Evaluate Habitat Use and Population Dynamics of Lampreys in Cedar Creek

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Annual Report for 2002 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 populations in Cedar Creek, Washington, a third-order tributary to the Lewis River. This annual report describes the activities and results of the third year of this project. Adult (n = 62), metamorphosed (n = 76), transforming (n = 4), and ammocoete (n = 315) stages of Pacific and western brook lamprey were examined in 2002. Lampreys were captured using adult fish ladders, lamprey pots, rotary screw traps, and lamprey electrofishers. In addition, fifty-four spawning ground surveys were conducted during which 124 Pacific lamprey and 13 western brook lamprey nests were identified. Stream gradient of spawning grounds were surveyed to better understand spawning habitat requirements.

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). Though 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 recovery of Pacific lamprey populations in the CRB (Close et al. 1995).

Identifying the biological factors that are limiting lampreys in the CRB is critical for their recovery. 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 will 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 and western brook lamprey in Cedar Creek, Washington since 2000. Data collected during 2000 and 2001 are summarized in Stone et al. 2001 and Stone et al. 2002. This annual report summarizes results of research and analytical activities conducted during 2002. The objectives of this research are to: 1. Estimate abundance, examine biological characteristics, and determine migration timing of adult Pacific lampreys; 2. Determine larval lamprey distribution, habitat use, and examine biological characteristics; 3. Determine emigration timing and estimate the abundance of recently metamorphosed lampreys; and 4. Evaluate spawning habitat requirements of adult lampreys.

Life History

The Pacific lamprey ranges from southern California to Alaska and is parasitic and anadromous (Scott and Crossman 1973). Adults enter the stream 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). They deposit between 10,000 - 200,000 eggs and die within 3 - 36 days after spawning (Kan 1975, Pletcher 1963). Larvae hatch in about 19 days at 15 °C (Pletcher 1963) and spend 4 - 6 years as ammocoetes in fine sediment, pumping water through their branchial chamber, filtering diatoms, algae, and detritus (Beamish and Levings 1991). Pacific lampreys transform from ammocoetes to macropthalmia in July to October. The macropthalmia migrate to the ocean between late fall and spring (van de Wetering 1998). They spend 1 - 4 years as adults feeding as external parasites on marine fish (Beamish 1980).

The western brook lamprey ranges from southern California to British Columbia (Scott and Crossman 1973). They are non-parasitic and complete their life cycle in freshwater, obtaining lengths of 160 mm (Close et al. 1995). 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 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 of low flow and high organic matter. Ammocoetes remain in the sediment nursery areas for 3 - 6 years and feed similarly to Pacific lamprey ammocoetes. The mature ammocoetes metamorphose into adults from August to November and over-winter without feeding. Adults become sexually mature in March and die shortly after spawning.

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 mile 87. The Cedar Creek drainage is89.3 km^2 and included diverse stream types and habitat conditions, contains five major tributaries (Chelatchie, Pup, Bitter, Brush, and John Creeks), and is inhabited by Pacific, western brook, and possibly river lampreys (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 3) and rainfall is measured at the Grist Mill (Figure 4).

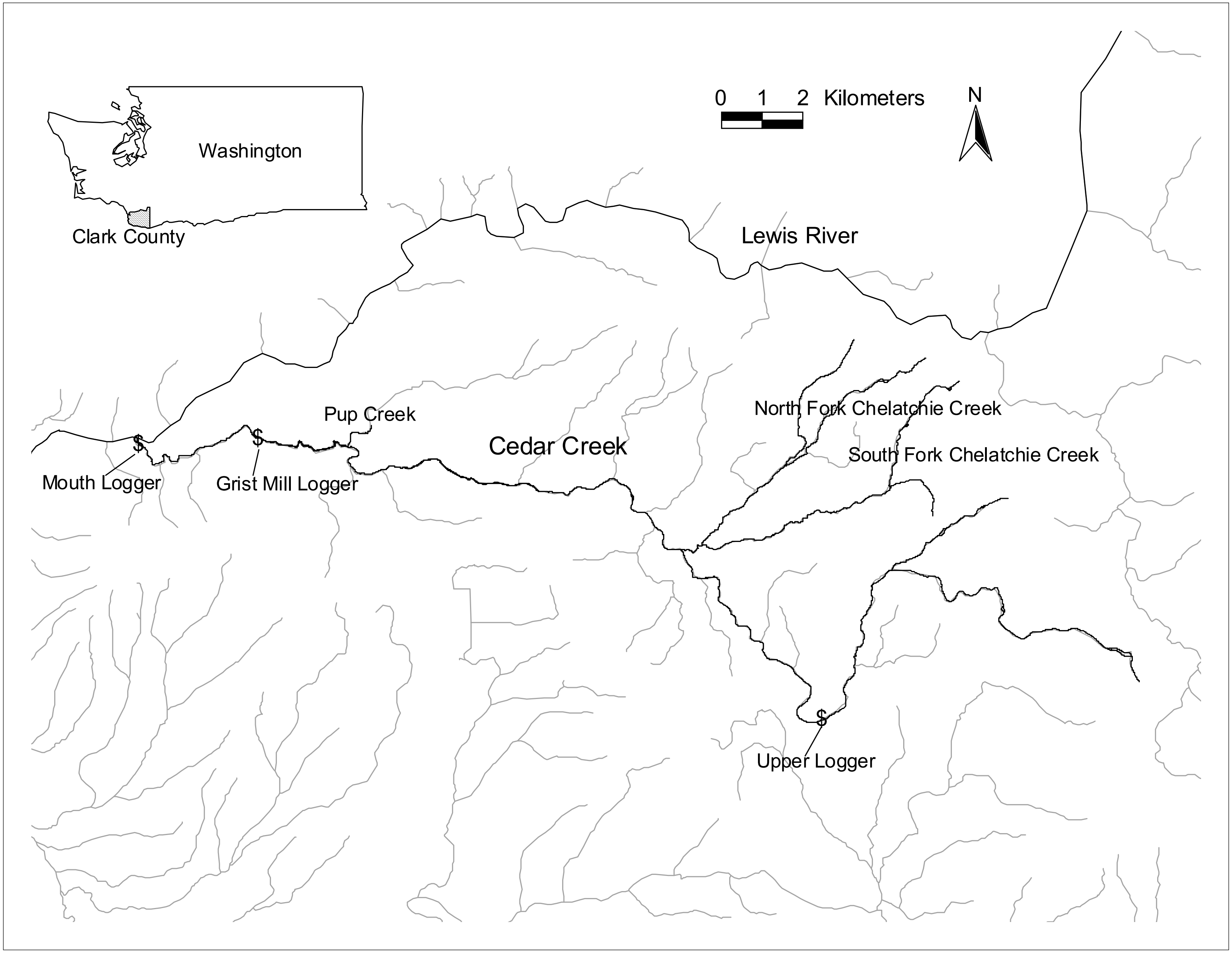

Figure 1. Cedar Creek in Clark County, Washington depicting the location of USFWS temperature loggers.

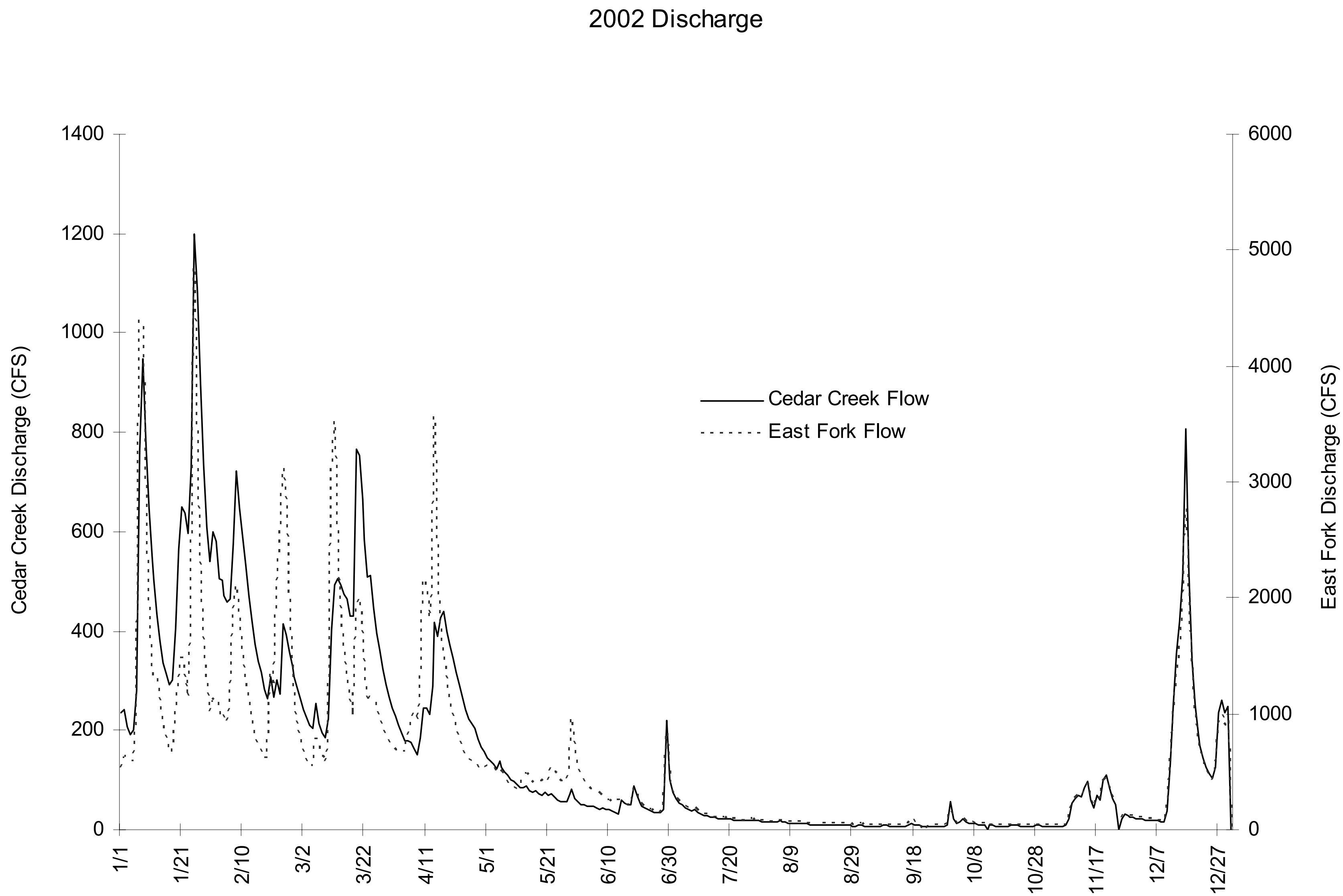

Figure 2. Discharge for East Fork Lewis River, Heisson Station (USGS) and Cedar Creek (Washington Department of Ecology), 2002.

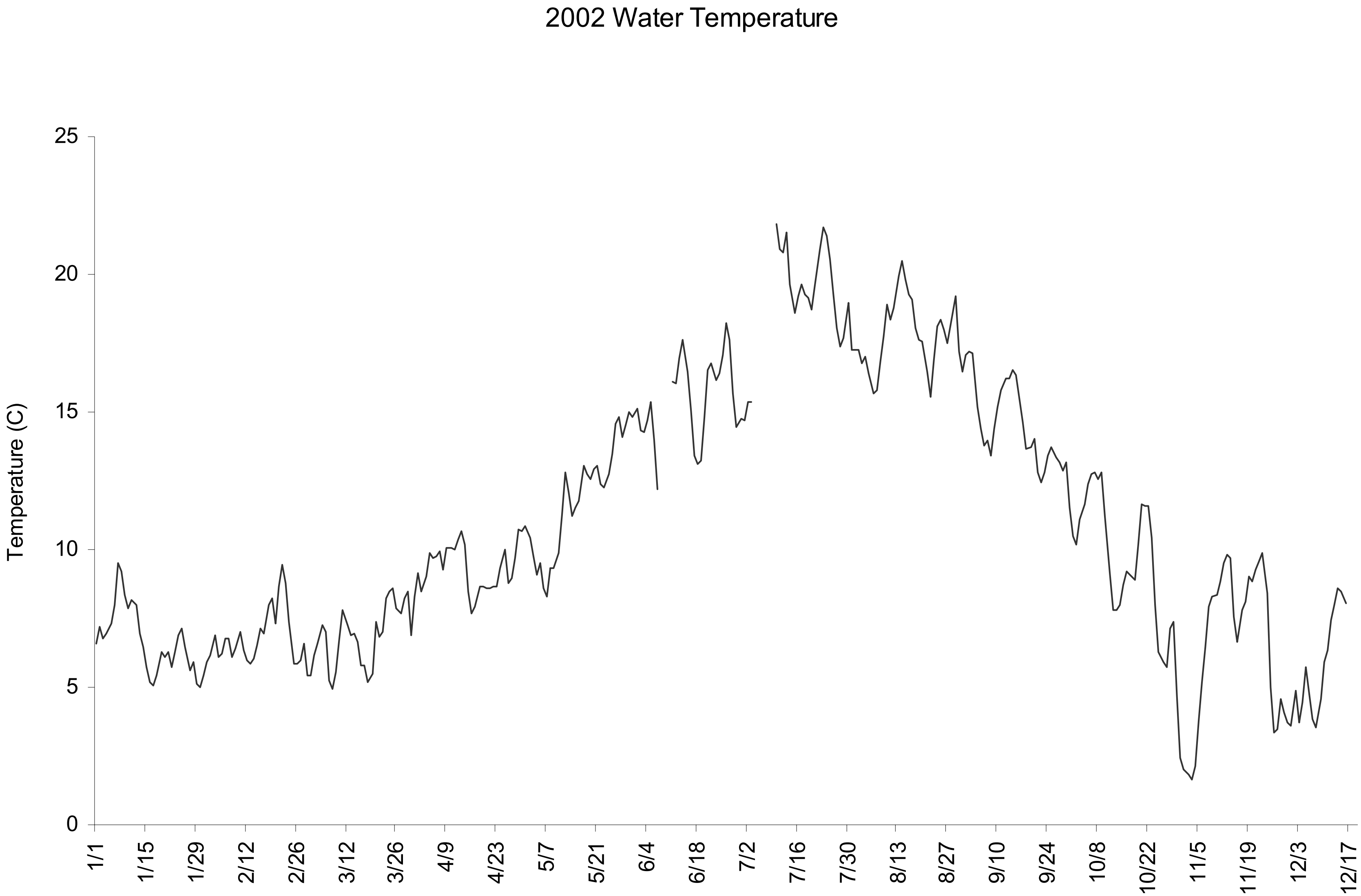

Figure 3. Water temperatures recorded on Cedar Creek at the Grist Mill using an Onset Hobo® temperature logger, 2002. Data was not recorded from June 8-11, 2002 and July 4-9, 2002.

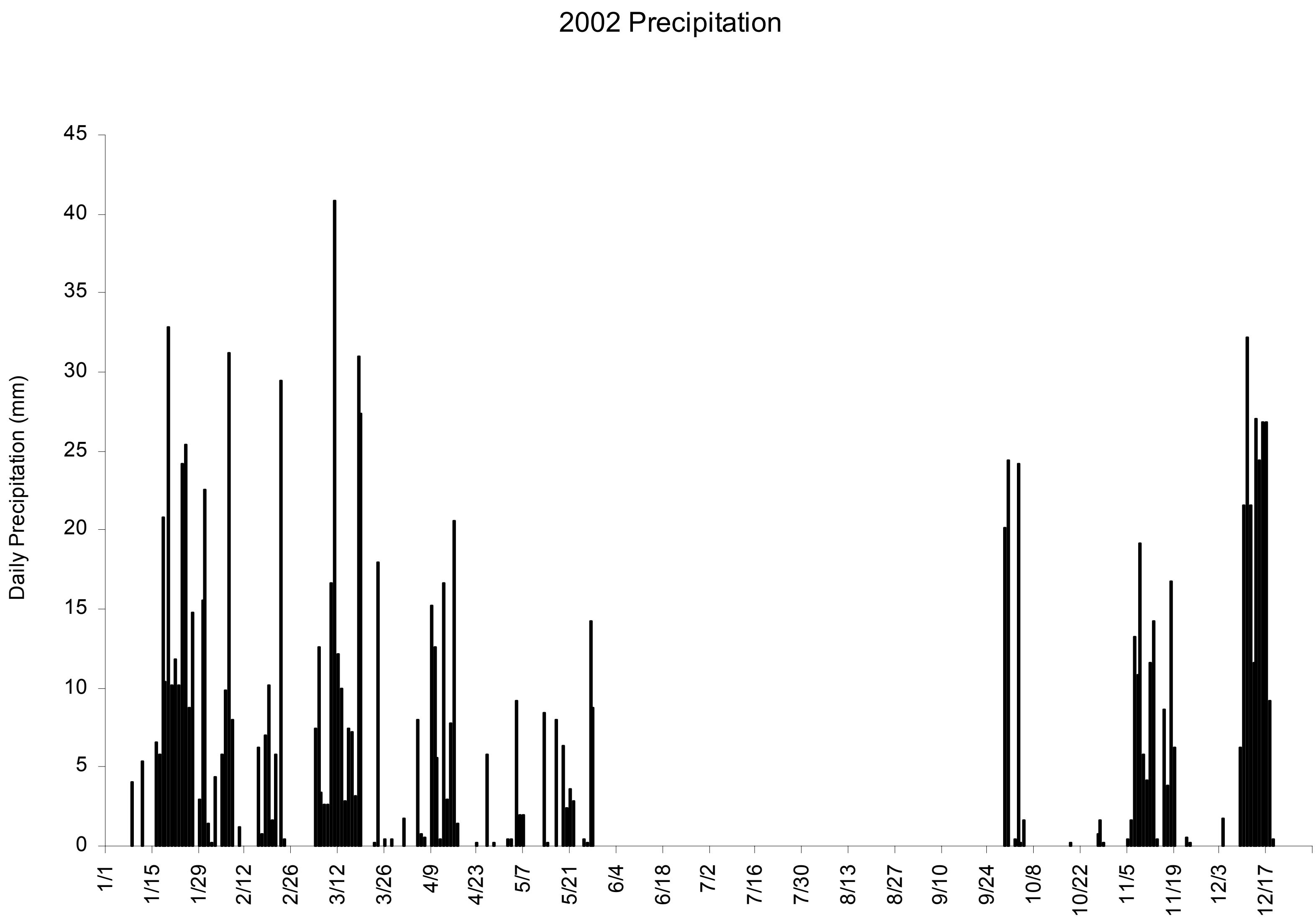

Figure 4. Precipitation recorded on Cedar Creek at the Grist Mill using an Onset Hobo® rain gage, 2002.

Methods

Lamprey Density

The spatial distribution and habitat association of larval lampreys in Cedar and Chelatchie creeks was assessed during 2002 using a stratified systematic point-sampling technique. A total of nine sample reaches, situated 1000 m apart, were examined in the Chelatchie Creeks and upper Cedar Creek beginning August 22 and ending September 10.

Sample reaches were divided into six transects spaced 10 m apart. Each transect contained two sampling points; the sampling points on even-numbered transects were located at 1/3 and 2/3 of the wetted width and the sampling points on odd-numbered transects were located at water's edge (Figure 5). Sampling points had an area of 1 m^2. Specific habitat characteristics were measured at each sample reach, transect, and sample point (Table 1).

Larval lampreys were removed from each sample point by 70% depletion electrofishing (Pajos and Weise 1994). An AbP-2 backpack electrofisher (Engineering Technical Services, University of Wisconsin, Madison, Wisconsin) was used. 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). Once larvae emerged, 30 pulses/second was applied to stun the larvae. Each point was sampled for 90 seconds per pass, with a minimum of two and a maximum of five passes. Lampreys measuring $\leq$30 mm could not be effectively depleted, therefore they were enumerated but not used in any analyses. Captured lampreys were anesthetized with MS-222 (Summerfeldt and Smith 1990), identified to species, and measured for length and weight.

Reaches where lampreys were not collected during 2000, 2001, and 2002 were resampled for presence/absence. Three points containing likely larval lamprey habitat (i.e. sand and gravel mixture) were selected and sampled by electrofishing as previously described. Captured lampreys were enumerated and released.

A pilot study was conducted to establish depletion efficiency of the AbP-2 backpack electrofisher at the predetermined settings. One cubic meter net pens having 0.4 mm mesh were filled with approximately 15.2 cm of fine substrate and placed in the creek. Thirty larval lampreys were captured with a backpack electrofisher and placed in one pen while the other was left empty for a control. The pens were allowed to settle for 24 hours. Each pen was sampled by a crew unaware of the pen assignments. Larval lampreys were removed, enumerated, measured, and released. After five passes, the remaining larvae were removed from the pen with the electrofisher, enumerated, measured, and released.

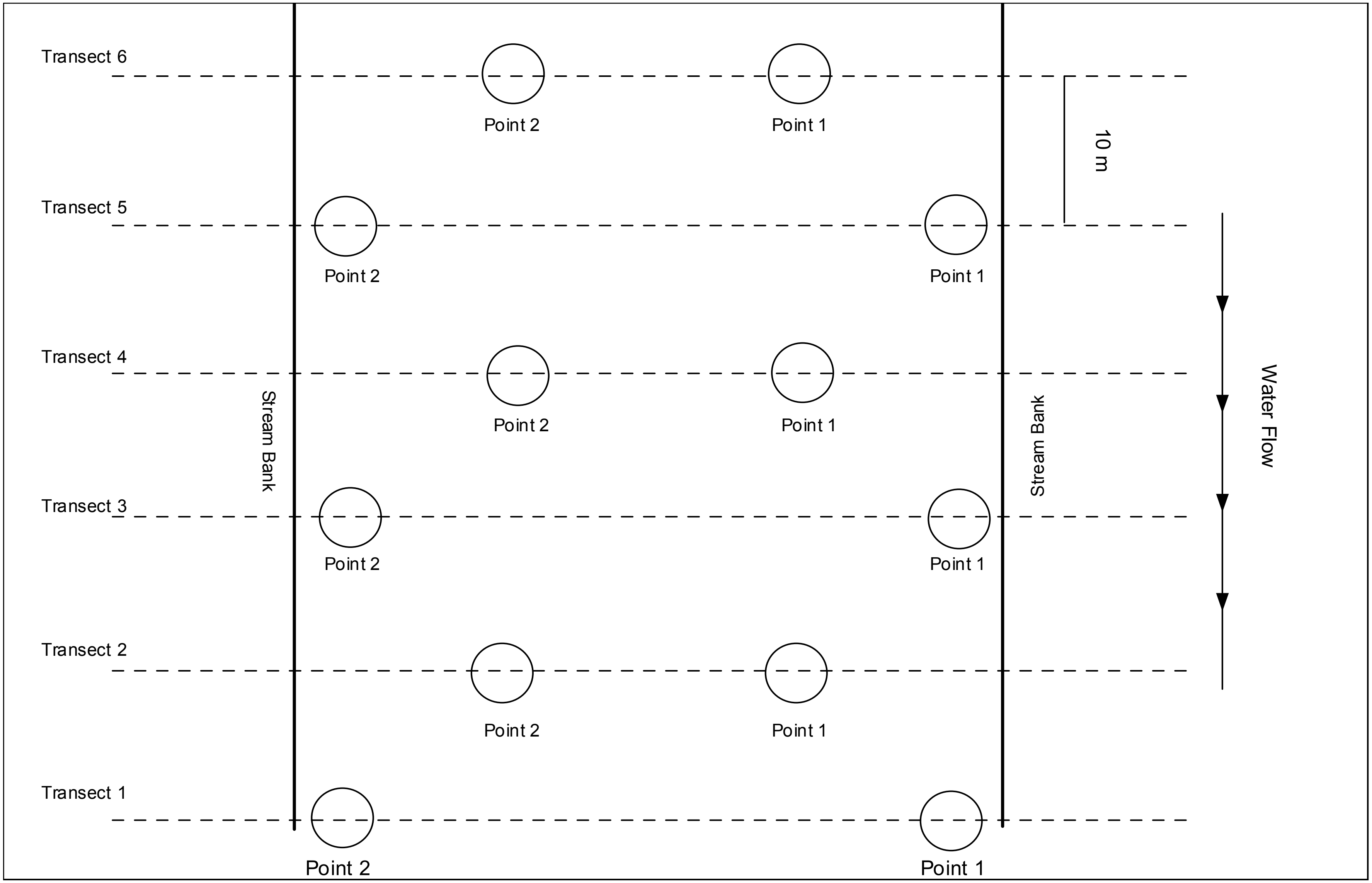

Figure 5. Transect and point layout for each sample reach during the electrofishing survey, Cedar Creek, WA, 2002.

Table 1. Habitat characteristics measured at each electrofishing sample reach Cedar Creek, Washington, 2002.

Habitat Characteristic	Sample Reach	Transect	Point
Water Temperature (C^o)	X		
pH	X		
Dissolved Oxygen (%)	X		
Dissolved Oxygen (mg/L)	X		
Conductivity (μS/cm)	X		
Specific Conductivity (μS/cm)	X		
Gradient	X		
GPS Waypoint	X		
Wetted Width (m)		X	
Canopy Cover (%)		X	
Water Depth (ft)			X
Water Velocity (ft/s)			X
Percent Substrate*			X
Fine Substrate Depth (cm)			X
Gravel Embeddedness			X

* Fines (<9 mm), small gravel (9-16 mm), large gravel (17-64 mm), cobble (65-256 mm), boulder (257-4096), and bedrock (>4096 mm)

Emigrants

Emigrating lampreys were captured by a floating rotary screw trap (constructed by E. G. Solutions, Inc., Corvallis, OR) with a five-foot diameter cone placed in a pool upstream of Grist Mill falls in Cedar Creek. The trap operated from March 25, 2002 to December 13, 2002, when it was removed due to high flow. When fishing, the trap was checked daily during high flows and approximately every other day during low flow conditions. An experimental battery-powered motor was attached to the trap during late summer low flows in attempt to rotate the cone during low flows. The screw trap was replaced with a new model on November 7.

Trap efficiency was estimated through mark/recapture (Thedinga et al. 1994). Captured lampreys were removed from the trap livebox, anesthetized, identified to species, and measured for length and weight. Half of the daily total captured ammocoetes were marked using red, yellow, and green elastomer injections in the left or right and anterior or posterior areas of the body. Half of captured macropthalmia and western brook adults were marked with fin clips removed from the upper or lower caudal. 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 50 mm and all wounded lamprey were released downstream without a mark.

Trap retention was estimated through mark/recapture. 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 released approximately 50 m downstream of the trap. Additionally, nine trap retention trials were conducted using fish collected at the mouth of Cedar Creek with an electrofisher. This capture method was used to conduct trials using 30 fish during periods when fish were not captured in the screw trap.

To determine short-term survival and mark retention, larval lampreys were captured from the mouth of Cedar Creek using an electrofisher, anesthetized, identified to species, measured for length and weight, and marked using colored elastomer injections. Captured lampreys were held in an aerated cooler for two trials with durations of 24 and 72 hours. Mortalities were noted and fish were returned to the mouth of Cedar Creek.

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 a 92 cm length of 30 cm diameter PVC pipe with funnels on each end. Funnel openings measured 5 cm in diameter (Figure 6). Four adult pot traps were deployed downstream from the falls near the base of the ladder, five at the mouth of Cedar Creek, and two pots 100 m upstream from the rotary screw trap. An additional pot was placed inside the adult ladder.

Figure 6. Photo of lamprey pot trap used to capture adult Pacific lamprey in Cedar Creek, WA, 2002.

Captured lampreys were anesthetized, measured for length and weight, and marked with a PIT tag and a dorsal fin clip. Adults were marked with an additional silver nitrate brand beginning in September, 2002. Girth measurements were recorded beginning in September in the anterior region just behind the last gill opening, in the medial region between the dorsal fins, and in the posterior region between the dorsal insertion and the caudal. 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. Based on 2000 and 2001 nest density (Figure 7), the areas surveyed in 2002 were divided into six index reaches in high nest density areas and four non-index reaches in low or zero nest density areas. Index reaches were surveyed once per week and non-index reaches were surveyed once per month. 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 (pebble counts), and flow. GPS waypoints were collected at each nest when possible. Nests were marked with weighted flagging to determine nest longevity (the period of time that the nest remained identifiable in the creek). As western brook nests look similar to animal hoof prints, only those nests containing adults were counted.

Stream gradient was measured using a Topcon lazar level in four index reaches and one non-index reach at the end of the spawning period. Habitat units were designated as pools, riffles, runs (Hawkins et al. 1993), and riffle/runs (several small riffles and adjoining runs too small to measure as individual units). Gradients were averaged over the habitat units.

Variance between observers in substrate measurement technique was tested in 2002. In a section of Cedar Creek containing Pacific lamprey spawning habitat, one observer randomly selected and measured 30 pebbles. A second observer measured the same 30 pebbles. This experiment was conducted three times using new pebbles and variance was tested using a t-test ($\alpha = 0.05$). To test for variance within each observer's substrate measurements, each observer randomly selected and measured 30 pebbles three times and this was analyzed using an Analysis of Variance ($\alpha = 0.05$).

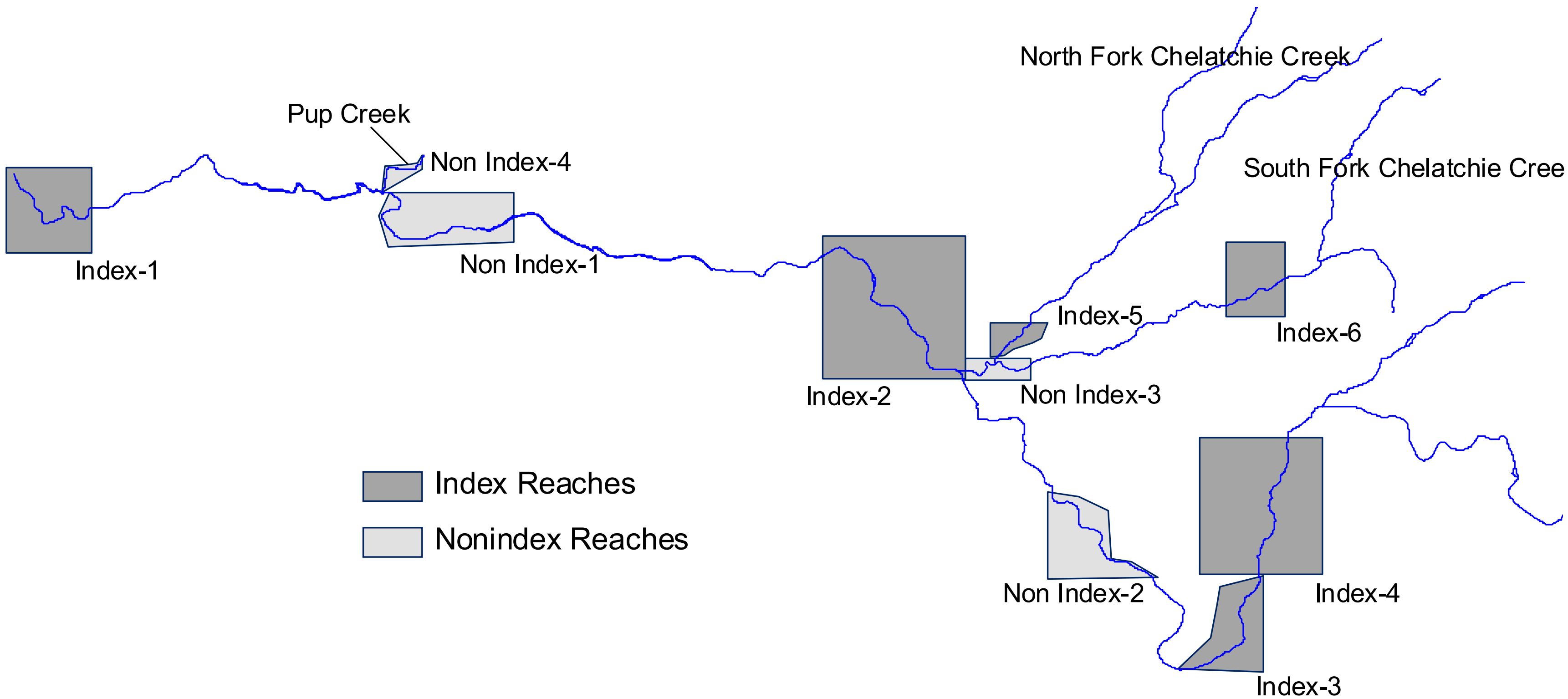

Figure 7. Areas routinely surveyed for Pacific lamprey and western brook lamprey nests. Areas in between were surveyed once during the spawning season, Cedar Creek, WA, 2002.

Results

Lamprey Density

Larval Pacific and western brook lampreys were identified during the 2002 electrofishing survey. Western brook lampreys were identified only in the Chelatchie Creeks sample reaches. Pacific lampreys were identified in the Chelatchie Creeks and mainstem sample reaches. Species identification followed the caudal pigmentation protocol (Richards et al. 1982).

Seven out of nine reaches sampled contained lamprey (Figure 8). Thirty-two percent of the points sampled had at least one lamprey and the mean number of lamprey in these points was three. The maximum number of lamprey captured at a single point was twelve. Estimated population, probability of capture, standard error, and density were not calculated because too few fish were captured. Eighty-six percent of the lampreys were removed within the first two passes. A total of 74 Pacific ammocoetes and three transformers were collected. Two transformers were in stages of early eye development and one transformer was in full eye development with a partially developed mouth. Seven western brook ammocoetes and one transformer in early eye development were collected.

Maximum, mean, and minimum lengths of ammocoetes collected were 130, 76, and 30 mm, respectively. Maximum, mean, and minimum weights of ammocoetes collected were 4.8, 1.03, and 0.1 g, respectively. The mean length and weight of transformers captured in early eye development were 127 mm, and 4.1 g. The transformer captured in full eye development was 122 mm, and weighed 3.1 g.

Substrate types most often present in sample points containing lamprey were large gravel (17-64 mm), cobble (65-256 mm), and fines (<9 mm). Fine substrate depth was measured when fines were present in the quadrat and ranged from 4.5 – 27 cm. Habitat data collected within each sample reach is summarized in Table 2.

Sample reaches 2002-5 (located in Chelatchie Creek) and 2002-9 (the upper most sample reach), and reaches 2001-6 and 2001-7 (located near the "boot" of upper Cedar Creek) were resurveyed for lamprey presence/absence. Of these reaches, 2001-7 and 2001-6 contained lamprey, and 2002-5 and 2002-9 did not. In 2001-6, stream morphology had been altered by beavers and was backwatered and silted in. A total of 29 ammocoetes were captured from three points in this reach.

During the electrofishing efficiency study, roughly half (56%) of the larval lampreys were removed from the net pen within five passes lasting 90 seconds each. The substrate was turned-over and the pen was shocked six more times to remove the remaining lamprey. One larval lamprey was removed from the control pen.

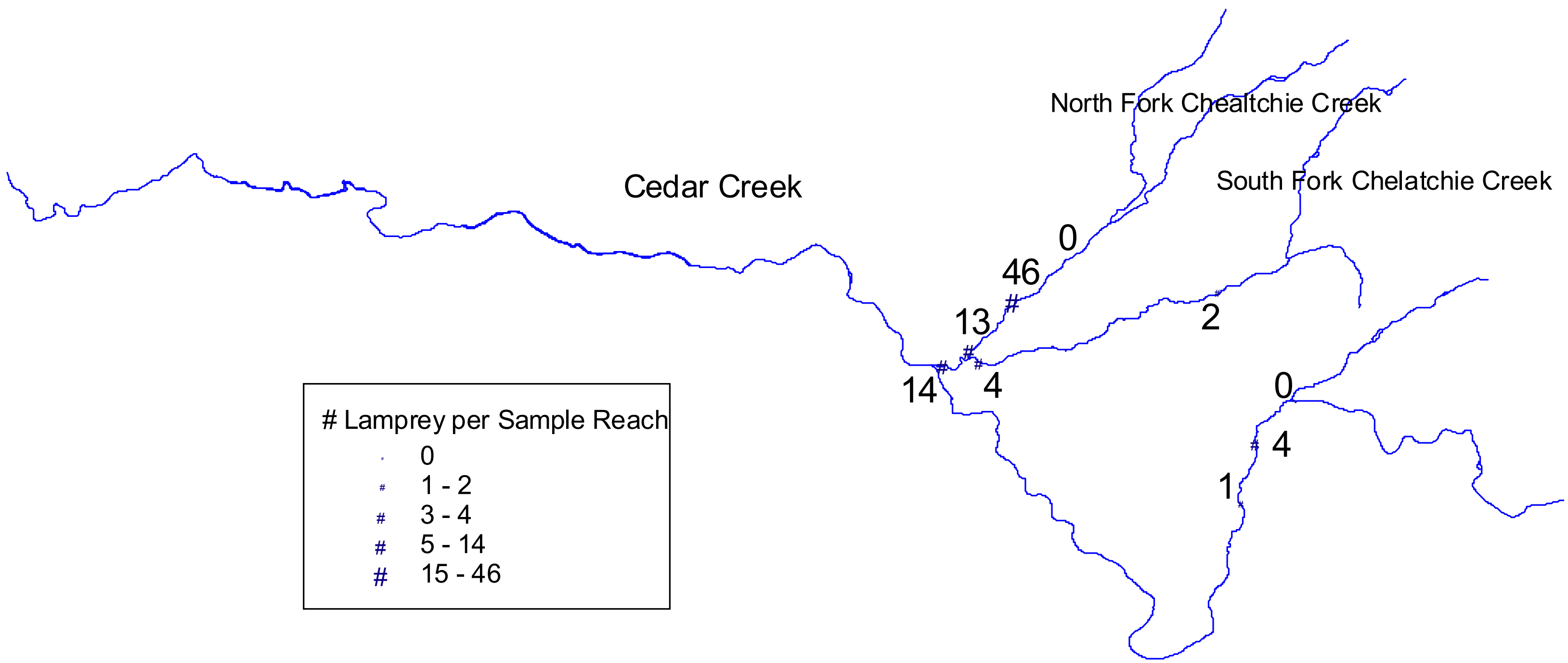

Figure 8. Number of larval lamprey captured at each sample reach during the electrofishing survey, Cedar Creek, WA, 2002. Point size is relative to the number of lamprey captured.

Table 2. Minimum, mean, and maximum values of habitat characteristics measured at each electrofishing sample reach, Cedar Creek Washington, 2002.

Sample Reach	Min	Mean	Max
Water Temperature (°C)	9.6	13.2	17.3
pH	7.7	7.8	8.2
Dissolved Oxygen (%)	68.9	83	98
Dissolved Oxygen (mg/L)	7.1	8.7	10.5
Conductivity (μS/cm)	28.1	52.3	87
Specific Conductivity (μS/cm)	36	68.6	107.3
Transect	Min	Mean	Max
Wetted Width (m)	2.3	4.7	8.4
Canopy Cover (%)	7.5	71.8	100
Point	Min	Mean	Max
Water Depth (ft)	0.1	2	0.6
Water Velocity (ft/s)	0.1	0.2	1.5
Fine Substrate Depth (cm)*	4.5	11	27
Gravel Embeddedness*	1	-	5

* Fine substrate depth was measured when fines were present in quadrat

♦ Gravel embeddedness rating: 5 = less than 5% covered with silt; 4 = 5-25%; 3 = 25-50%; 2 = 50-75%; 1 = greater than 75%

Emigrants

The floating rotary screw trap fished for approximately 258 days during sampling year 2002. A total of 241 Pacific lamprey ammocoetes, 76 Pacific lamprey macropthalmia, 1 western brook adult, and 1 western brook ammocoete were captured (Table 3). Twenty-four Pacific lamprey ammocoetes, six macropthalmia, and one western brook adult were subsequently recaptured. Average trap efficiencies were estimated to be 14% for ammocoetes and 10% for macropthalmia. Population estimates were not calculated for 2002.

Ammocoetes were captured during all months the trap was fishing except August when flow in Cedar Creek was low (Figure 9). Peak ammocoete captures occurred in March-April, June, and November. A spike in ammocoete captures occurred in early October. Ammocoete movement during March-April, and November was associated with discharge and movement during May-July, and October was not. Recaptures occurred during all months ammocoetes were captured.

Peaks in macropthalmia movement were more isolated, occurring in May-June, and November-December, with a small peak in October. Macropthalmia movement was associated with discharge (Figure 10). Recaptures occurred only during June, November, and December.

The two survival/mark-retention trials conducted showed no mortality due to the marking procedure. Additionally, 100% of the marks were clearly visible with no indication of tissue irritation. The color of elastomer dye and location on the fish had no effect on the visibility of the mark.

Trap retention success was low with our older model screw trap, and averaged 16% for ammocoetes and 33% for macropthalmia over a period of 24 hours in a range of flow and debris conditions. Retention studies continued with the new trap launched on November 7, 2002. During high flow conditions when the cone and the debris wheel were spinning, retention success averaged 66% for ammocoetes and 71% for macropthalmia.

Table 3. Data collected from juvenile lampreys captured in the rotary screw trap at the Grist Mill, Cedar Creek Washington, in 2002.

	Ammocoete*	**Macropthalmia**	**Adult Western Brook**
Minimum Length (mm)	19	96	-
Average Length (mm)	89.7	130.4	121
Maximum Length (mm)	137	162	-
Minimum Weight (g)	0.1	1.3	-
Average Weight (g)	1.36	3.2	3.9
Maximum Weight (g)	4.2	5.5	-
Total Captured	241	76	1
Trap Efficiency Marks	169	62	1
Number Recaptured	24	6	1
Average Trap Efficiency (%)	14	10	-

*includes one western brook lamprey ammocoete

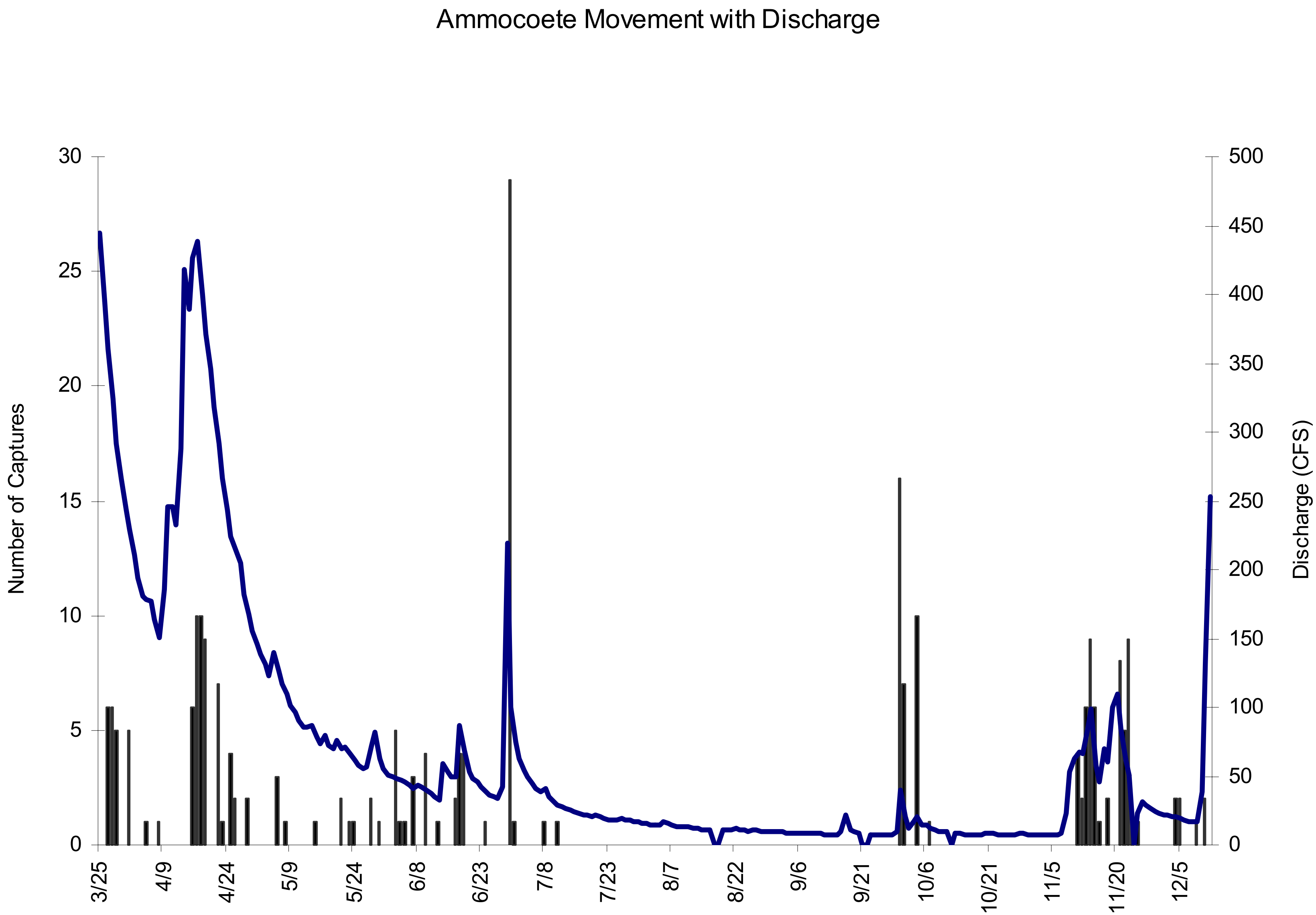

Figure 9. Ammocoete captures and discharge, Cedar Creek, WA, 2002.

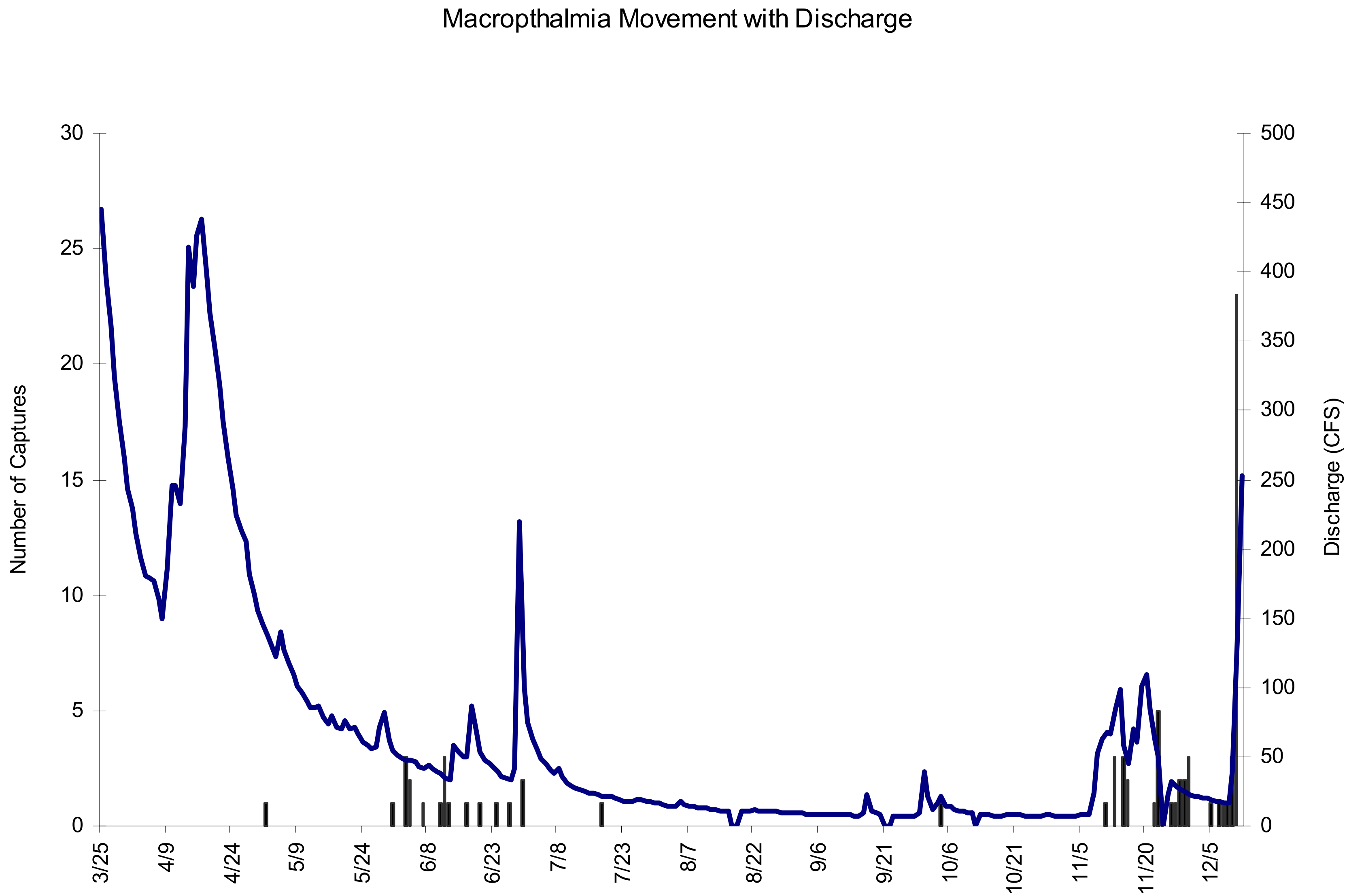

Figure 10. Macropthalmia captures and discharge, Cedar Creek, WA, 2002.

Adult Pacific Lampreys

A total of 61 adult Pacific lampreys were captured in Cedar Creek in 2002 (Figure 11). Adults were captured between May 14, 2002 and November 19, 2002. Lamprey pot traps in various locations on the creek captured 43 adults. One adult Pacific lamprey was captured in the ladder and 18 were captured in a pot placed inside the ladder. All adults captured were in pre-spawning condition. Five of these fish were later recaptured in the lamprey pots. Average “time at large” was 20 days, with a minimum of 7 days and a maximum of 56 days. Capture efficiency with the adult lamprey pots is 8% and a rough population estimate was calculated to be 700 Pacific lamprey adults.

Adults moved in two pulses, one during late spring-early summer and the other in late summer-early fall. Captures occurred independent of peak discharge events (Figure 11). Temperature and day length were not associated with movement, but a longer time series is needed to be certain.

Maximum, mean, and minimum Pacific lamprey adult lengths were 633, 543, and 422 mm, respectively. Maximum, mean, and minimum Pacific lamprey adult weights were 430, 284, and 139 g, respectively. The length to weight relationship can be described by $y = 380.08e^{0.0012x}$ with $R^2 = 0.6473$. Girth measurements were recorded from 24 fish. Average anterior girth was 97 mm, average medial girth was 94 mm, and average posterior girth was 78 mm respectively.

Spawning

Fifty-four spawning ground surveys were conducted during the spawning period (April 25, 2002 through July 16, 2002). A total of 124 Pacific lamprey nests and 13 western brook lamprey nests were identified and GPSed. Temperatures during this time ranged between 10 and 22 °C.

The two species of lamprey in Cedar Creek use different parts of the drainage to spawn (Figure 12). Pacific lamprey nests were most abundant downstream of the Chelatchie forks and upstream of the Cedar Creek “boot”. Western brook lamprey nests were most abundant on the Chelatchie forks, but infrequently occurred on the Pup Creek tributary and on mainstem Cedar Creek. On three occasions, western brook lampreys were found excavating in previously sampled Pacific lamprey nests in mainstem survey reaches.

Habitat parameters were recorded for Pacific and western brook lamprey nests (Table 4). 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. Pacific lamprey and western brook lamprey nests were concentrated in low gradient habitat units breaking into higher gradient units throughout the study area (Figure 13).

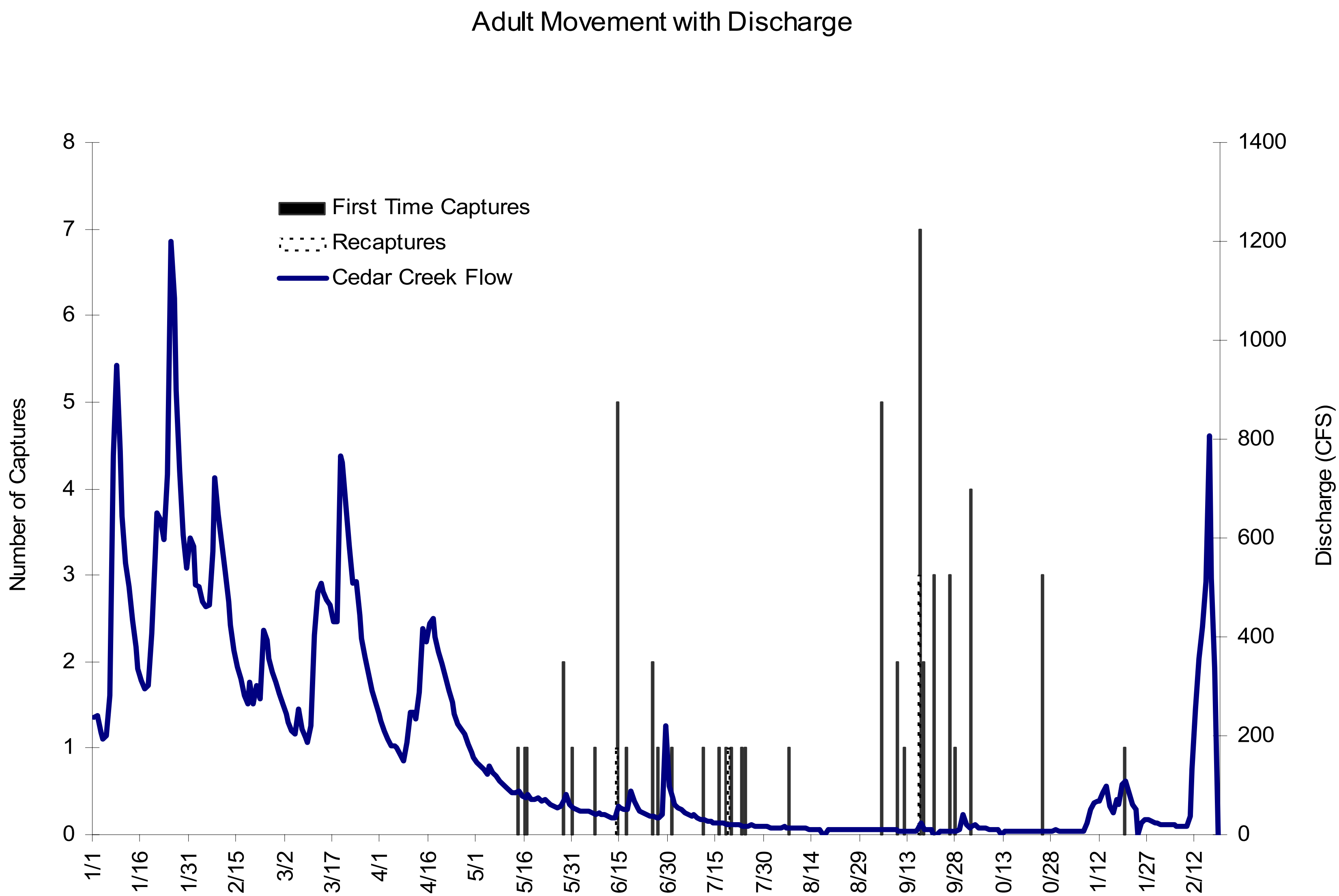

Figure 11. Adult Pacific lamprey captures and discharge, Cedar Creek, WA, 2002.

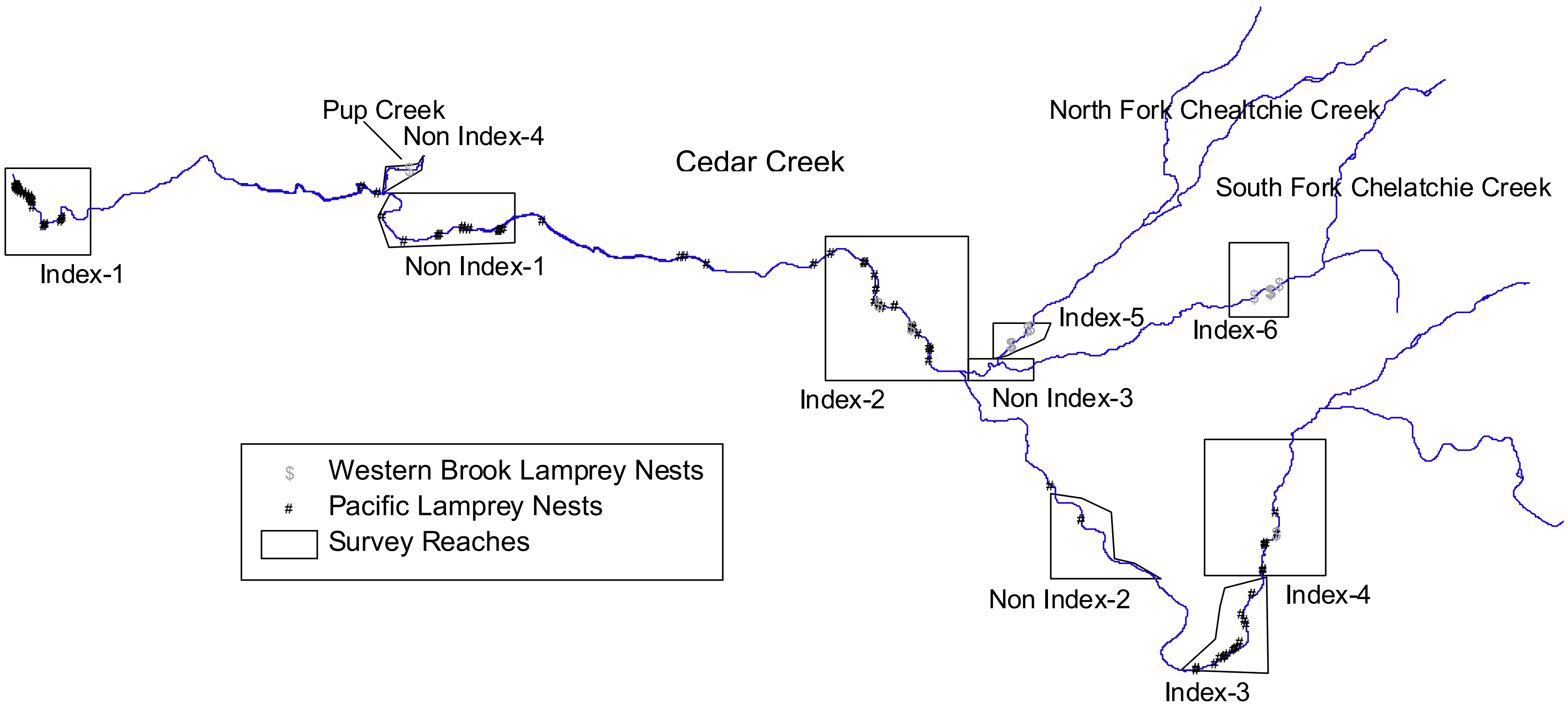

Figure 12. Location of Pacific lamprey and western brook lamprey nests, Cedar Creek, WA, 2002.

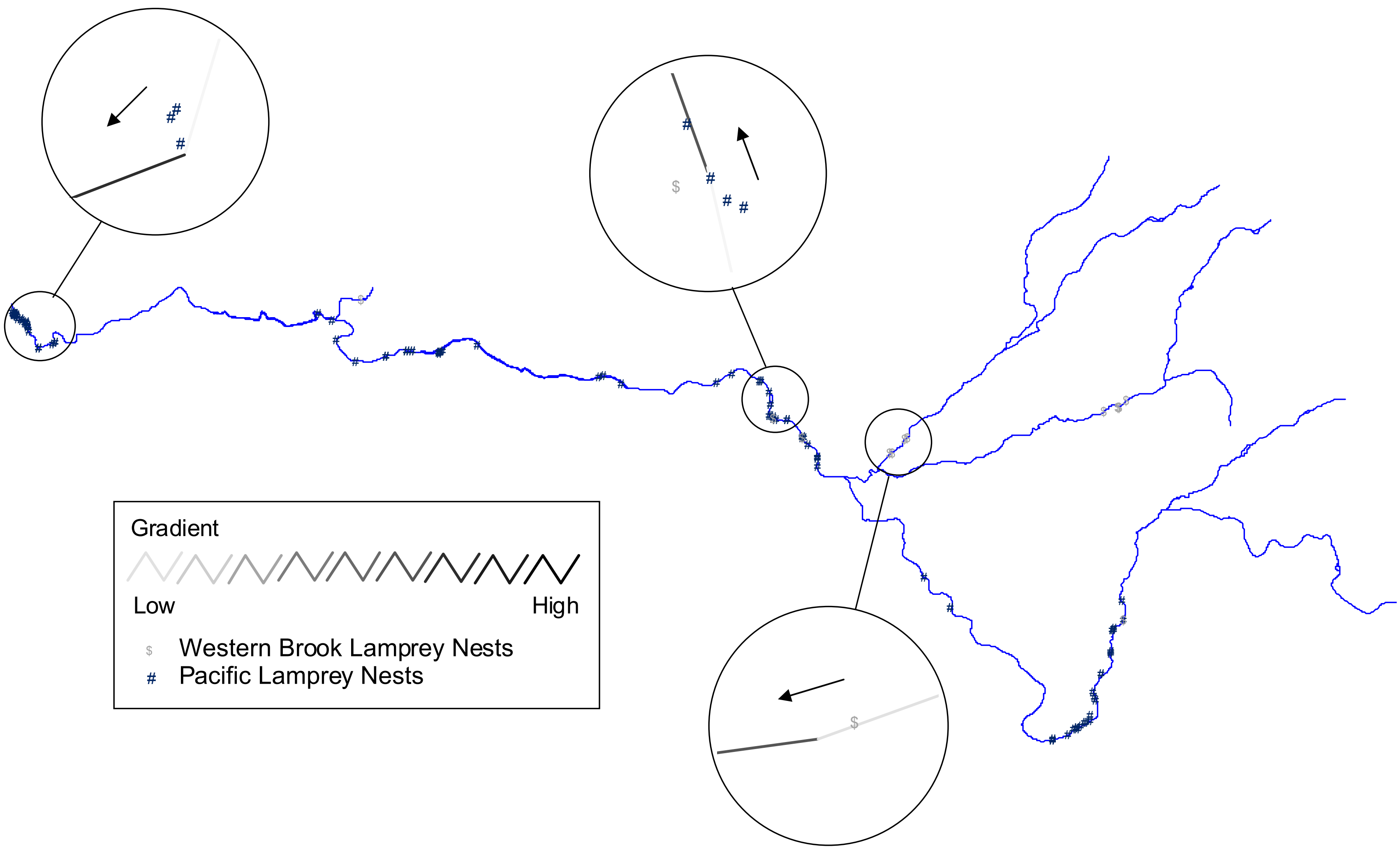

Figure 13. Location of Pacific lamprey and western brook lamprey nests with gradient. Circles show areas magnified, Cedar Creek, WA, 2002.

Pacific lamprey spawning activity was observed twice during the spawning period in May. A single female was observed constructing a nest and digging in areas around the nest near mouth of Cedar Creek. Another event was witnessed with two males and one female constructing nests and actively spawning, also near the mouth of Cedar Creek. Both sexes participated in nest construction. The female spawned with one male in five sessions with a period of rest and further construction following each. Photos of this spawning event and a detailed description of spawning behavior observed can be found on the CRFPO webpage (http://columbiariver.fws.gov).

Two Pacific lamprey carcasses were observed during spawning ground surveys. Identifiable as a female by eggs remaining in the body cavity, one carcass was found in heavily degraded pieces. One male carcass was found intact in a lateral scour pool 1 m downstream from a nest. Both carcasses were found on Index Reach-1 at the mouth of Cedar Creek.

Western brook spawning activity was observed on several occasions during the spawning period. A minimum of one and a maximum of seven lampreys were observed at each nest. The lampreys worked together to move pebbles outside of the nest, each sucking on to a spot on larger rocks, collectively moving them out of the way. The western brook lampreys were not easily scared away and close observation of individuals with an aquascope was possible.

Observers did not vary in substrate measurement technique. The variance between observers was not significant ($P = 0.4079$). The variance within each observer also was not significant ($P = 0.1493$, $P = 0.0599$).

Discussion

Pacific and western book lampreys are active in Cedar Creek through much of the year. Adult Pacific lampreys enter the creek between May and November. It is uncertain whether early migrants immediately spawn or if they overwinter as do the late migrants. Both species begin to move during the spawning period, which lasts from April to June. Larval lampreys are distributed throughout much of the creek, with greatest densities in habitats having slow water velocity, low gradient, and sandy sediments. Ammocoete movement, as observed through screw trap operations, occurs throughout the year and is associated with both discharge patterns and transformation. Ammocoetes transform during August and September. Macropthalmia move out with high water during late fall-winter and also in late spring. Macropthalmia movement during the summer occurs regardless of flow.

An electrofisher specifically designed for removing larval lampreys was used in this study to determine larval presence/absence and density at both the reach and subreach (1 m^2 sample point) scales. The ability to effectively categorize a sample point as one that “contains larval lampreys” is dependent upon how effective our sampling gear is at capturing larval lampreys. Our data suggests that if lampreys are present within a sample point, we are likely to detect it within the first two passes, and therefore our "sample point" classifications are probably very accurate. The ability to effectively categorize a reach as one that "contains larval lamprey" is dependent upon how effective the sampling protocol is at capturing the variability of the habitat in that reach. Half of the sites resampled for larval presence/absence in 2002 contained lampreys when surveys 1-2 years previous had determined that larval lampreys were absent. This discrepancy could indicate that our sample design is unable to accurately determine presence/absence at the reach level under very low larval densities or patchy habitat. However, one of these "false negatives" had undergone a complete habitat modification as a result of a beaver impoundment, which significantly modified the habitat in favor of supporting lampreys. Therefore, it is important to recognize that larval lamprey distribution may shift over time with changes in habitat features. If this sample design is used, we recommend verifying "absence" data by sampling supplementary points within the reach. Additionally, our data show, through poor depletions and gear efficiency estimates, that calculating accurate density estimates at the sample point scale is difficult and doing so at the reach scale is largely impossible.

Larval lamprey presence at any particular sample point was determined by habitat variables at the reach and subreach scales. The three reaches sampled on Cedar Creek in 2002 did not have habitat conducive to supporting high densities of lamprey and therefore, few were collected. The habitat on Chelatchie Creek (north and south forks) was appropriate and all but one site supported lampreys. This relationship between microhabitat and lamprey distribution was observed in previous years (Stone et al. 2001, Stone et al. 2002) as well as in other systems (Close 2001).

Ammocoete movement was associated with discharge but not transformation. Ammocoetes were captured during all months the trap was fishing except August when discharge in Cedar Creek was at a lowpoint. From March through July and November through December, ammocoetes moved during high discharge periods that were likely scouring events. However, ammocoete movement in September and October was not related to scouring events. In the past, larger ammocoetes moved during these periods of decreasing discharge, which also coincided with peak macropthalmia migration (Stone et al. 2002). It is likely that the larger ammocoetes are starting their transformation further downstream. Beamish and Levings (1991) also documented an increase in the abundance of larger ammocoetes moving during macropthalmia migration. This length-relationship was not significant in 2002 and movement did not coincide with peak macropthalmia movement. In previous sample years (Stone et al. 2002), ammocoetes were only recaptured during these periods, which indicated active migration. In 2002, recaptures occurred during all months ammocoetes were captured.

Macropthalmia moved in late spring and late fall-winter with changes in discharge. Beamish and Levings (1991) observed that macropthalmia emigration was almost always associated with high discharge events. In Cedar Creek, peak movement occurred in June when discharge was decreasing and in November-December when discharge was increasing. This also was the period when marked macropthalmia were recaptured. This relationship was observed in other sample years (Stone et al. 2001, Stone et al. 2002).

Population estimates for emigrants were not calculated because too few fish were recaptured within each marking period. Through a trap retention pilot study, we have identified that a small portion of fish that make it into the livebox are retained. Once the trap retention is improved, our catches will increase and this will afford us more fish with which to work. However, this will not improve our trap efficiencies (assuming that marked fish escape at a rate that is equal to unmarked fish). Though our overall trap efficiencies are relatively high (14% for ammocoetes and 10% for macropthalmia), recaptures are very sporadic and the efficiencies over each marking period are highly variable. Additionally, we might not be meeting a few of the assumptions of a mark/recapture experiment. Though we have tested mark retention, mark recognition, and survival after marking, we have not tested whether marked fish are as vulnerable to being captured as unmarked fish, and whether marked fish become randomly mixed with unmarked fish. Likely, these assumptions have not been violated and they will not be tested in the field. However, one assumption that does pose a problem is that the fish are actively leaving the system. Data in the past (Stone et al. 2002) suggest that ammocoetes do not actively move until they reach a specific size, and therefore any population estimates based on recaptures due to scour events would be misleading. For ammocoetes, population estimates should be limited to those times when larger ammocoetes are emigrating at the same time as macropthalmia.

Adult Pacific lamprey movement was detected through capture in the adult ladder and pot traps. Movement is divided into an early pulse of spawners (May-July) and a late pulse of upstream migrants (September-November) and this pattern remains consistent among years (Stone et al. 2001, Stone et al. 2002). It is possible that these pulses do not reflect timing of movement and instead reflect differences in trap efficiency over time. Pacific lampreys have been observed scaling the falls that border the adult ladder (Tom Burns, WDFW, personal communication). It is likely that under certain flows Pacific lampreys are drawn more towards the falls than the adult ladder. Under these flows, lamprey may bypass our traps and movement would not be detected.

Pacific and western brook lampreys spawned in different sections of the Cedar Creek drainage. Of the areas surveyed (Cedar, Pup, and Chelatchie creeks), Pacific lampreys were observed spawning only within mainstem Cedar Creek. Western brook spawning was concentrated in the Chelatchie creeks and Pup Creek tributaries, and rarely was observed in Cedar Creek. This separation is due to habitat preferences. Pacific lampreys prefer to spawn in larger substrate and faster water velocities than western brook lampreys. There were three instances when one western brook female was observed excavating in a Pacific lamprey nest. In this situation, the Pacific lampreys removed much of the large substrate to create the nest, leaving the preferred spawning substrate of the western brooks. This behavior also was observed in previous years (Stone et al. 2002) as well as in Gibbons Creek (Scott Barndt, U. S. Forest Service, Bozeman MT, personal communication.).

The clear segregation between Pacific and western brook spawning preferences, when compared with data from electrofishing surveys, indicate a possible discrepancy in species identification. Pacific lampreys did not spawn in the Chelatchie creeks during 2000, 2001, and 2002, and there have been no reports from Washington Department of Fish and Wildlife that indicate that they spawned there previous to 2000. However, larval Pacific lampreys were found in greater numbers than larval western brook lampreys during the electrofishing surveys conducted on Chelatchie Creek. Though upstream migration of larvae is possible, it is very likely due to their poor swimming performance. The identification protocol used (Richards et al. 1982) is based on caudal pigmentation and is in need of reevaluation. Studies are currently being conducted by USGS Biological Research Division at Cook, Washington to quantify the level of misidentification. Additional field studies need to examine if caudal pigmentation is affected by habitat.

Modifications will be made during the 2003 sampling year. The sample design will be adjusted to allow us to better meet the objectives of the study. Modifications also will allow us to provide more technical information to other agencies and the public.

The sample design for assessing larval abundance and habitat use will be modified. One problem that we encountered with the stratified systematic sampling approach was that too few (approximately 30% in 2000, 12% in 2001, and 32% in 2002) of the points sampled contained lampreys. Multivariate statistics rely on "successes" to model relationships between lamprey occurrence/density (if possible) and habitat. To increase the number of "successes", we will add an adaptive cluster sampling technique to our current methods. If ammocoetes are collected from a sample point, additional points adjacent to the original point will be sampled. If ammocoetes are not collected from the sample point, no further sampling will occur adjacent to the original point. This cluster technique will allow us to increase the number of "successful" points sampled, improving the significance and power of our habitat use models (logistic and categorical regression).

Electrofishing gear efficiency will be evaluated. We plan to expand the 2002 pilot study and evaluate the electrofishing efficiency over varying substrate types, lamprey densities, and flow conditions. This will help us better assess the accuracy of density estimates based on depletion electrofishing, the number of passes needed to make these estimates, and the accuracy of our presence/absence determinations based on one and two pass electrofishing.

Several modifications will be made to our emigrant sampling protocol. We will motorize the screw trap with an improved design that will operate independently for a longer duration to allow us to fish the trap during the summer. We will begin testing mark retention/survival with macropthalmia using dyes of varied concentration and exposure duration. Dyes are likely less intrusive than removing portions of the caudal fin. Bismark Brown (Ewing et al. 1990) has been demonstrated to be successful in marking juvenile salmonids and may be used successfully with lampreys. Retention studies will continue over the next sampling season under various environmental and mechanical conditions.

More effort will be expended on capturing adult Pacific lampreys and monitoring their movements. Individual pots will be placed inside the water uptake for the Grist Mill where employees have observed Pacific lampreys congregating. Additional pots will be placed at bridges crossing Cedar and Chelatchie creeks. Pots will be placed 100 m downstream of our release site to determine if marked fish are moving downstream. In addition, an experimental floating capture device will be constructed and placed at the Grist Mill falls. This device consists of a board with a notch cut out of the top and a collection chamber on the backside. Water will modestly flow down the face of the board as an attractant. To better understand their movement pattern, 20 Pacific lampreys will be fitted with radio-telemetry tags and their movements will be recorded with both fixed station and mobile receivers during 2003.

Spawning ground surveys will be expanded to include more area and will be conducted more frequently. Reaches will be expanded based on 2002 data and dusk surveys will take place twice a month during the peak of spawning. Portions of selected reaches will be surveyed daily, if possible, to better understand the dynamics at individual nests. Surveyors will carry a mobile radio-tracking unit to determine where marked fish are holding and/or spawning. They also will carry a digital underwater camera to record the spawning behavior of both species. Gradient surveys will continue after the spawning season in reaches not surveyed in 2002. Temperature loggers will be placed in more locations to evaluate if a relationship exists between cumulative nest density and water temperature. A rigorous observer variance study will be conducted to evaluate individual's difference in nest identification.

Sampling efforts on Cedar Creek will continue for 2003 and an annual report, similar to this, will be delivered during the early months of 2004.

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