Evaluate Habitat Use and Population Dynamics of Lamprey in Cedar Creek

BPA Project #2000-014-00

Annual Report for 2004 Sampling Season

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Abstract

Pacific lamprey (*Lampetra tridentata*) in the Columbia River basin have declined to a remnant of their pre-1940s populations 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, but little research has been conducted on these species within the Columbia River basin. 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 fifth year of this project. Adult (n = 367), macropthalmia (n = 75), and ammocoete (n = 302) stages of Pacific and western brook lamprey were examined in 2004. Lampreys were captured using an adult fish ladder, lamprey pots, rotary screw trap, and a lamprey electrofisher. In addition, 45 spawning ground surveys were conducted during which 273 Pacific lamprey and 27 western brook lamprey nests were identified. Non-use data was collected from spawning grounds to develop a predictive model of spawning habitat requirements. Backpack electrofisher efficiency and the 70% depletion model were examined in a controlled field study with low fish densities in 2004.

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 us to describe fluctuations in abundance and measure responses to environmental disturbances. Such knowledge may eventually allow us to use models to predict future population trends.

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 and 2003 are summarized in four annual reports (Stone et al. 2001, Stone et al. 2002, Pirtle et al. 2003 and Lê et al. 2004). This annual report summarizes results of research and analytical activities conducted during 2004. The objectives of this research are to: 1. Estimate abundance, measure biological characteristics, determine migration timing of adult Pacific lampreys; 2. Evaluate spawning habitat requirements of adult lampreys; 3. Determine outmigration timing and estimate the abundance of recently metamorphosed lampreys (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 in July to 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 is 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 to 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, 3) and rainfall is measured at the Grist Mill (Figure 3).

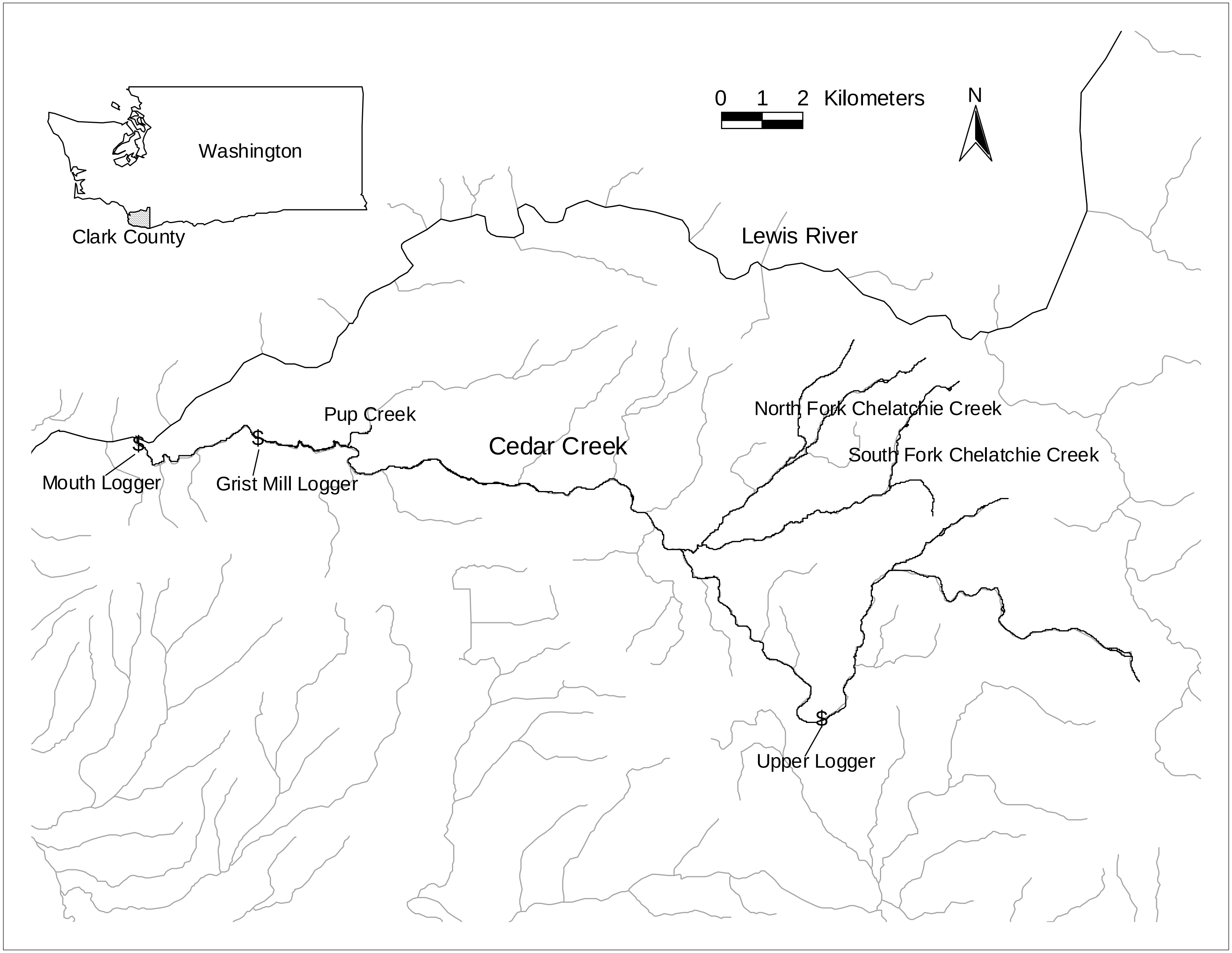


Figure 1. Cedar Creek in Clark County, Washington depicting the location of USFWS temperature loggers, 2004.

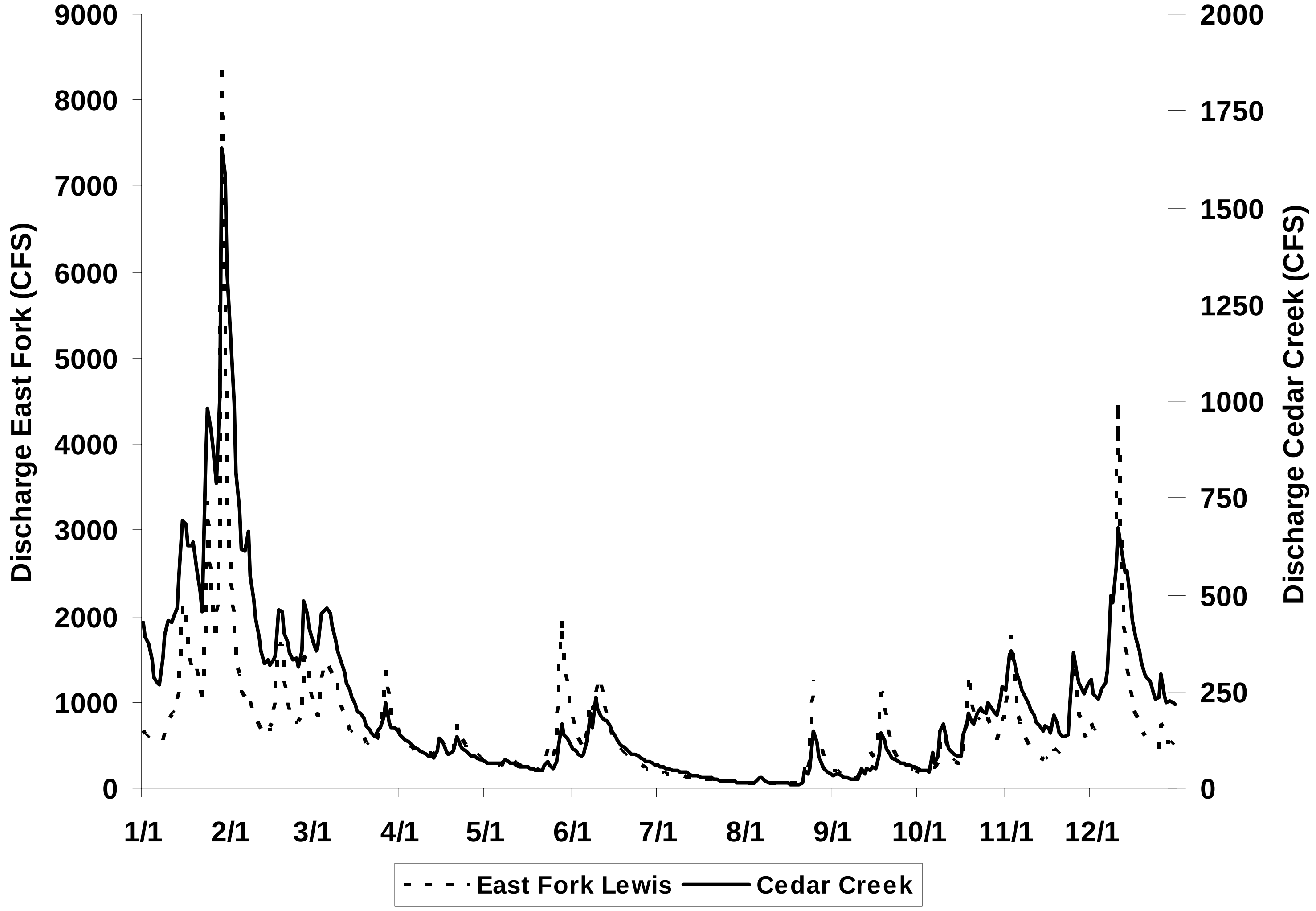


Figure 2. Discharge for East Fork Lewis River, Heisson Station (USGS) and Cedar Creek (Washington Department of Ecology), 2004.

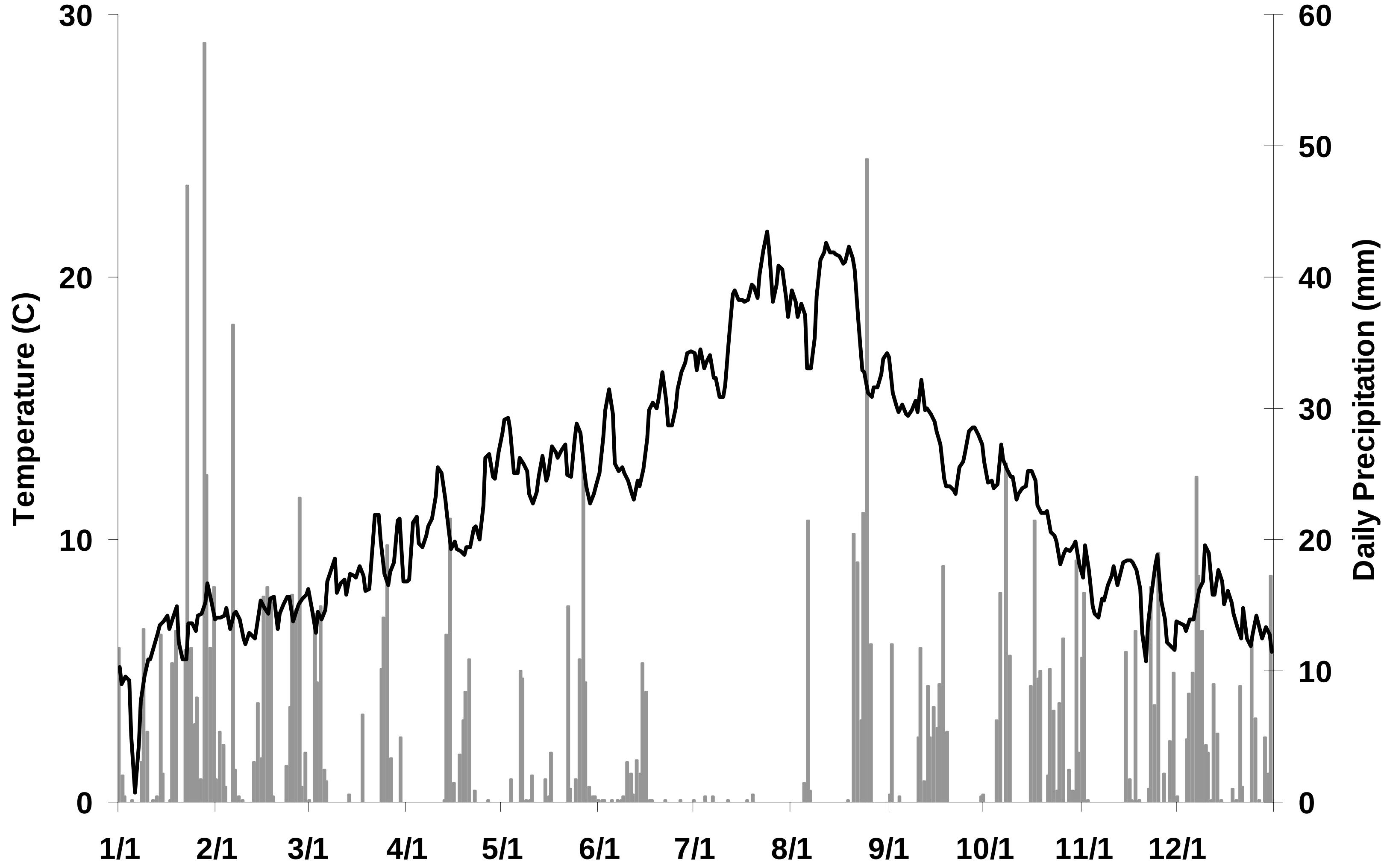


Figure 3. Water temperatures and precipitation recorded on Cedar Creek at the Grist Mill, 2004.

Methods

Adult Pacific Lampreys

Adult Pacific lampreys were captured in the Washington Department of Fish and Wildlife adult ladder at the Grist Mill falls and in lamprey pot traps. The pot traps consisted of four types: 1) 92 cm length of 20 cm diameter PVC pipe with funnels on each end; 2) 92 cm x 20 cm PVC pipe with a funnel on one end, an internal funnel and a one inch thick round of wood on one end; 3) 92 cm x 25 cm PVC pipe with a funnel on one end, an internal funnel and a one inch thick round of wood on one end; and 4) 92 cm x 30 cm with funnels on each end. Funnel openings measured 5 cm in diameter (Figure 4).

Compared to previous years of the project, more effort was expended on capturing adult Pacific lampreys to increase adult catch, marked fish, and chances of recapture. Additional pot traps were deployed on traplines to supplement the regular pot trap locations used in previous study years (Lê et al. 2004). On April 7, 2004, four adult pot traps were deployed downstream from the falls near the base of the ladder and two pots were placed at the mouth of Cedar Creek. Two additional pots were placed inside the adult ladder. On April 15, 2004, one trapline with four pot traps was deployed at the mouth of Cedar Creek (Figure 5). A second trapline with three pot traps was deployed at the Grist Mill, downstream of the falls. We tracked the effectiveness of individual capture methods (i.e., pots at mouth, pots at mill, pots in adult ladder, ladder alone).

Lamprey pot traps and the adult fish ladder were checked daily. Captured lampreys 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 the trap and recaptured individuals were released approximately 100 m upstream of the trap.

Spawning

Lamprey nests were identified by foot surveys during the spawning period. Foot surveys began April 26th and continued until July 28th. The areas surveyed in 2004 were divided into seven index reaches in high nest density areas (Figure 6). Index reaches were surveyed on average once per week. Exploratory reaches, areas in-between designated sample reaches, were surveyed once during the spawning period for nest presence/absence.

Physical characteristics of nests were measured, including: habitat type (Hawkins et al. 1993), nest dimensions, substrate (dominant, sub-dominant and %fines [adapted from Geist et al. 2002 for lamprey habitat]), and flow. If applicable, presence of adults on the nest was noted as well as number and sex of fish. When possible, locations of each nest were recorded with global positioning system (GPS) technology. Nests were marked with weighted flagging to determine nest longevity. Weighted flags were removed on subsequent surveys if the nest no longer appeared viable. As Western brook nests look similar to animal hoof prints, only those nests containing adults were counted.

In order to characterize spawning habitat preferences for Pacific and Western brook lamprey we sampled non-use points. Non-use areas were selected by randomly choosing a point within 1-10 paces up or downstream of the nest and 1-10 paces towards the center of the stream from the nest (Geist et al. 2002). Physical characteristics including habitat type, substrate, and flow were measured at the non-use area. Non-use points were sampled for every nest (use) point unless a cluster of nests was present, in which case one non-use point would be sampled as a representative for the cluster.

Emigrants

Emigrating lampreys 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 21 through the end of the calendar year with periods of non-operation due to high or insufficiently low flow. On July 16th, 2004 during low flow conditions, the trap was removed with plans for redeployment in mid-October. The screw trap was cleaned and repaired during the period of low flow, mid-July through September. It was deployed again on October 19 and operated throughout the fall until December 14th when it was pulled due to high flows and damage to the drum wheel. Repairs were made to the trap but it was not redeployed in 2004.

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. Lampreys measuring less than 60 mm and all wounded lampreys were released downstream without a mark.

Trap retention was estimated periodically throughout the year. On randomly chosen days, half of the daily total captured macropthalmia and ammocoetes were given a unique mark and were placed back into the livebox.

Ammocoetes were marked using an orange colored elastomer injection in the left posterior area and macropthalmia were marked with a posterior dorsal fin clip. Trap retention fish were returned to the livebox and sampled the following day. Recaptured fish were counted and released approximately 50 m downstream of the trap.

Larval Lamprey Density

In 2003 a pilot study was started to assess backpack electrofisher removal efficiency and to validate the 70% depletion protocol (Pajos and Weise 1994) used for juvenile Pacific lamprey (*L. tridentata*) (Lê et al. 2004). Ammocoetes, ranging in number from 24 to 130, were placed in 1 m^2 net pen enclosures (Figure 7) and removed via the 70% depletion protocol. These densities were on the upper end of what were detected during larval lamprey distribution sampling in 2002 (Stone et al. 2002). We continued this study in 2004 with ammocoete densities at the lower end of this range (1-15 fish/m^2). These represent densities more often detected in nature for larval lampreys (Stone and Barndt 2005).

One cubic meter net pens having 0.4 mm mesh were filled to a depth of 15.2 cm with fine substrate and placed in Cedar Creek. Lampreys were electroshocked upstream of the experimental location and kept in buckets with sediment and a flow through screen. Known numbers of lamprey in two size categories (>60mm, <60mm) were added to two net pen enclosures and were allowed to acclimate for 24 hours before sampling occurred. Each net pen was sampled with a three-person crew (2 people netting, 1 backpack electrofisher operator). An effort was made to keep field personnel consistent throughout the duration of the study. Only the electrofisher operator knew the densities of the ammocoetes seeded in the net pen.

Abiotic parameters such as water temperature, conductivity, and visibility inside and outside of the net pens, were recorded before each trial. 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. Each trial was sampled for 90 seconds per pass. There were at least two, but no more than five passes per trial. Total numbers of lamprey caught per pass were recorded. Captured lamprey were anesthetized with MS-222, (Summerfeldt and Smith 1990) and measured for length (size category).

Results from the current year of the study will allow us to assess our electrofishing gear for efficiency at lower densities of ammocoetes and the use of the 70% depletion model for juvenile Pacific lamprey. Sampling efficiency and probability of detection were calculated using data from the gear efficiency trials in 2003 and 2004.

Figure 4. Lamprey pot traps used to capture adult Pacific lamprey in Cedar Creek, WA, 2004. Top photo depicts pot trap with funnels on both ends. Bottom photo depicts pot trap with internal funnel.

Figure 5 Pot trap line at the mouth of Cedar Creek, WA 2004

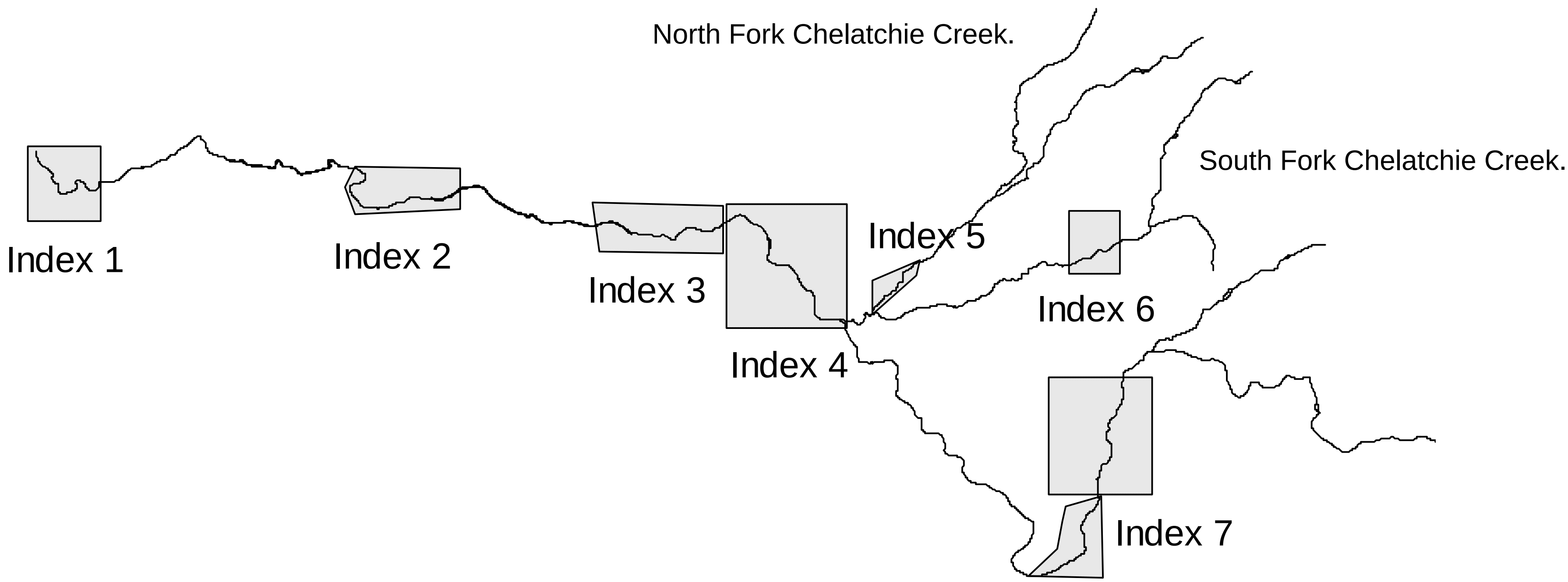


Figure 6. Areas routinely surveyed for Pacific lamprey and Western brook lamprey nests, Cedar Creek, WA 2004.

Figure 7. Net-pen enclosures used to assess backpack electrofisher efficiency and the 70% depletion model on Cedar Creek, WA 2004.

Results

Adult Pacific Lampreys

A total of 367 adult Pacific lampreys were captured in Cedar Creek in 2004 (Figure 8). Adults were captured between April 7 and November 30, 2004. Lamprey pot traps deployed at the mouth captured 31 lampreys (8% of total catch) and near the Grist Mill captured 40 adults (11%). Fifty-two adult Pacific lampreys were captured free swimming in the ladder (14%) and 232 were captured in two pots placed inside the ladder (69%). Twelve were captured in the screw trap (3%). All but seven adult lampreys captured were in pre-spawning condition. Lampreys caught per day (CPUE) averaged 0.035 fish per day for pots at the mouth and at the Grist Mill. CPUE for the ladder was 0.95.

Of the 367 adults captured, 355 were marked with PIT tags and five were marked with an additional hole punch on the anterior dorsal fin in lieu of PIT tags (PIT tag supply was depleted that day). Seventy-three marked fish were later recaptured. Capture efficiency for adults was 21% for all methods combined. A population estimate was calculated to be 1765±357 for Pacific lamprey adults.

Adults were captured in two pulses, one during late spring-early summer and the other in late summer-early fall. Captures occurred independent of peak discharge events however they did seem to correlate with rain events (Figure 8).

Maximum, mean, and minimum Pacific lamprey adult lengths were 707, 560, and 382 mm, respectively. Maximum, mean, and minimum Pacific lamprey adult weights were 500, 305, and 137 g, respectively. The length to weight relationship can be described by $y = 1.196x - 365.39$ with $R^2 = 0.7423$.

Spawning

Forty-five spawning ground surveys were conducted during the spawning period (April 26, 2004 through July 28, 2004). A total of 273 Pacific lamprey nests and 27 Western brook lamprey nests were identified and locations were assigned coordinates with GPS. Water temperatures during this time ranged between 9.5 and 21 °C.

The two species of lampreys in Cedar Creek utilize different areas of the drainage to spawn (Figure 9). Pacific lamprey nests were most abundant near the mouth of Cedar Creek. Western brook lamprey nests were only seen on the Chelatchie Creek forks.

As in previous years, habitat characteristics were recorded for Pacific and Western brook lamprey nests. Pacific lampreys spawned in pool tail-out habitats, runs, and low gradient riffles having large gravel substrate. Western brook lampreys spawned in pool tail out habitats and low gradient runs with small gravel substrate.

Non-use habitat characteristics were measured for the first time in 2004. 108 and 16 non-use points were sampled in association with Pacific and Western brook lamprey nests respectively. Characteristics commonly seen at non-use points included deeper water, higher velocity, and large gravel/bedrock. Many non-use points were located in higher gradient habitats and pools vs. tail outs.

No Pacific lamprey spawning activity was observed during spawning ground surveys in 2004. Video of spawning events from the 2003 spawning season and a detailed description of spawning behavior observed is available on the CRFPO webpage (http://columbiariver.fws.gov).

A pair of Pacific lampreys (1male, 1 female) were observed on a nest near the mouth of Cedar Creek in Index 1. Two spawned out Pacific lamprey carcasses were seen in Index 1.

Western brook lamprey spawning activity was not observed in 2004. One or two fish were present on each nest identified. Two Western brook carcasses were seen in Index 5 on Chelatchie Creek.

Emigrants

The rotary screw trap fished for 172 days during sampling year 2004. Our inability to fish the trap during certain parts of the year was due a variety of factors such as high flow (most of January) which precluded safe operation, no battery powered operation during low flow months (July to mid-October) and necessary trap repairs (December). Despite these periods of inoperability, total days fished in 2004 almost doubled days fished in 2003 but an overall decrease in catch (compared to 2003) was observed for all life history stages of Pacific lamprey and Western brook lamprey adults. A total of 302 Pacific lamprey ammocoetes, 75 Pacific lamprey macropthalmia, 9 Western brook lamprey ammocoetes, and 3 Western brook lamprey adults were captured via the rotary screw trap. In 2004, trap efficiency marks were given to 200 and 68 Pacific lamprey ammocoetes and macropthalmia, respectively. Marks were given to 8 and 3 Western brook lamprey ammocoetes and adults, respectively. Nineteen Pacific lamprey ammocoetes, 4 macropthalmia, and one Western brook ammocoete were subsequently recaptured. Average trap efficiencies were estimated to be 9.5% for Pacific lamprey ammocoetes, 6% for Pacific lamprey macropthalmia and 11% 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, $p < 0.05$). There were no significant differences in length, weight or condition factor in Western brook ammocoetes (ANOVA, $p > 0.05$). No Western brook adults were captured during the post-summer period.

Population estimates were not calculated in 2004 for all life history stages 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 February, March-April, June and November-December (Figure 10). Ammocoete movement during February was associated with discharge and movement from April and June was not (Figure 10). Recaptured ammocoetes were low relative to the number of fish marked (Table 1).

Peaks in macropthalmia captures occurred in late April, June and November (Figure 11). Peak macropthalmia capture was not associated with discharge (Figure 11). Relative to the number of macropthalmia marked, recaptures in 2004 were low (Table 1).

Larval Lamprey Density

The second phase of the controlled field study to examine the efficiency of the backpack electrofisher and to validate the 70% depletion model (Pajos and Weise 1994) at low densities was conducted from August 10 to September 2, 2004. A total of 22 trials were completed. A minimum of one and a maximum of 15 juvenile lampreys were used in each trial. Temperature and conductivity were consistent between trials and throughout the study period. Average temperature inside and outside of the net pens was 19.37°C and 19.35°C, respectively. Average conductivity inside and outside of the net pens was 73.8 µs and 73.6 µs, respectively. The visibility within net pens was generally clear (75-100%) and did not impair sampling with the exception of trials 15 and 16 which had 50-75% visibility due to a large rain event the day before.

The 70% depletion model was tested this year with lower, more realistic densities of fish than what was used last season. The electrofisher failed to detect presence within the initial two passes in several trials (14% of total trials). This brought into question the suitability of using the 70% depletion model for larval lamprey sampling due to the fact that lamprey distribution in nature is patchy and low densities are likely.

The distribution of larval lamprey densities was calculated using data from the stratified systematic sampling protocol utilized in 2002. The probability of finding N individuals in a sample site was then calculated (Pielou 1969). The probability of finding zero larval lamprey in a reach is 83% and decreases to 15% for finding one individual and so on until the probability reaches zero for twelve larval lamprey per reach (Figure 12).

Sampling efficiency, as a function of larval lamprey density, was calculated using combined data from the controlled trials in 2003 and 2004. We define efficiency as the depletion model divided by the actual number when the model predicted fewer animals than the actual estimated number. Efficiency was equal to 1 when the model was equal to the actual. Efficiency was greater than 1 when the model overestimated the actual. For example, in trial number 6 in 2004 there were 10 total ammocoetes, 6 ≥60 mm and 4 <60 mm. The depletion model estimated 4 fish ≥60 mm versus the actual number 6, therefore the efficiency was 4/6 or 67%. The depletion model estimated 6 fish <60 mm, therefore the efficiency was 6/4 or 150%. The depletion model estimated 10 fish when combining size categories therefore the efficiency was 10/10 or 100%. Efficiency increased as density increased for all size groups using this method (Figure 13 a-c).

The probability of detecting a larval lamprey was calculated based on the probability of occurrence and sampling efficiency (Peterson et al. 2002). For fish <60 mm the probability was 95%, for fish >60 mm it was 82% and for both size groups combined the probability of detecting larval lamprey was 89%.

Finally, sampling efficiency as a function of density and pass number was determined. Table 2 shows the results for efficiency per pass separated into three density categories: all densities together (1-130), densities of 1-15 fish and densities greater than 15. Efficiency generally decreased from pass to pass for all densities tested. However, efficiency increased from pass 4 to pass 5 for several treatments (Table 2).

Within passes, the efficiency decreased as density increased for passes 1, 2 and 5. Within passes 3 and 4 the efficiency increased as density increased (Figure 14).

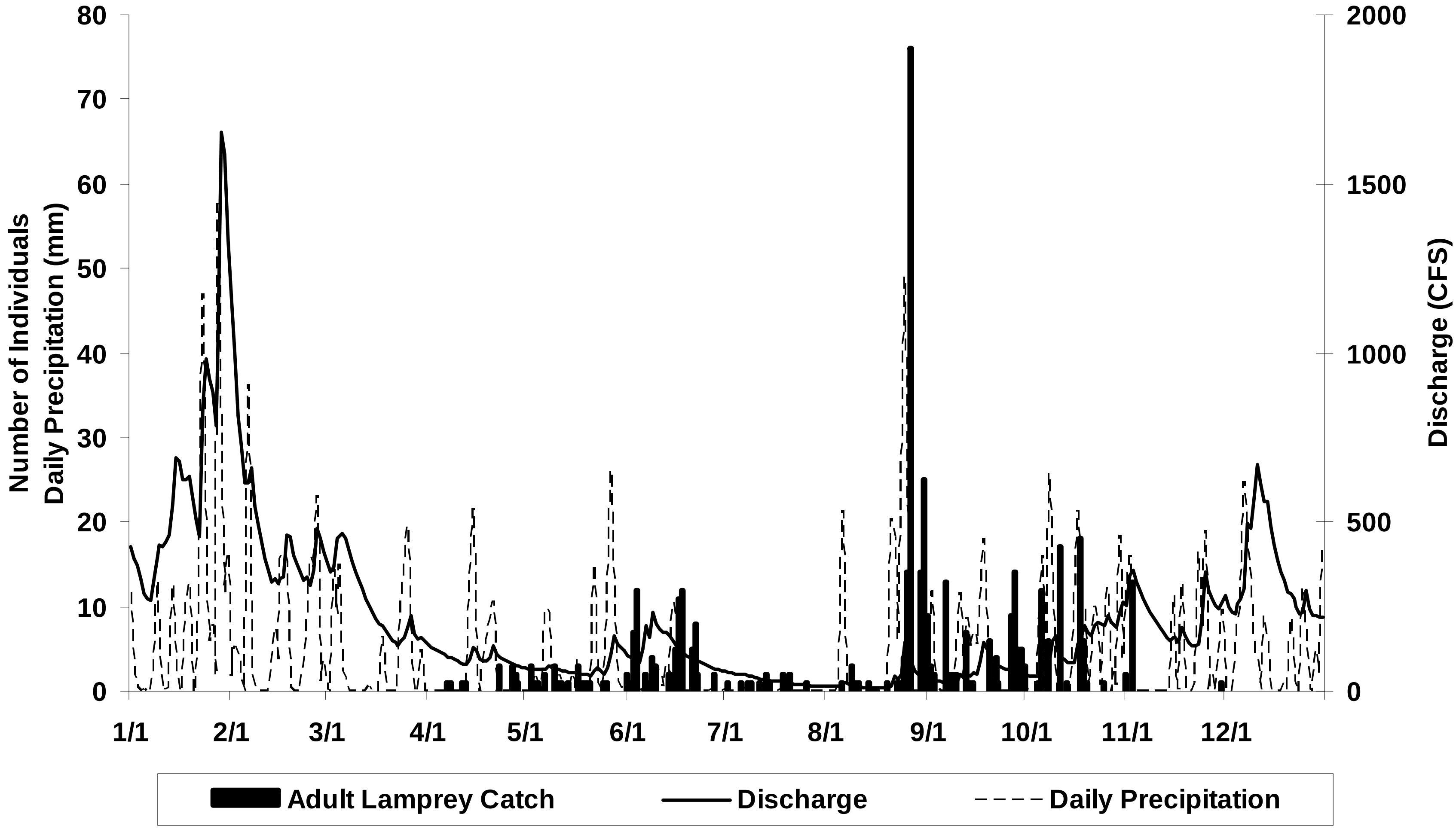


Figure 8. Pacific lamprey adult captures with daily precipitation and discharge on Cedar Creek, WA 2004.

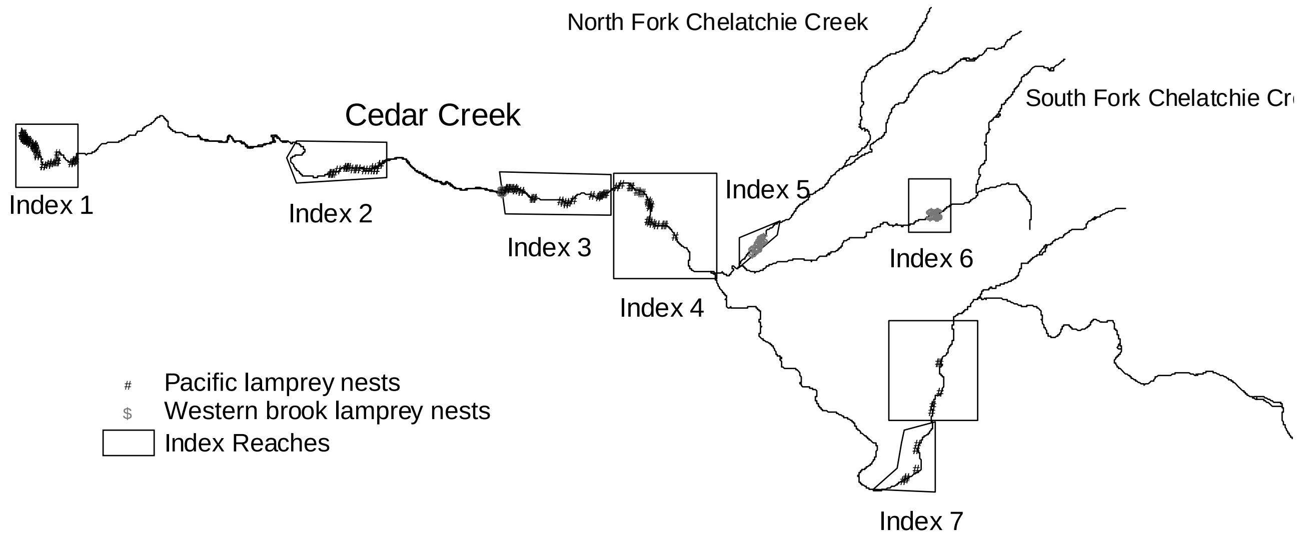


Figure 9. Locations of Pacific and Western brook lamprey nests on Cedar and Chelatchie Creeks, WA 2004.

Table 1. Data collected from juvenile lampreys captured in the rotary screw trap, Cedar Creek, WA 2004.

Pre-Summer January 21 - July 16, 2004

	Pacific Lamprey		Western Brook Lamprey	
	Ammocoete	**Macrophalmia**	**Ammocoete**	**Adult**
Minimum Length (mm)	37.0	119.0	119.0	99.0
Average Length (mm)	98.3	138.5	135.6	106.3
Maximum Length (mm)	138.0	155.0	145.0	112.0
Minimum Weight (g)	0.1	1.7	3.0	1.6
Average Weight (g)	1.6	3.3	3.7	2.1
Maximum Weight (g)	4.1	5.0	4.6	2.3
Minimum Condition Factor	0.88	0.59	1.13	1.64
Average Condition Factor	1.54	1.21	1.41	1.70
Maximum Condition Factor	2.52	1.75	1.60	1.83
Total Captured	278	35	8	3
Trap Efficiency Marks	182	33	7	3
Number Recaptured	6	4	1	0
Average Trap Efficiency (%)	3.3	12.0	14.3	0

Post-Summer October 19 - December 14, 2004

	Pacific Lamprey		Western Brook Lamprey	
	Ammocoete	**Macrophalmia**	**Ammocoete**	**Adult**
Minimum Length (mm)	48.0	106.0	129.0	NA
Average Length (mm)	100.0	121.3	129.0	NA
Maximum Length (mm)	125.0	153.0	129.0	NA
Minimum Weight (g)	0.2	1.6	3.1	NA
Average Weight (g)	1.7	2.5	3.1	NA
Maximum Weight (g)	3.1	4.7	3.1	NA
Minimum Condition Factor	1.02	1.10	1.44	NA
Average Condition Factor	1.49	1.41	1.44	NA
Maximum Condition Factor	1.92	2.66	1.44	NA
Total Captured	42	40	1	0
Trap Efficiency Marks	18	35	1	0
Number Recaptured	1	0	0	0
Average Trap Efficiency (%)	5.5	0.0	0.0	NA

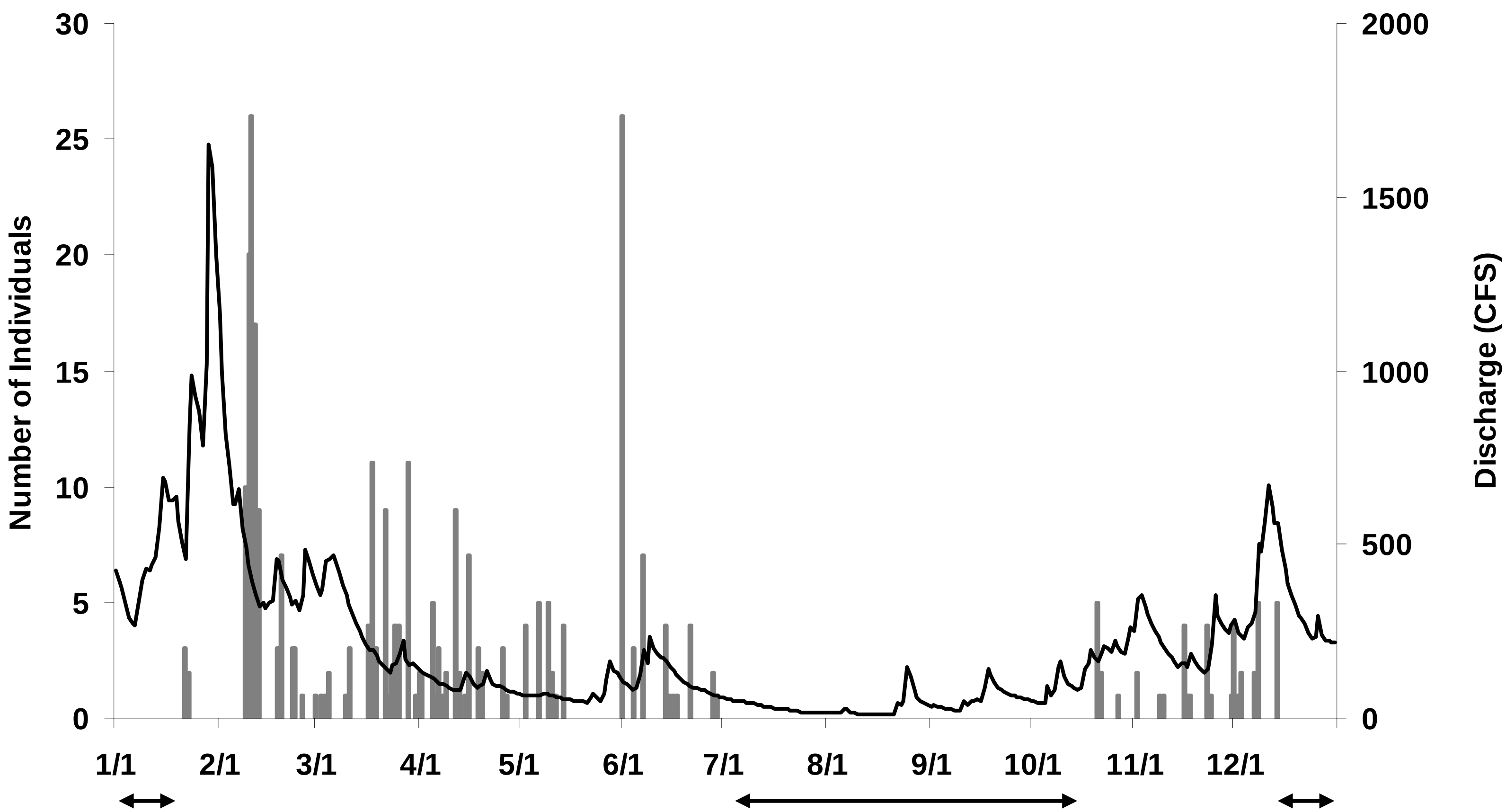


Figure 10. Ammocoete captures with discharge, Cedar Creek, WA, 2004. Arrows indicate periods of screw trap inoperability due to high flows in the winter months and insufficient flows during the summer and early fall.

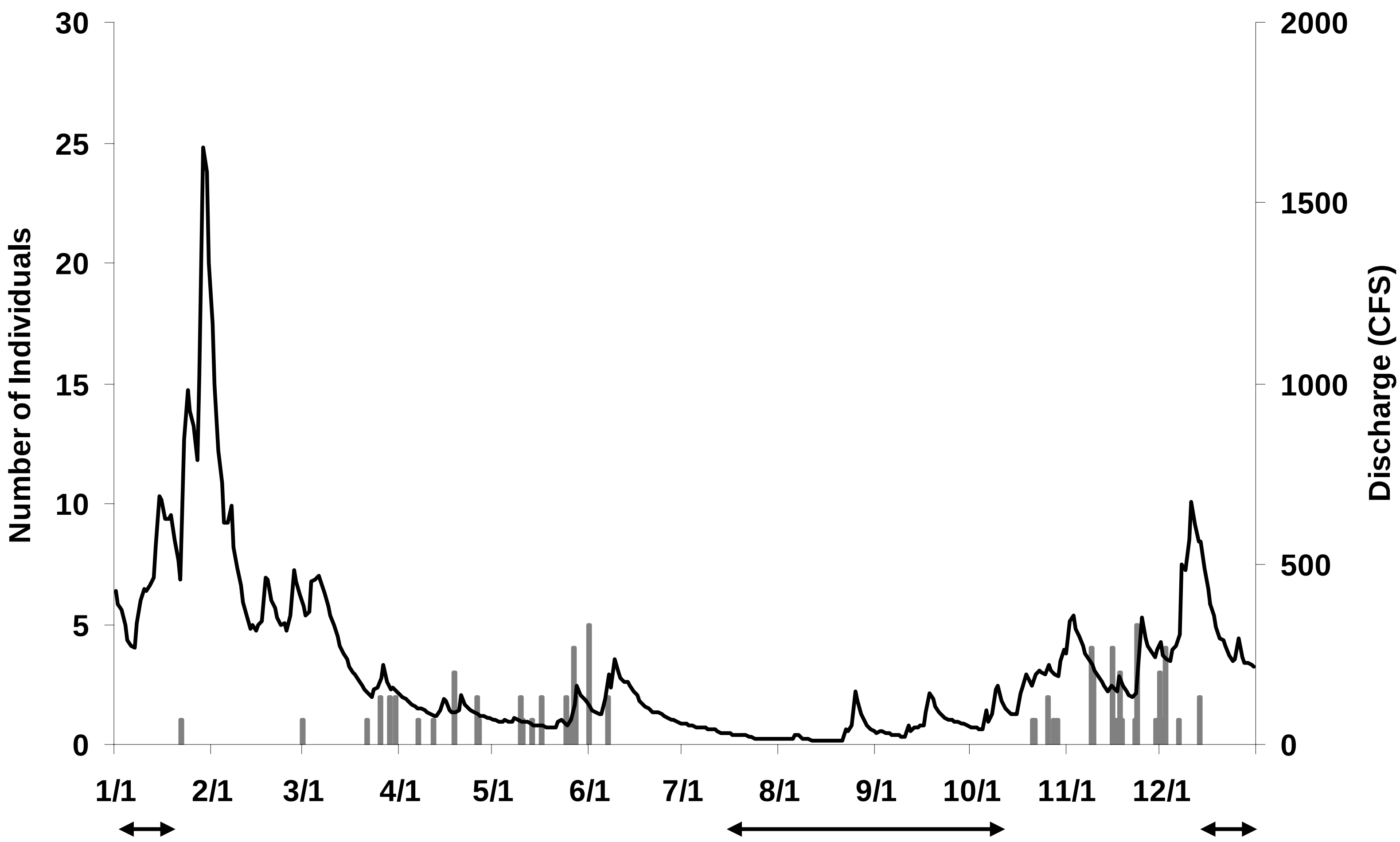


Figure 11. Pacific lamprey macropthalmia captures with discharge, Cedar Creek, WA, 2004. Arrows indicate periods of screw trap inoperability due to high flows in the winter months and insufficient flows during the summer and early fall.

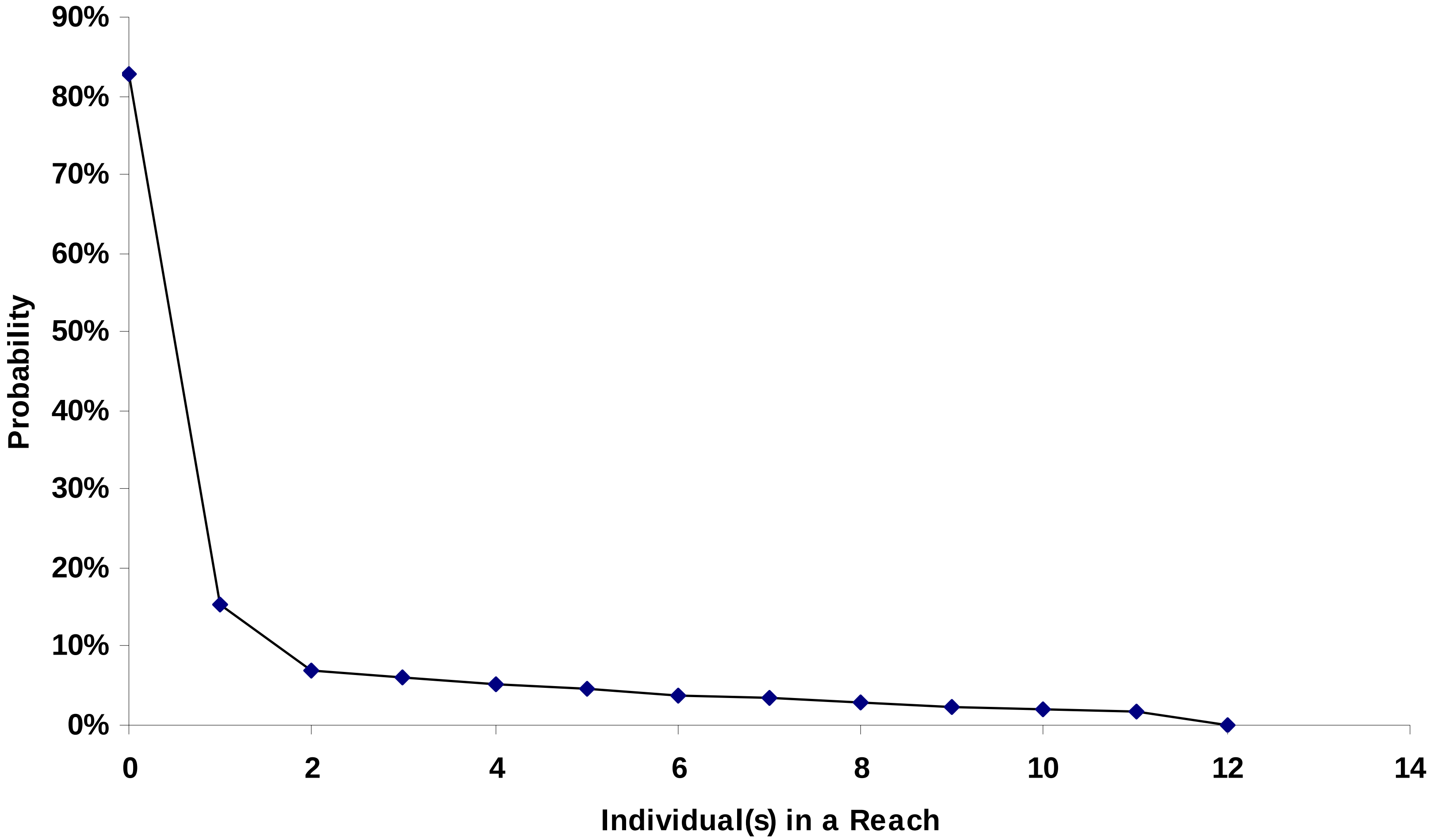
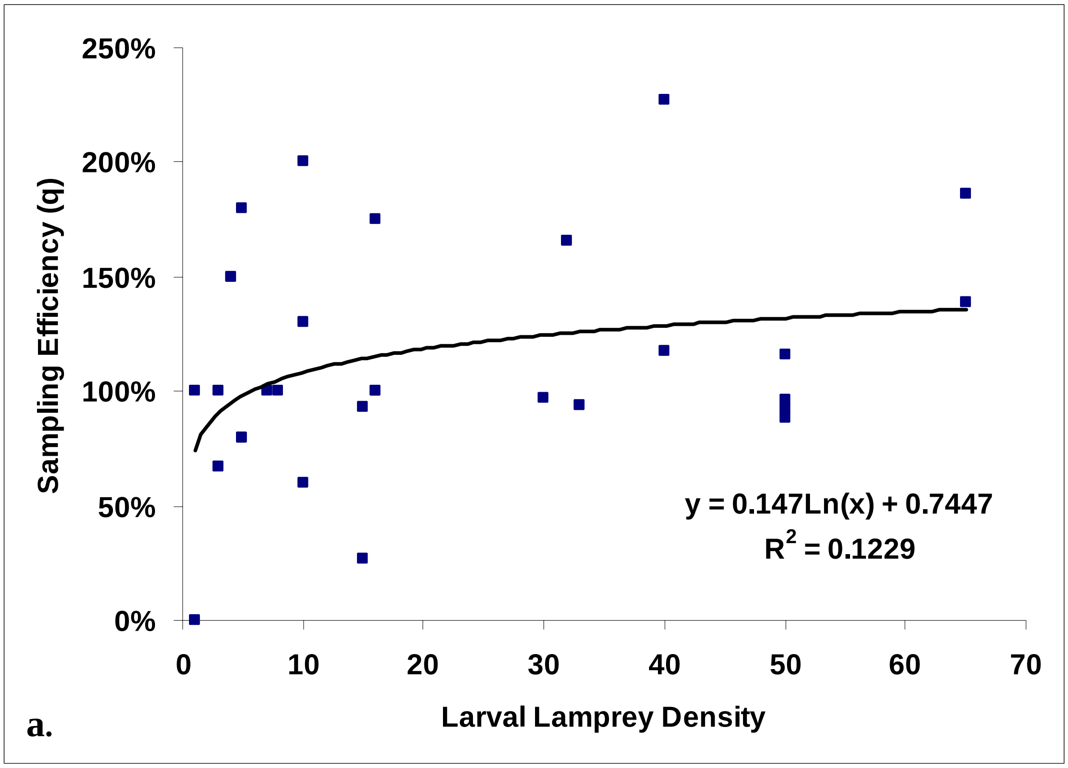


Figure 12. Probability(p) of finding N larval lamprey in a reach on Cedar Creek, WA 2004.
$p = (\beta/1+\beta)^{\alpha+x})*(\Gamma(\alpha+x)/(\Gamma(x+1)\Gamma(\alpha))$, where $\alpha = 0.1$ and $\beta = 5.53902$.



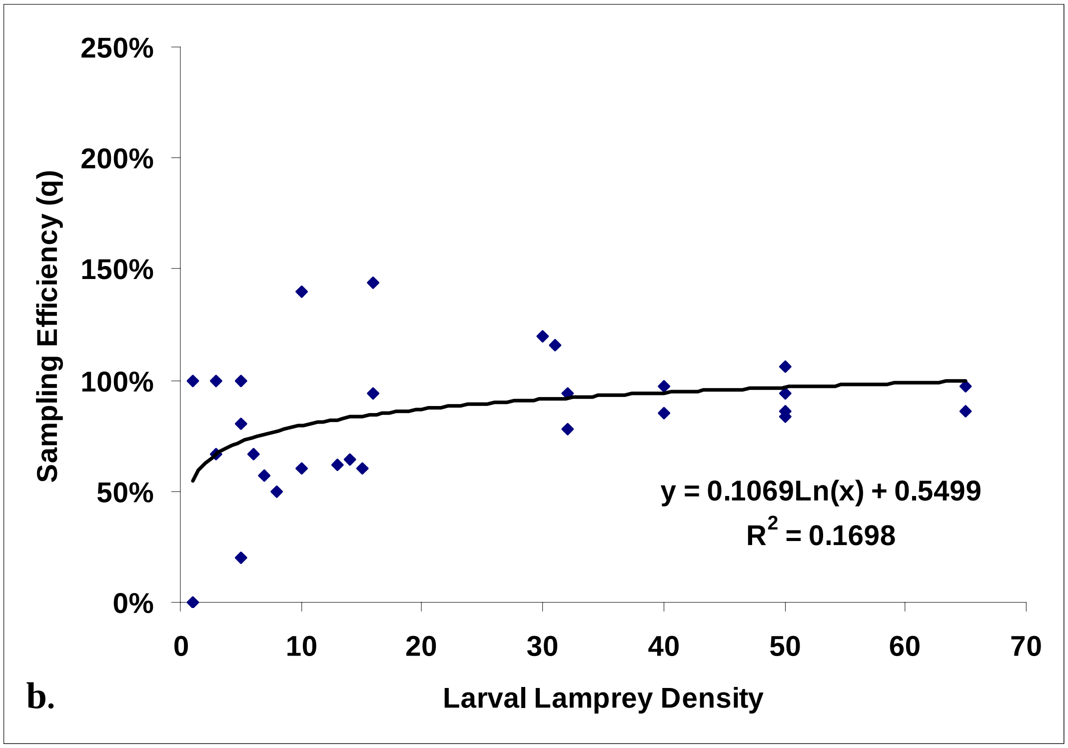


Figure 13 a-b. Sampling efficiency (q) versus larval lamprey density. a. fish <60 mm. b. fish >60 mm.

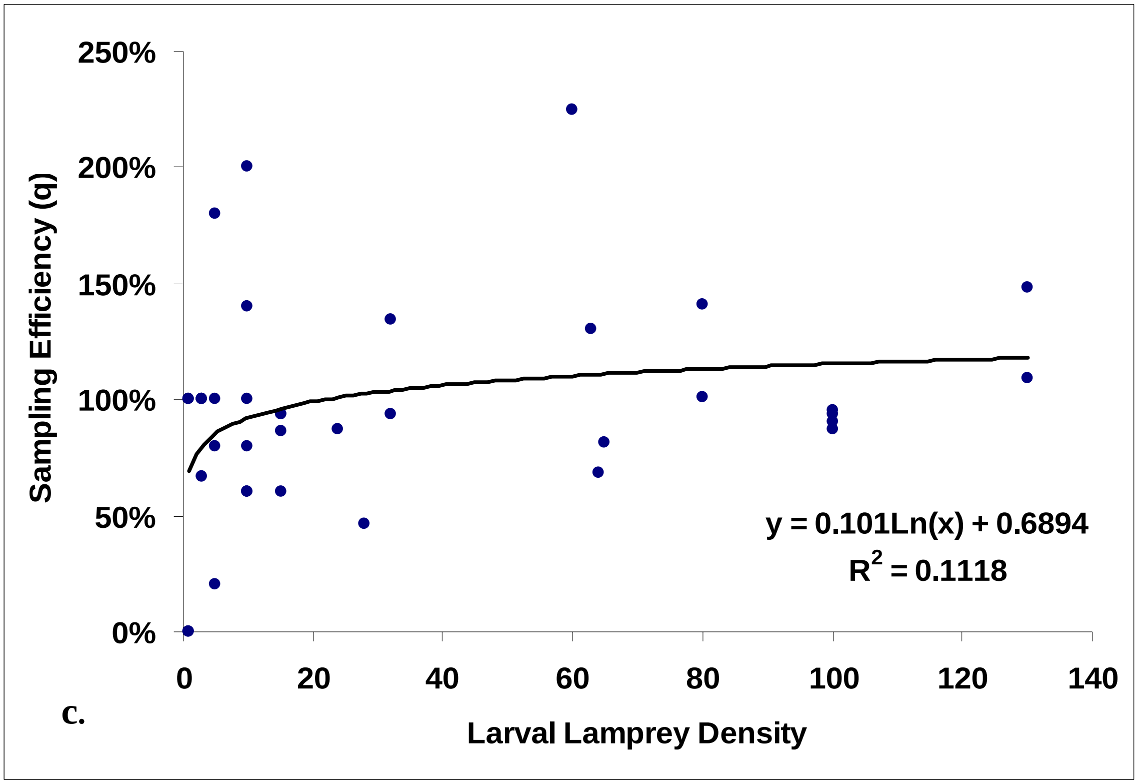


Figure 13 c. Sampling efficiency (q) versus larval lamprey density. c. Either <60mm, >60mm or size groups combined, whichever sample was largest.

Table 2. Sampling efficiency by pass as a function of ammocoete size and density.

Fish Size		Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
All Sizes	Densities 1-130	40%	40%	24%	27%	22%
	Drop in efficiency per pass	38%	1%	41%	-15%	20%
	Densities<15/m^2	47%	43%	7%	0%	33%
	Drop in efficiency per pass	22%	8%	85%	100%	-33%
	Densities> 15/m^2	31%	35%	34%	36%	13%
	Drop in efficiency per pass	16%	-15%	4%	-7%	65%
<60 mm	Densities 1-130	27%	24%	10%	6%	6%
	Drop in efficiency per pass	30%	10%	59%	36%	2%
	Densities<15/m^2	42%	37%	4%	0%	11%
	Drop in efficiency per pass	14%	13%	89%	100%	-11%
	Densities> 15/m^2	13%	13%	12%	8%	3%
	Drop in efficiency per pass	16%	-6%	12%	34%	59%
≥60 mm	Densities 1-130	30%	26%	8%	4%	20%
	Drop in efficiency per pass	28%	12%	69%	47%	-373%
	Densities< 15/m^2	46%	43%	10%	0%	67%
	Drop in efficiency per pass	12%	7%	77%	100%	-67%
	Densities> 15/m^2	18%	15%	7%	5%	2%
	Drop in efficiency per pass	16%	18%	50%	31%	60%

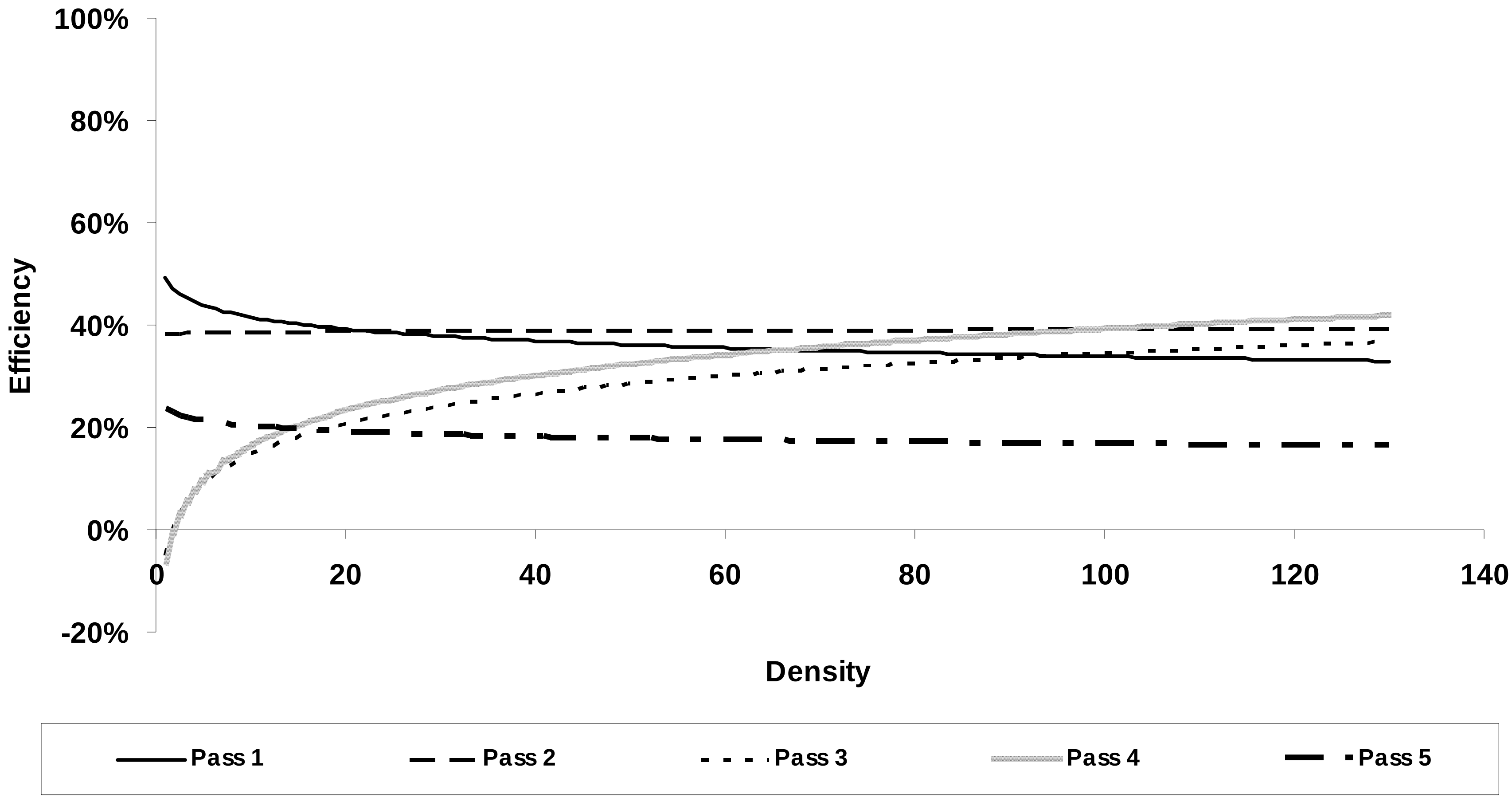


Figure 14. Sampling efficiency as a function of density (by electrofishing) per pass. All sizes of ammocoetes were combined. Pass 1: y = -0.0333Ln(x)+0.492; Pass 2: y = 0.0022Ln(x) + 0.3814; Pass 3: y = 0.086Ln(x)-0.0511; Pass 4: y = 0.0998Ln(x)–0.0648; Pass 5: y = -0.015 Ln(x)+0.2363.

Discussion

Adult Pacific lampreys were captured in Cedar Creek between April and December in the adult ladder and pot traps deployed at various locations. Capture during migration is usually divided into an early pulse (April-July) and late pulse of upstream migrants (September-November) (Stone et al. 2001, Stone et al. 2002, Lê et al. 2004). In 2004 the spring/early summer pulse came primarily in June and the late pulse primarily from late August to late September. Though adult movement is usually seasonal, the pulses of upstream migration in early June and August of 2004 coincided with spikes in precipitation and discharge (Figure 8).

Literature indicates that early migrants overwinter before spawning the following spring (Pletcher 1963, Beamish 1980, Farlinger and Beamish 1984). With no direct evidence we have been uncertain as to whether early migrants to Cedar Creek immediately spawn or if they overwinter as do the late migrants. In April 2004 a post-spawn Pacific lamprey was recaptured in the screw trap after being at large for almost one year. This fish was an early migrant, originally captured and tagged in May 2003. This fish had lost 30% of its total length and 17% of its mass. Although this is our only documented case of an early migrant overwintering, the physical condition of early migrants caught in the ladder and pots suggests that most fish do not spawn until the following year. These early migrant lampreys are large and robust and show no outward signs of gamete formation or loss of body mass. Exceptions to this are captures of post-spawn adults in the screw trap that have drifted downstream and are therefore not actively migrating upstream.

In 2004, more effort was expended on capturing adult Pacific lampreys than in previous years of the project. Additional pot traps were placed on traplines at the mouth (Figure 5) and near the mill to increase catch of marked and unmarked fish. We captured more adult Pacific lampreys in 2004 than in all previous study years combined. While the additional pot traps placed at the mouth and mill did contribute to the increase in total catch in 2004, the most successful means of capturing adult lampreys was still the pots in the adult ladder. Two hundred thirty two lampreys were caught in ladder pots in 2004 versus 19 in 2003. Whether this translates into a larger adult population migrating up Cedar Creek this season or more adults simply choosing to travel through the ladder versus up the falls is difficult to determine. We are currently analyzing trap catchability and population estimates using mark-recapture techniques.

Pacific lampreys were observed spawning within mainstem Cedar Creek again in 2004. Western brook lamprey spawning was observed in the Chelatchie creek tributaries. This separation is due to habitat preferences because Pacific lamprey prefer to spawn in larger substrate and faster water velocities than Western brook lamprey (Stone et al. 2001, 2002, Pirtle et al. 2003, Lê et al. 2004). We continue to see habitat changes in Cedar Creek from year to year. Productivity returned to Indices 3 and 4 (now named Index 7), where fine sediment smothered the spawning habitat in 2003. Fifteen nests were observed in this reach in 2004 versus only one in 2003. Non-index reaches were converted into Index reaches or exploratory reaches based on activity in 2003. Non-index reach 6 was converted to Index 3 based on restoration work conducted on this reach by Fish First to improve the spawning habitat for salmonids. Thirty five nests were seen on Index 3 in 2004 versus three prior to the restoration. Non-index reach 5 was an exploratory reach and therefore was only visited once in 2004. Much of the habitat was suitable for spawning and nest activity was observed so this area will potentially become an Index reach in 2005. Three other exploratory reaches were surveyed in 2004. Two out of the four exploratory reaches may be visited regularly as Index reaches in 2005.

Spawning ground surveys were redesigned in 2004 to include the collection of non-use habitat data along with nest, or use, data that has been collected for several years of the project. Logistic regression analysis is being applied to the habitat characteristics measured (substrate composition, water velocity and depth) in use and non-use areas to develop relationships. These relationships will ultimately be used to predict probability of nest occurrence for a given combination of substrate, water depth and velocity.

Ammocoete movement, as observed through screw trap operations, occurs throughout the year and is influenced by both discharge and ammocoete transformation. Smaller ammocoetes are historically scoured out in Cedar Creek following high discharge flows in the winter (Stone et al. 2001, 2002, Pirtle et al. 2003, Lê et al. 2004) (Figure 10) and are therefore considered to be passively migrating downstream. Ammocoetes captured in February and November, two months that usually would be included in the winter migration period, were significantly larger (ANOVA, $p<0.05$) than ammocoetes captured in all other months. These months also had the highest percentage of individuals that were transforming into macropthalmia (5% and 20% respectively). A large pulse of ammocoetes moving downstream at the beginning of February was smaller on average and was captured directly after a high discharge period. Larger ammocoetes, and all of the transformers captured in February, moved towards the end of the month during a very low discharge period. Likewise, the November large ammocoetes moved during low flow periods, potentially indicating active movement of larger and transforming ammocoetes. June, a month when larger ammocoetes are usually on the move, had higher than normal discharge due to unseasonable rainfall and a smaller average size of captured ammocoetes.

Macropthalmia outmigrate during late fall-winter during high discharge events and also in late spring and summer, regardless of flow (Figure 11). Beamish and Levings (1991) observed that macropthalmia emigration was almost always associated with high discharge events. In Cedar Creek, peak movement occurred in May-June when discharge was decreasing and in November-December when discharge was increasing. Though only four marked macropthalmia were recaptured in 2004, they were recaptured during these periods. This relationship was observed in other sample years (Stone et al. 2001, Stone et al. 2002, Lê et al. 2004). Total macropthalmia catch in 2004 was drastically less than 2003 when 460 were captured. A lower abundance of ammocoetes ready to transform is most likely the cause of the reduced macropthalmia catch as the screw trap fished for more days and during periods that were non-operational in 2003. Population estimates for emigrants were not calculated because too few fish were recaptured within each marking period. Recaptures are very sporadic and the efficiencies over each marking period are highly variable.

Lê et al. (2004) discussed the need for relocating the screw trap to the mouth of Cedar Creek to improve safety, efficiency and exposure to the larger percentage of lampreys produced downstream of the current trap location. The Section 10 permitting process with the NOAA Fisheries was completed in 2004 and we are currently analyzing the logistics involved with moving and anchoring the screw trap at the mouth. The new location should provide flows sufficient for safe operation, continuous sampling, and will enable us to characterize emigrant activity for the entire Cedar Creek drainage.

One of the challenges of the project has been to calculate reliable larval population estimates. In 2002, the crews resampled sites from previous years and detected lamprey larvae where none were detected before. This led to a concern that electrofishing did not adequately detect lamprey at low densities or in a patchy environment. There is also a concern that the 70% depletion model was unable to expand the sample counts into an accurate population estimate.

In 2003, a gear and model efficiency study was initiated using net pens with preferred substrate and flow and stocked larval densities representative of the upper range of preliminary core samples from the field. The upper end of the range was chosen to insure enough larvae was counted from electroshocking so the 70% depletion model could be tested. The results indicated that at high densities, $\geq 24/m^3$, enough lamprey could be induced to emerge from the substrate with at least 2 passes for successful detection of presence. However, the 70% depletion model overestimated the abundance of smaller larvae at the upper range of densities. The 70% depletion model presumes that each successive pass of the electroshocking gear would yield fewer fish than from the previous pass (Pajos and Weise 1994). This was not always true. However, there was no correlation between the bias from the 70% depletion model and instances when the fish counts did not decline progressively with each pass.

In 2004, the study was repeated with densities representative of the lower range of densities observed in 2002. The results indicated that the bias observed during 2003 did extend into lower densities. The study also showed that at very low densities, i.e. $1/ m^3$, electrofishing failed to coax the single larvae to the surface at the end of 5 passes in half of the trials (i.e. failed to detect presence). At densities between 3 and $5/m^3$, electrofishing moved at least one larvae to the surface (i.e. successfully detected presence) and the 70% depletion model generated population estimates that were between 20% and 100% of the actual abundance. The results improved as densities increased.

A probability of finding a given number of individuals in a sample site (Pielou 1969) without discriminating among habitat types was calculated from the 2002 study. That data set suggested an 83% chance of finding zero ammocoetes per site, 15% for one ammocoete, 7% for two, and even lower percentages for higher detections (Figure 12). Thus in Cedar Creek, the probability of finding high concentrations of ammocoetes is low when no consideration was given for habitat preferences. There was not enough data to generate a probability curve specifically for the habitat preferred by lamprey ammocoetes (i.e. sandy substrate with low flow and back eddies).

Efficiency curves were calculated at low and high densities < 60 and ≥ 60 mm size groups and for mixed sized groups (Figure 13 a-c). As expected, the detection efficiency is low when densities are low and we often fail to detect presence at 1/ m^3.

The combination of the probability of finding N individuals with the efficiency curves is the probability of detection. That would be 95% for lamprey <60 cm, 82% for lamprey ≥ 60 cm, and 89% for mixed size groups.

In 2005 we will focus on controlled experiments to address the questions revealed by the field study in 2004. We will attempt to address: 1) susceptibility of larval lampreys to electrofishing and; 2) assessment of electrofishing as a tool for determining presence and estimating abundance in the context of several variable factors such as density, larval size, and habitat conditions. Answers to these questions will ultimately provide insight into higher level questions such as presence/absence per sample point and streamwide distribution and abundance at sample point and area/stream levels.

Sampling efforts on Cedar Creek will continue for 2005. Modifications introduced in 2004 will continue in 2005 so that we may better meet the objectives of the study. Analyses are ongoing for adult Pacific lamprey population estimates, larval lamprey presence and abundance, and spawning habitat characteristics. Analysis and conclusions of these studies will be disseminated in the literature, lamprey workshops and meetings as well as an annual report, similar to this, delivered during the early months of 2006.

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