Ammocoete**	**Adult**
Minimum Length (mm)	61.0	106.0		
Average Length (mm)	99.1	120.5		
Maximum Length (mm)	119.0	138.0		
Minimum Weight (g)	0.3	1.8		
Average Weight (g)	1.6	2.7		
Maximum Weight (g)	2.7	4.3		
Minimum Condition Factor	1.18	1.26		
Average Condition Factor	1.51	1.49		
Maximum Condition Factor	1.92	1.73		
Total Captured	13	21	0	0
Trap Efficiency Marks	12	21		
Number Recaptured	0	0		
Average Trap Efficiency (%)	NA	NA		

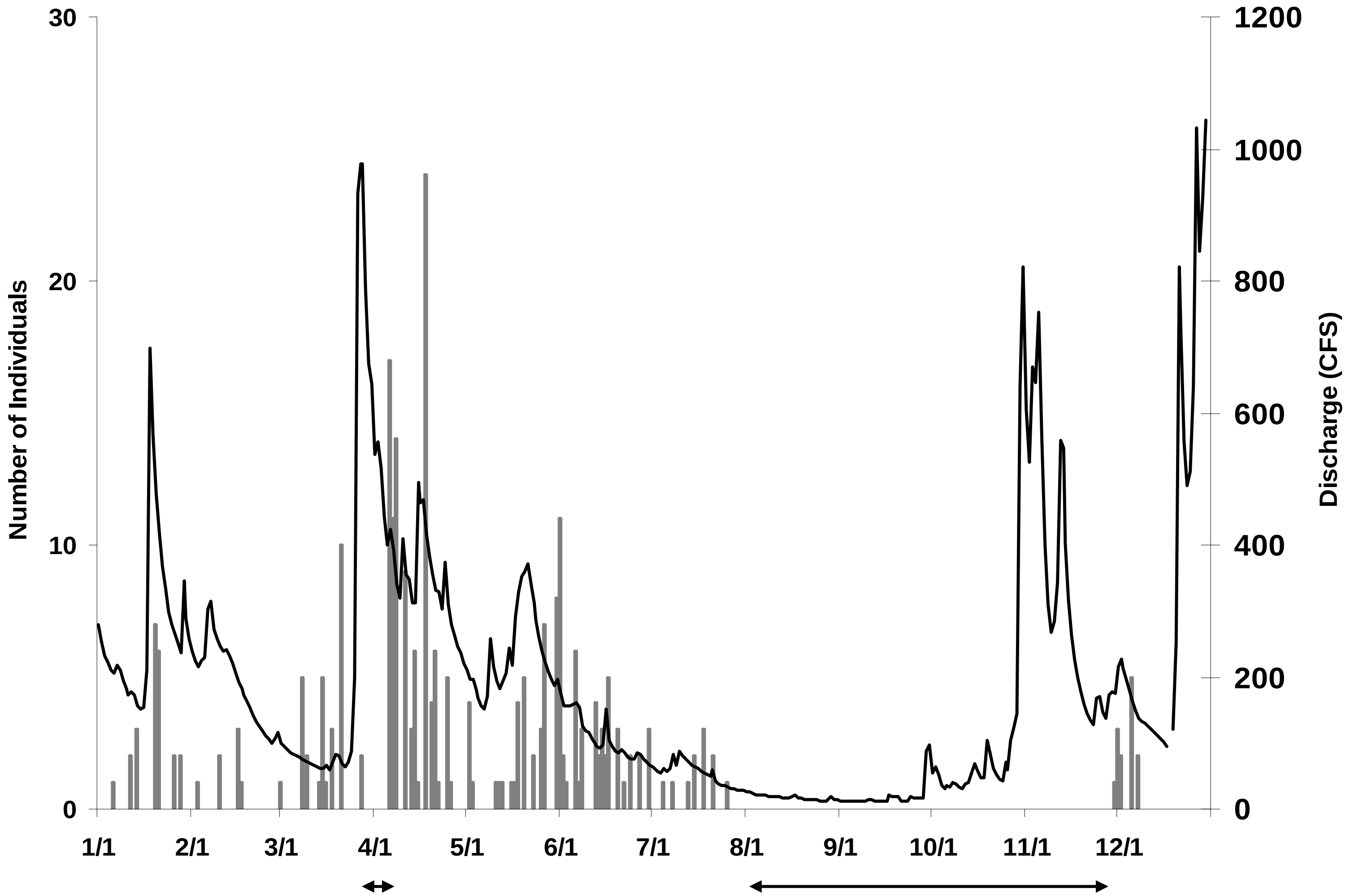

Figure 7. Pacific lamprey ammocoete captures with discharge, Cedar Creek, WA, 2005. Arrows indicate period of screw trap inoperability.

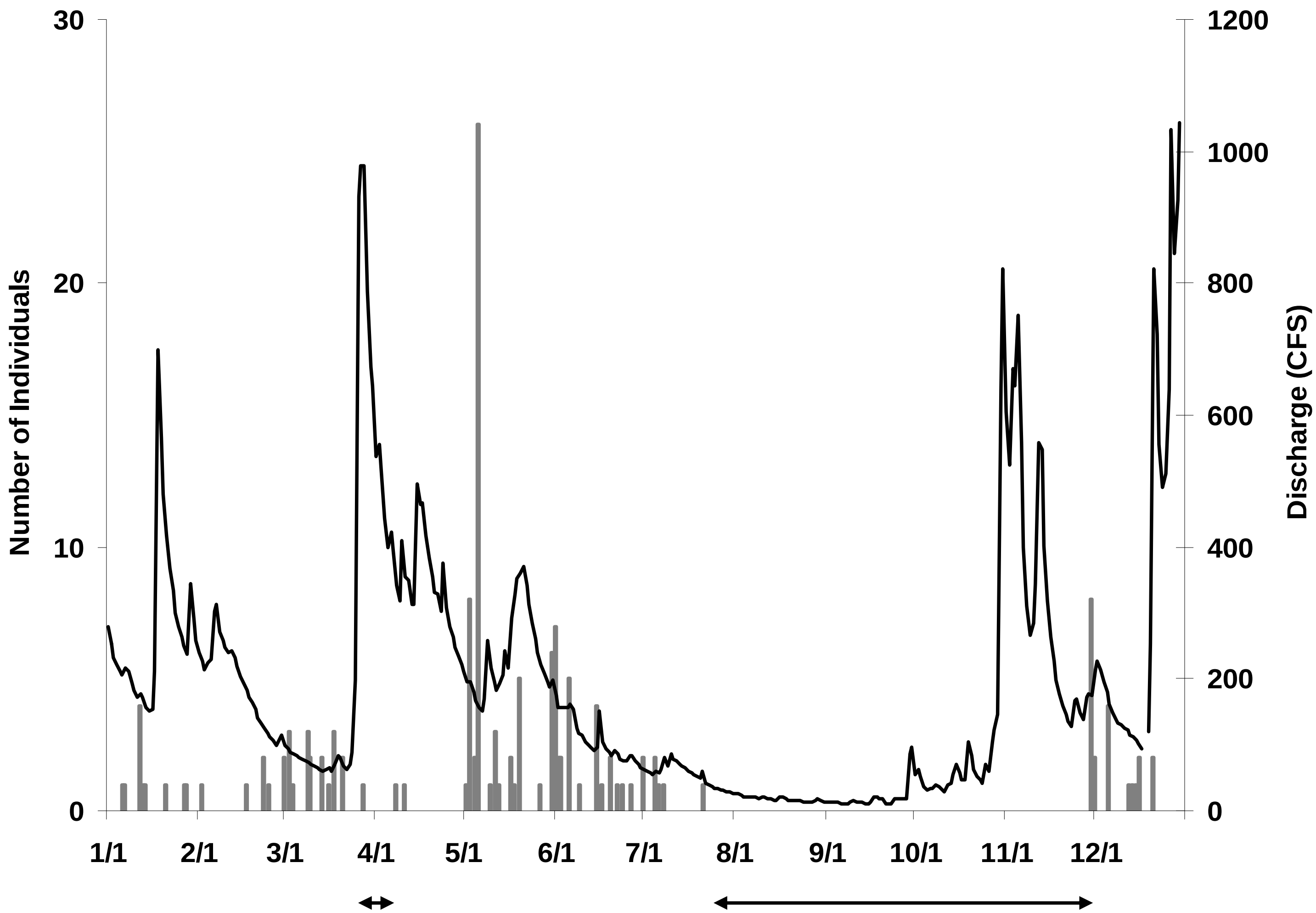

Figure 8. Pacific lamprey macropthalmia captures with discharge, Cedar Creek, WA, 2005. Arrows indicate period of screw trap inoperability.

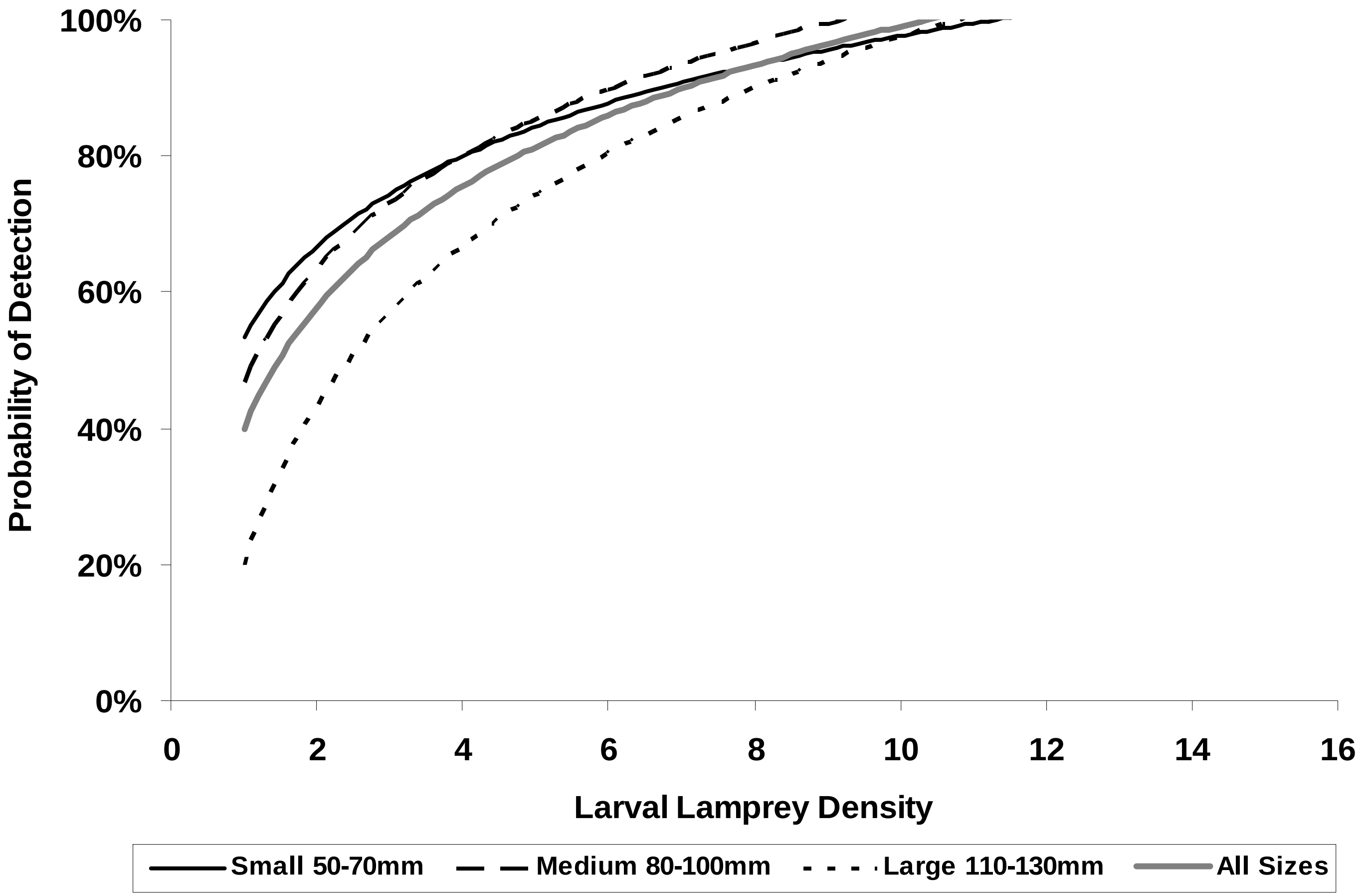

Figure 9. Probability of detection of Pacific lamprey ammocoetes by density. Small ammocoetes: y = 0.1924Ln(x)+0.5333, R^2 = 0.22; medium ammocoetes: y = 0.2404Ln(x)+0.4667, R^2 = 0.3472; large ammocoetes: y = 0.3366Ln(x)+0.2, R^2 = 0.49; all sizes combined: y = 0.2565Ln(x) + 0.4, R^2 = 0.3422.

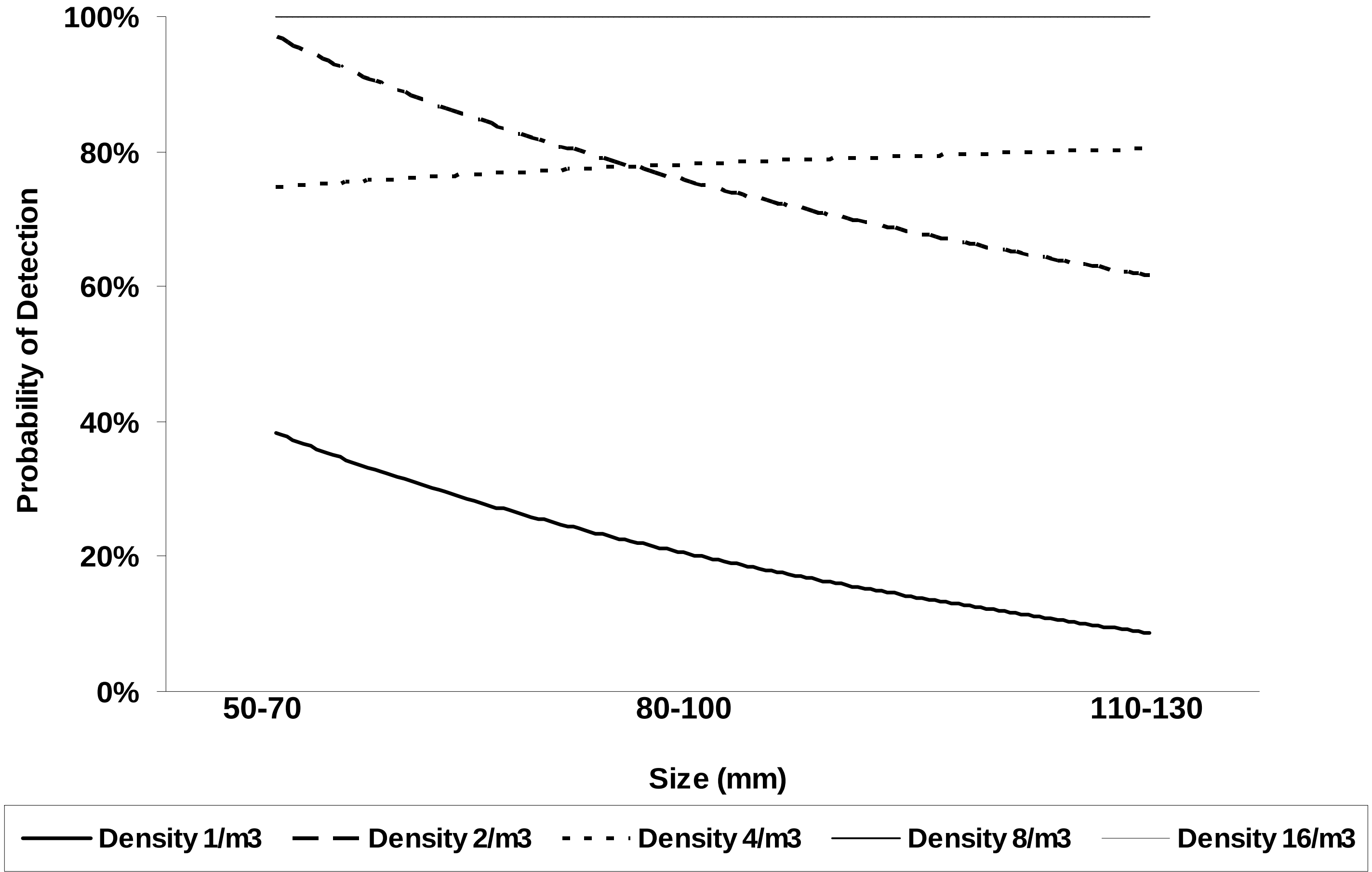

Figure 10. Probability of detection of Pacific lamprey ammocoetes by size. Density 1: y = -0.2707Ln(x)+0.3839, R^2 = 0.0873; density 2: y = -0.3225Ln(x)+0.9704, R^2 = 0.1238; density 4: y = 0.0518Ln(x)+0.7468, R^2 = 0.0032; densities 8 and 16: y = 1.

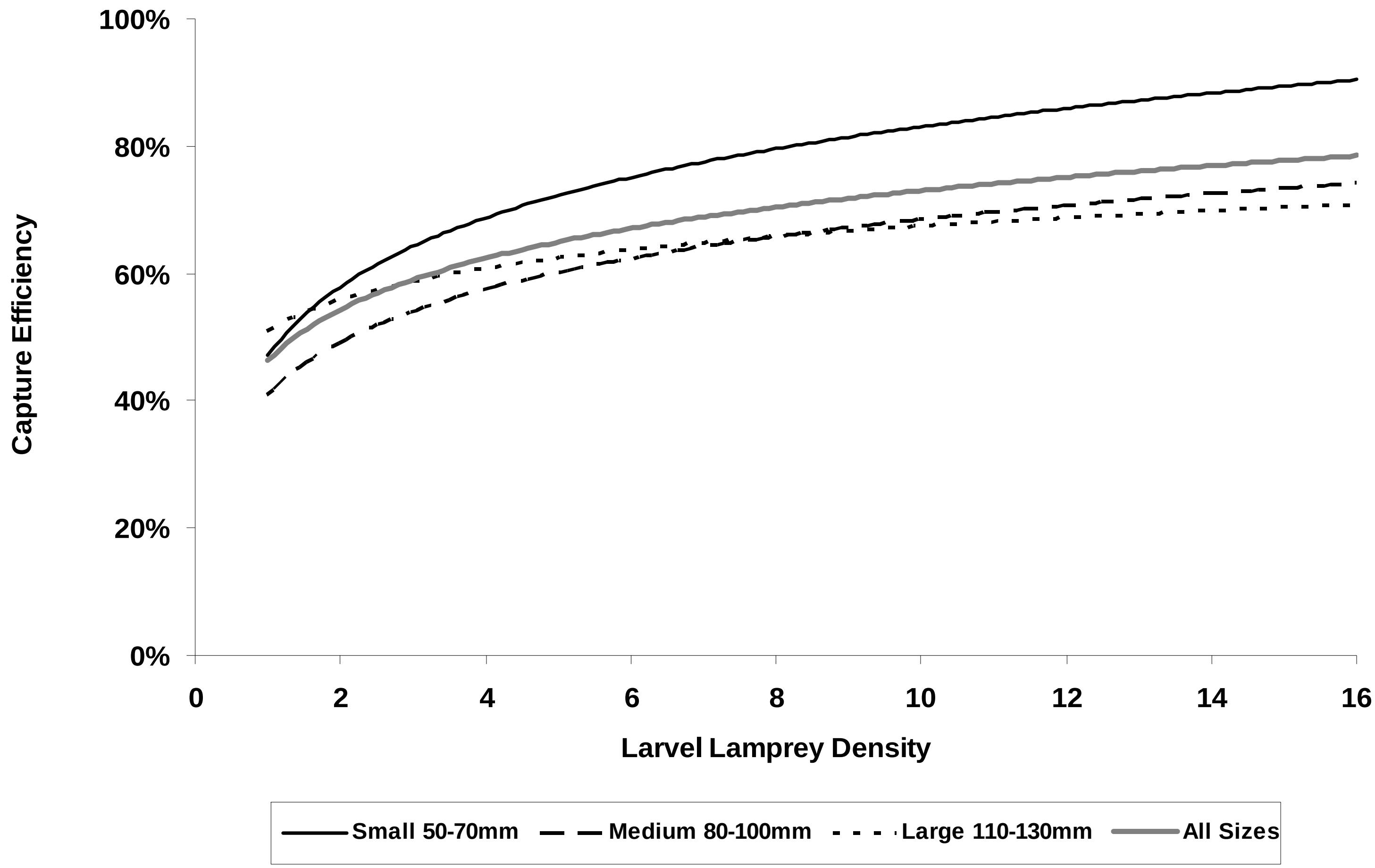

Figure 11. Cumulative capture efficiency (5 minutes of electrofishing) of Pacific lamprey ammocoetes by density. Small ammocoetes: y = 0.1563Ln(x)+0.4708, R^2 = 0.236; medium ammocoetes: y = 0.1202Ln(x)+0.4083, R^2 = 0.1624; large ammocoetes: y = 0.0721Ln(x)+0.5083, R^2 = 0.0557; all sizes combined: y = 0.1162Ln(x)+0.4625, R^2 = 0.1383.

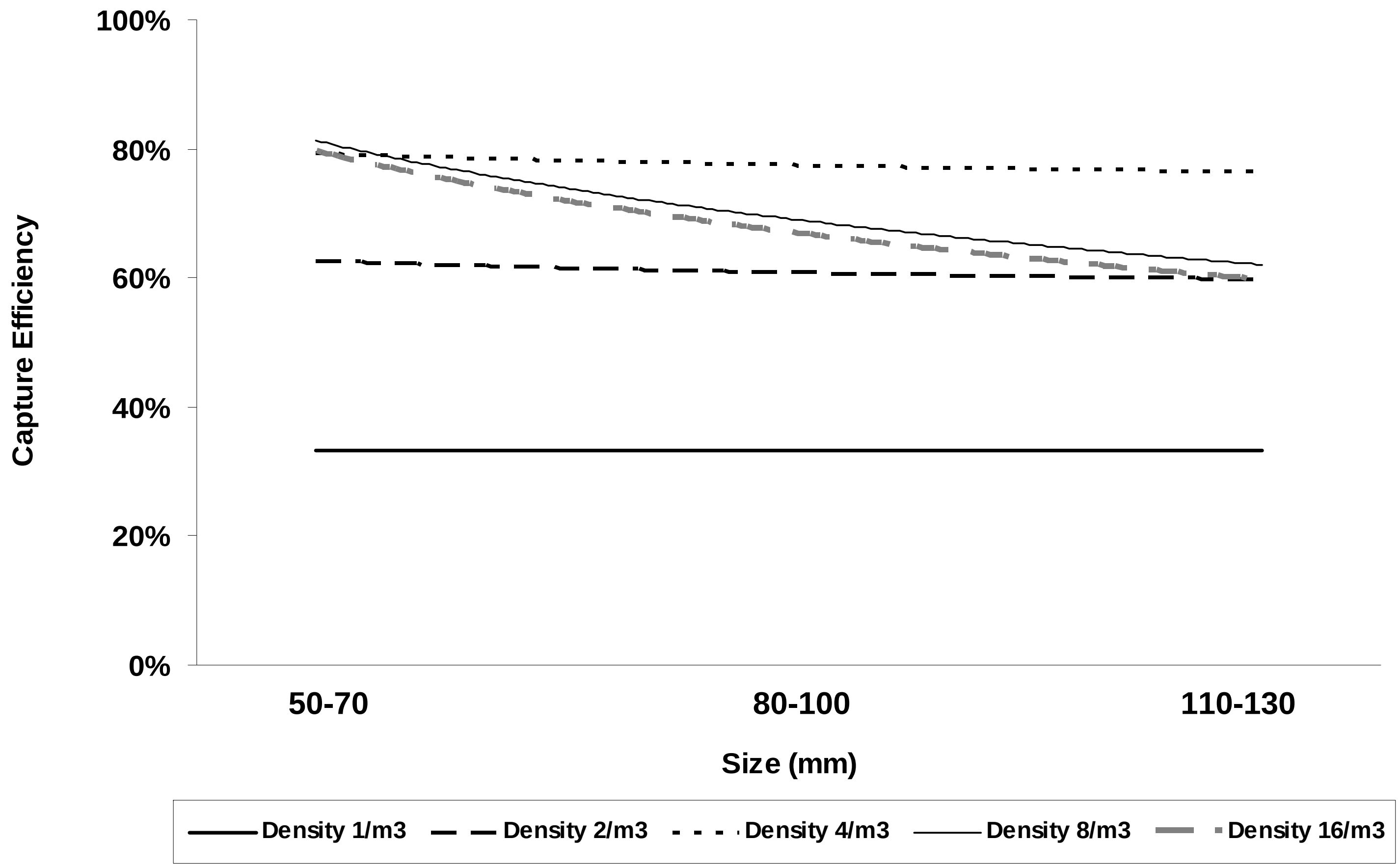

Figure 12. Cumulative capture efficiency (5 minutes of electrofishing) of Pacific lamprey ammocoetes by size. Density 1: y = -2E-16Ln(x) + 0.3333, R^2 = 4E-32; density 2: y = -0.0263Ln(x) + 0.6268, R^2 = 0.0033; density 4: y = -0.0259Ln(x) + 0.7932, R^2 = 0.0041; density 8: y = -0.1757Ln(x) + 0.8133, R^2 = 0.2613; density 16: y = -0.1814Ln(x) + 0.7959, R^2 = 0.26.

Discussion

Adult Pacific lamprey were captured in Cedar Creek between April and December. While 367 adults were captured in 2004, only 140 were captured in 2005. Variation in annual catch in Cedar Creek over the duration of the project is shown in Figure 13. Variation is also present in the lower Columbia as evidenced by adult Pacific lamprey counts at Bonneville Dam (Figure 14).

It is difficult to determine the cause behind variations in annual catch, especially with similar effort. One direct result of the variation seems to be in the amount and location of spawning activity in Cedar Creek. In 2003 we captured only 156 adults. This cohort of adults spawn in the spring of 2004 and the majority of spawning activity occurred near the mouth of Cedar Creek, probably by fish entering Cedar Creek from the Lewis River just prior to spawning. In 2004 when 367 adults were captured, the bulk of the spawning activity in spring of 2005 occurred upstream of the Grist Mill and adult fish ladder. After capturing only 140 adults in 2005, we expect most of the spawning activity in spring of 2006 to again occur at the mouth. In Cedar Creek there seems to be a correlation between numbers of adults captured and location of spawning activity which could potentially mean that lamprey adults are generally moving upstream and staying there to spawn. It has been speculated from sea lamprey studies that Pacific lamprey adults may not display fidelity to their natal streams (Kostow 2002) and probably migrate up and downstream until the spawning season commences.

Similar effort for capturing adult Pacific lamprey was expended in 2005 as 2004. The most successful pots continued to be the ladder pots with 52% of the adults being captured via this method. Single pot traps at the Grist Mill and the fish ladder (free swimming) were the next successful methods of capture. There was no clear peak in adult capture in 2005. A small peak occurred in early summer and another in the fall which is consistent with previous years' migration timing results.

The pot retention trials indicated that pot traps with an internal funnel were more successful at retaining fish than the single funnel design. Every fish retained in the internal funnel pot trap remained in the second chamber of the pot. Similarly, every fish captured in an internal funnel pot is found in the second chamber. Pot retention trials are continuing in 2006 to increase the sample size. Results from the retention study will improve our future adult capture efficiencies as well as those from other projects in the region which regularly consult the CRFPO regarding the collection of adult Pacific lamprey.

Western brook lamprey spawning activity was seen solely in the forks of Chelatchie Creek. Very little activity was observed in 2005 but two large spawning events were witnessed with approximately 20 individuals participating on one nest.

Pacific lamprey spawning occurred throughout Cedar Creek in 2005. There was heavier than normal activity upstream of the adult fish ladder. Although spawning habitat conditions vary annually in Cedar Creek, the location of spawning activity may be more a reflection of the number of lamprey captured at the Grist Mill and fish ladder. As mentioned above, this could indicate that lamprey are moving upstream and staying there to spawn instead of migrating up and downstream while overwintering before the spawning season.

Heavy rains in March and April of 2005 delayed the start of the spawning surveys. Due to high water the upper reaches of Cedar Creek and Chelatchie Creek were not surveyed until mid May and the lower reaches including the mouth were not surveyable until the beginning of June. When surveys were finally conducted no new Pacific lamprey nests were detected. Most nests had debris in the bottom and algal growth on overturned rocks. Five percent of the nests were excavated to look for viable embryos but none were found. Therefore, statistically only between 0-50% of the structures called nests appeared to be nests. One possibility is that we are significantly overestimating nest numbers. Alternatively, we believe it is more likely that we sampled nests after embryos had hatched and larvae emerged. Weather and flow conditions are two variables that are uncontrollable; however, to obtain accurate nest counts sampling needs to commence at the beginning of the spawning season.

Similarly, the length of the Pacific lamprey spawning season and nest longevity were not determined because high water precluded us from identifying any nests within a few days of completion and observe them through the time when they were no longer discernable. Receding water often revealed nests not detected on previous surveys. Nests were frequently observed on the creek margins where the water was shallower and the flow less swift, however, these too were old upon initial observation. In 2006 we will again try to determine the length of the spawning season, nest longevity and the accuracy with which we enumerate Pacific lamprey nests. An accurate determination of the spawning season and nest count is important for following trends in spawning and ultimately in distribution and status of Pacific lamprey.

Ammocoete movement, as observed by screw trap operation, occurred throughout the year with peaks in March, April and June. Ammocoetes migrate during peak flows (Stone et al. 2001, 2002, Pirtle et al. 2003, Lê et al. 2004, Luzier and Silver 2005) and discharge was particularly high during these periods (Figure 7). As seen in other years, this evidence suggests movement is passive (Lê et al. 2004, Luzier and Silver 2005). This also implies that over their freshwater residence time, ammocoetes accumulate downstream and the lower ends of spawning tributaries or mainstem areas and therefore these areas are important habitat for ammocoetes.

Macropthalmia emigration was not associated with high discharge events in 2005. Peak movement occurred in May and June when discharge was decreasing and again in December during a low discharge period. Total macropthalmia catch in 2005 doubled from a low of 75 in 2004 though the number of days the screw trap fished was comparable. Variation in the number of ammocoetes ready to transform annually in Cedar Creek is most likely the cause.

Pre-summer macropthalmia were significantly longer and heavier than post-summer macropthalmia (ANOVA $P<0.05$). Since macropthalmia are generally believed to transform during late summer early fall perhaps the pre-summer fish completed metamorphosis in 2004 but had not emigrated out of Cedar Creek and had already started eating whereas the post-summer macropthalmia had gone through metamorphosis in 2005. The amount of time that macropthalmia spend in fresh water before migrating to the ocean is not known. If they are utilizing fresh water streams and rivers as more than a direct route to the ocean their habitat requirements during this stage must be considered.

As expected, the probability of detection of Pacific lamprey ammocoetes with the electroshocker increased as density increased for all sizes of fish (Figure 9). This agrees with efficiency curves calculated in 2004 which showed that detection efficiency is low when densities are low and we often fail to detect presence at 1/ m^3 (Luzier and Silver 2005). Similarly, cumulative capture efficiency increased as density increased for all sizes of fish (Figures 11 and 12). When ammocoetes are distributed in higher densities they may need to move towards the surface as well as sideways through the sediment to escape the electric current. Whereas single ammocoetes or ammocoetes distributed in low densities have more places to escape without running into another fish and therefore are harder to bring to the surface. In areas where ammocoete density is low, there is a high probability of concluding they are absent when they are actually present. This should be taken into consideration when surveying for ammocoete distribution and the determination of lamprey status.

When distributed in higher densities (8-16 fish/m^3) the probability of detection is 100% regardless of ammocoete size (Figure 10). Smaller ammocoetes are more easily detected than larger fish when distributed at low densities (1-2 fish/m^3) (Figure 10). Similarly cumulative capture efficiency was highest for small ammocoetes (Figures 11 and 12). This suggests that smaller ammocoetes may be more sensitive to shocking and therefore more easily captured than larger ammocoetes and/or perhaps they are burrowed closer to the surface. The ease with which certain sizes of ammocoetes are detected and/or captured is important when considering the distribution of ammocoetes and the overall status of a lamprey population especially when ammocoetes are constantly migrating downstream to lower reaches as they age.

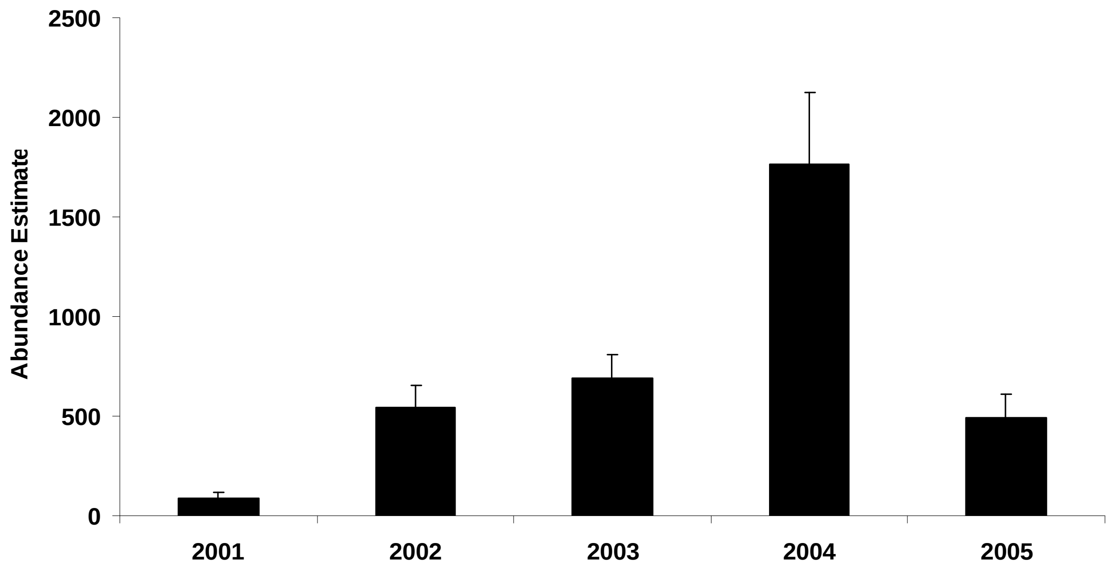

Figure 13. Abundance estimates for adult Pacific lamprey in Cedar Creek, WA over duration of project.

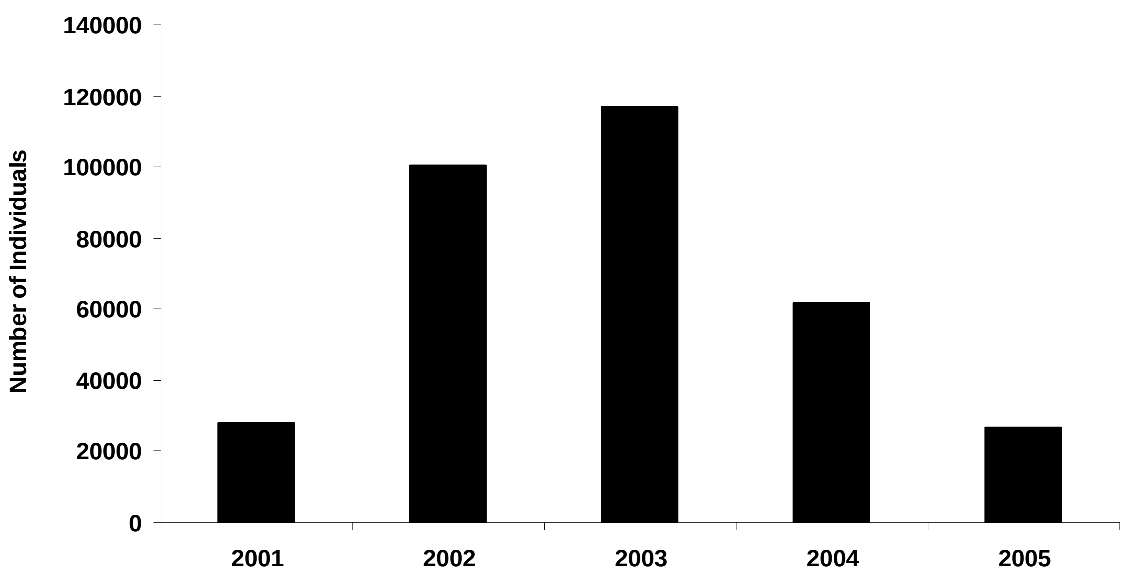

Figure 14. Number of adult Pacific lamprey passing Bonneville Dam from 2001-2005.

References

Beamish, R. J. 1980. Adult biology of the river lamprey (*Lampetra ayresi*) and the Pacific lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences. 37:1906-1923.

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.

Close, D. A.- Confederated Tribes of the Umatilla Indian Reservation. 2001. Pacific lamprey research and restoration project Annual Report 1999, Report to Bonneville Power Administration, Contract No. 00005455, Project no. 199402600, 196 electronic pages (BPA Report DOE/BP-0005455-1).

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. Report to Bonneville Power Administration, Contract No. 95BI39067.

Columbia River Basin Lamprey Technical Workgroup. Ed. Donna Allard. September 2003. 1 March 2005 columbiariver.fws.gov/lamprey.htm.

Hammond, R. J. 1979. Larval biology of the Pacific lamprey, *Entosphenus tridentatus* (Gairdner), of the Potlach River, Idaho. MS Thesis. University of Idaho, Moscow.

Holmes, J.A. and J.H. Youson. 1994. Fall condition factor and temperature influence the incidence of metamorphosis in sea lamprey, *Petromyzon marinus*. Can. J. Zool. 72:1134-1140.

Houde, E. D. 1987. Fish early life history dynamics and recruitment variability. American Fisheries Society Symposium. pp. 17-29.

Lê, B., C.W. Luzier, and T. Collier. 2004. Evaluate habitat use and population dynamics of lamprey in Cedar Creek. 2003 Annual Report, Project No. 200001400, 35 electronic pages (BPA Report DOE/BP–00004672-3). http://www.efw.bpa.gov/Publications/I00004672-3.pdf

Luzier, C.W. and G.S. Silver. 2005. Evaluate habitat use and population dynamics of lamprey in Cedar Creek. 2004 Annual Report, Project No. 200001400, 38 electronic pages, (BPA Report DOE/BP–00004672-4). http://www.efw.bpa.gov/Publications/I00004672-4.pdf

Kan, T. T. 1975. Systematics, variation, distribution, and biology of lamprey of the genus *Lampetra* in Oregon. PhD dissertation. Oregon State University, Corvalis, OR. 194 pp.

Kostow, K. 2002. Oregon Lampreys: Natural History Status and Problem Analysis. Report of Oregon Department of Fish and Wildlife. 111 pp.

Pirtle, J., J. Stone, and S. Barndt. 2003. Evaluate habitat use and population dynamics of lamprey in Cedar Creek. 2002 Annual Report, Project No. 200001400, 34 electronic pages (BPA Report DOE/BP–00004672-2). http://www.efw.bpa.gov/Publications/I00004672-2.pdf

Pletcher, F. T. 1963. The life history and distribution of lamprey in the Salmon and certain other rivers in British Columbia, Canada. MS thesis, University of British Columbia, Vancouver, B. C. 195 pp.

Potter, I.C., R.W. Hilliard, J.S. Bradley, and R.J. McKay. 1986. The influence of environmental variables on the density of larval lamprey in different seasons. Oecologia. 70:433-440.

Richards, J.E. 1980. The freshwater life history of the anadromous Pacific lamprey, *Lampetra tridentata*. MS thesis, University of Guelph, Guelph, Ontario. 99 pp.

Richards, J.E. and F.W.H. Beamish. 1981. Initiation of feeding and salinity tolerance in the Pacific lamprey *Lampetra tridentata*. Mar. Biol. 63:73-77.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Canadian Government Publishing Centre, Ottawa, Canada. 966 pp.

Stone, J. and S. Barndt. 2005. Spatial Distribution and Habitat Use of Pacific Lamprey (Lampetra tridentata) Ammocoetes in a Western Washington Stream. J. Fresh. Ecol. 20(1):171-185.

Stone, J., T. Sundlov, S. Barndt, and T. Coley. 2001. Evaluate habitat use and population dynamics of lamprey in Cedar Creek, 2000 Annual Report, Project No. 200001400, 28 electronic pages (BPA Report DOE/BP–00000014–1). http://www.efw.bpa.gov/Publications/I00000014-1.pdf

Stone, J., J. Pirtle, and S. Barndt. 2002. Evaluate habitat use and population dynamics of lamprey in Cedar Creek. 2001 Annual Report, Contract No. 00004672, 44 electronic pages (BPA Report DOE/BP–00004672-1). http://www.efw.bpa.gov/Publications/I00004672-1.pdf

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps In the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management. 14:837-851.

Van Den Avyle, M.J. 1993. Dynamics of exploited fish populations. *In* Inland Fisheries Management in North America. American Fisheries Society. Bethesda, MD.

van de Wetering, S.J. 1998. Aspects of life history characteristics and physiological processes in smolting Pacific lamprey, *Lampetra tridentata*, in a central Oregon stream. MS Thesis, Oregon State University.

Weisser, J.W. and G.T. Klar. 1990. Electric fishing for sea lamprey (*Petromyzon marinus*) in the Great Lakes region of North America. *In* Developments in electric fishing. Edited by I. G. Cowx. Cambridge University Press, Cambridge, UK. pp 59-64.