Evaluate Habitat Use and Population Dynamics of Lampreys in Cedar Creek

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Annual Report for 2001

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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)* 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 second year of this project. Adult (n = 24), metamorphosed (n = 247), transforming (n =4), and ammocoete (n = 387) stages from both species were examined in 2001. Lamprey were captured using adult fish ladders, lamprey pots, rotary screw traps, and lamprey electrofishers. Twenty-nine spawning ground surveys were conducted. Nine strategic point-specific habitat surveys were performed to assess habitat requirements of juvenile lamprey.

Introduction

Three lamprey species (*Lampetra tridentata*, *L. ayresi*, and *L. richardsoni*) include the Columbia River Basin (CRB) within their geographic ranges (Kan 1975). Pacific lampreys (*L. tridentata*) in the CRB have declined to only a remnant of their pre-1940s populations (Close et al. 1995) and the status of the river lamprey (*L. ayresi*) and the western brook lamprey (*L. richardsoni*) 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 lamprey success 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 mathematical models to predict future trends.

The success of rehabilitating Pacific lamprey in the CRB depends on whether Pacific lamprey exhibit homing behavior. A fish is thought to exhibit homing behavior when it returns to an area formerly occupied instead of going to other equally probable areas (Gerking 1959). McCleave (1967) recognized three types of homing: 1. Natal homing (adults returning to the stream of birth); 2. repeat homing (adults returning to the same stream to spawn each year); and 3. In-season homing (adults returning to the same stream after displacement within the breeding season). Sea lamprey (*Petromyzon marinus*) do not exhibit natal homing behavior (Bergstedt and Seeyle 1995) but instead respond to a bile acid-based larval pheromone released by conspecific larval lamprey (Bjerselius et al. 2000). Radio telemetry studies performed in the CRB indicate that Pacific lamprey may have low in-season homing fidelity. More extensive studies are needed to address whether Pacific lamprey exhibit natal homing behavior.

The United States Fish and Wildlife Service (USFWS) at the Columbia River Fisheries Program Office has been collecting quantitative baseline data for Pacific and western brook lamprey on Cedar Creek, Washington since 2000. Data collected during 2000 are summarized in Stone et al. 2001. The following annual report summarizes results of research and analytical activities conducted during 2001 and makes comparisons to data collected during 2000. The objectives of this research are to: 1. Estimate abundance, examine biological characteristics, and determine migration timing of adult Pacific lamprey; 2. Determine larval lamprey distribution, habitat use, and examine biological characteristics; 3. Determine emigration timing and estimate the abundance of recently metamorphosed lamprey; 4. Evaluate lamprey homing fidelity, survival rates, and ocean residence; 5. Verify diagnostic characteristics of larval lampreys and evaluate the effects of Passive Integrated Transponder (PIT) tags; and 6. Evaluate spawning habitat requirements of adult lamprey.

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 lamprey 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). It is non-parasitic and completes its 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 Columbia River mile 87. The Cedar Creek drainage includes 89.3 km^2 of 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 lamprey (Dan Rawding, Washington Department of Fish and Wildlife, Vancouver, WA, personal communication). Access to Cedar Creek is

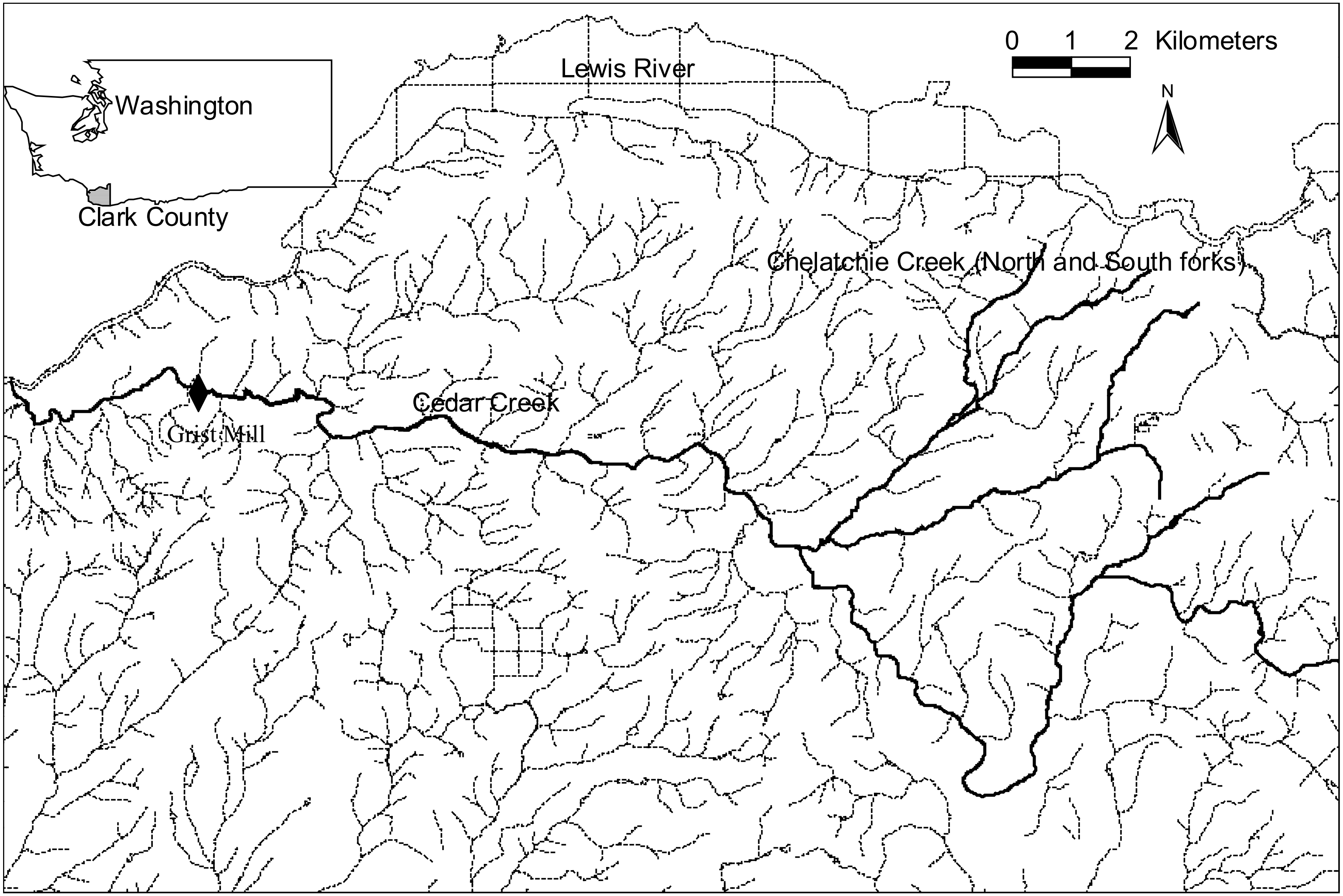

Figure 1. Cedar Creek in Clark County, Washington with diamond depicting the location of the Grist Mill.

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). In addition, USFWS records temperature at three locations along Cedar Creek, including the Grist Mill (Figure 3) and at another five locations in the four tributaries. Rainfall is measured by USFWS at the Washington Department of Fish and Wildlife (WDFW) adult ladder, which is situated approximately 4 km upstream of the mouth (Figure 4).

Methods

Lamprey Density

The spatial distribution and habitat association of larval lamprey in Cedar Creek was assessed during 2001 using a stratified systematic point-sampling technique. Nine sample reaches, situated 1000 m apart, were examined.

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 section, transect, and sample point (Table 1).

Larval lamprey 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. Lamprey measuring $\leq$30 mm could not be effectively depleted, therefore they were enumerated but not used in any analyses. Captured lamprey were anesthetized with MS-222 (Summerfeldt and Smith 1990), identified to species, and measured for length and weight.

Multivariate statistics were used to associate lamprey density with habitat characteristics using the data collected during 2000 and 2001. Independent variables were divided into reach scale measurements (temperature, pH, dissolved oxygen, conductivity, and gradient) and sub-reach scale measurements (depth, water velocity, habitat type, wetted width, canopy, quadrat location, and substrate). Backward elimination and stepwise selection logistical regressions were computed to model lamprey presence/absence (0, >0) (SAS

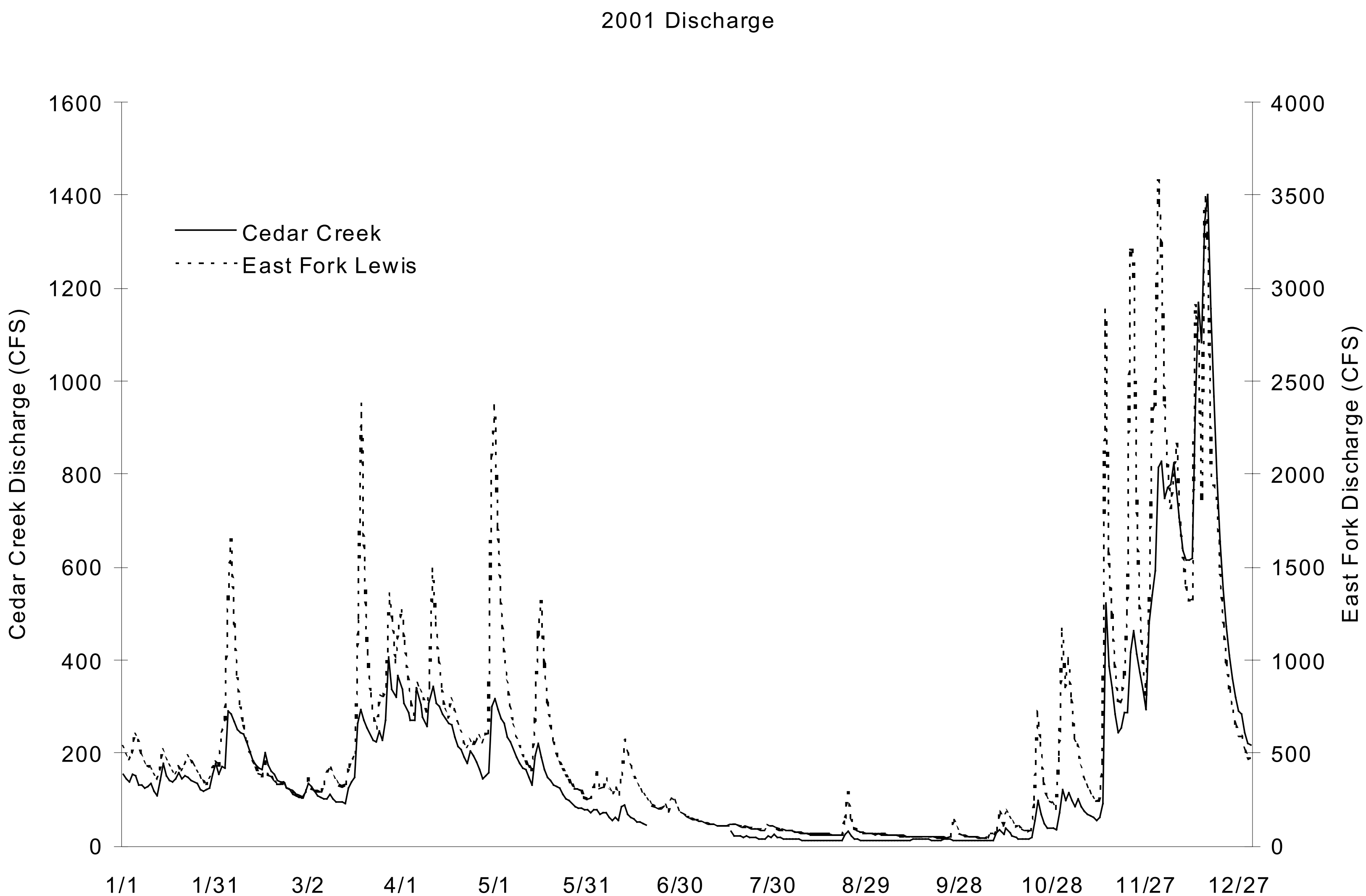

Figure 2. Discharge for East Fork Lewis River, Heisson Station (USGS) and Cedar Creek (Department of Ecology), 2001.

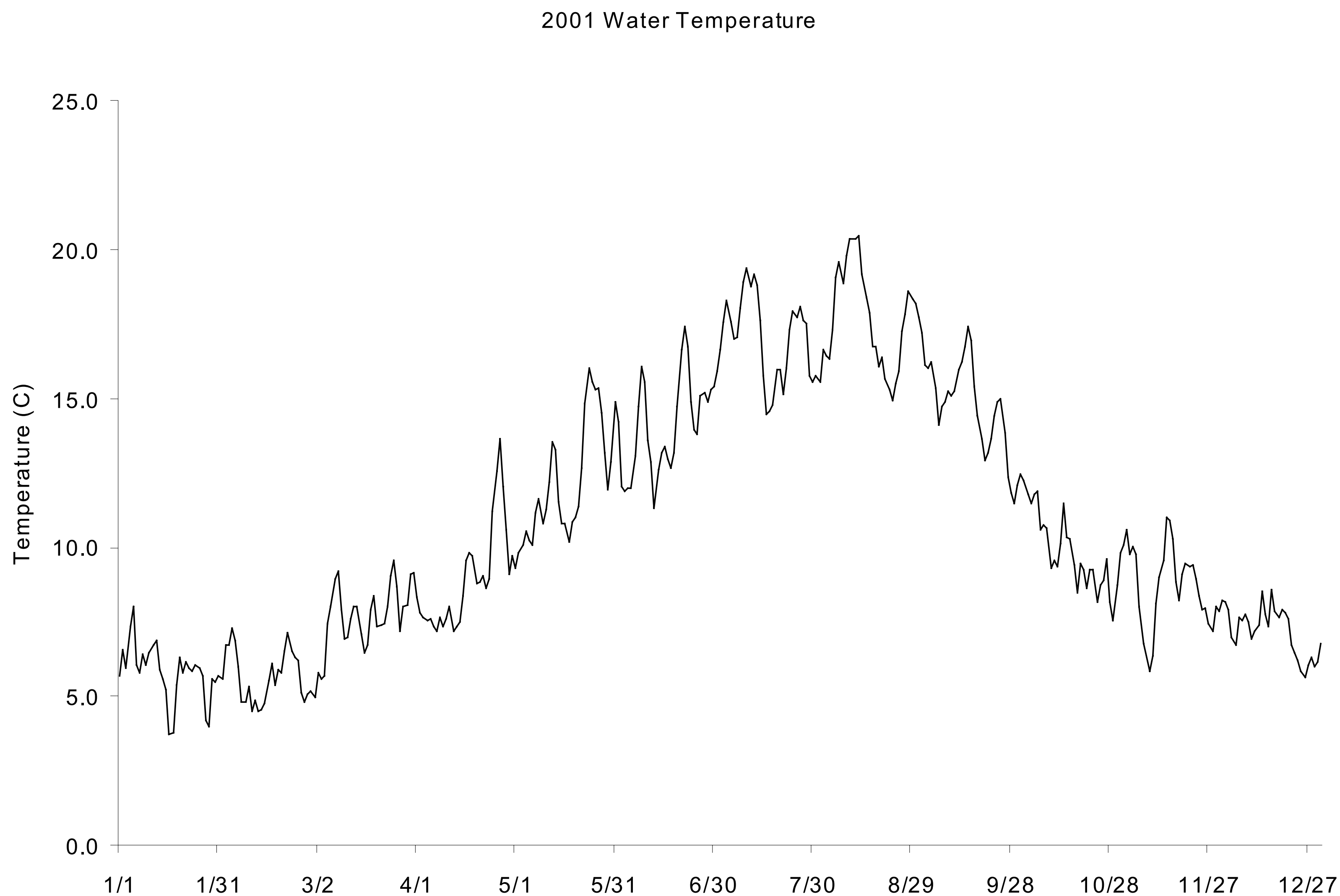

Figure 3. Water temperatures recorded on Cedar Creek at the Grist Mill using an Onset Hobo® temperature logger, 2001.

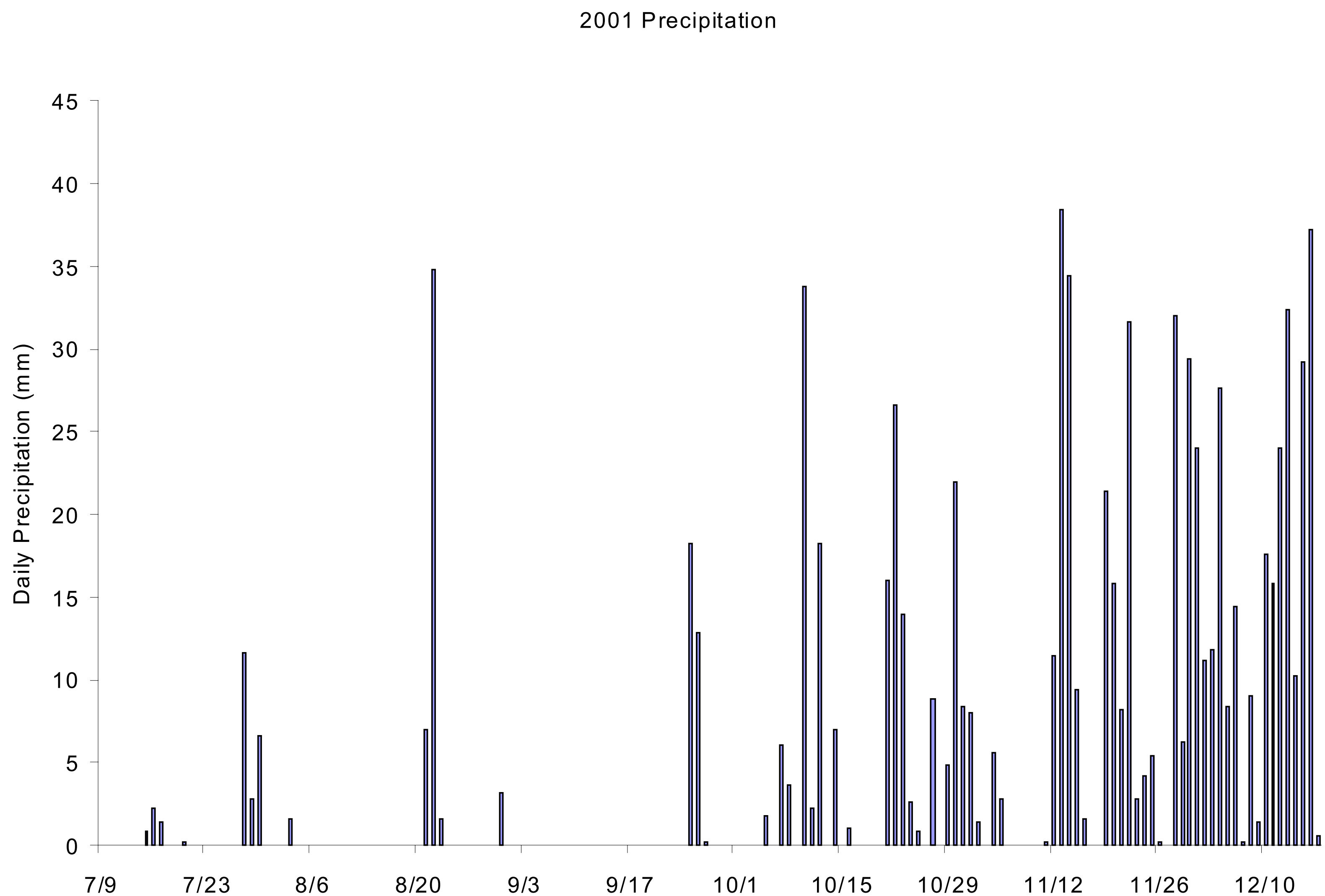

Figure 4. Precipitation recorded on Cedar Creek at the Grist Mill using an Onset Hobo® rain gage, 2001.

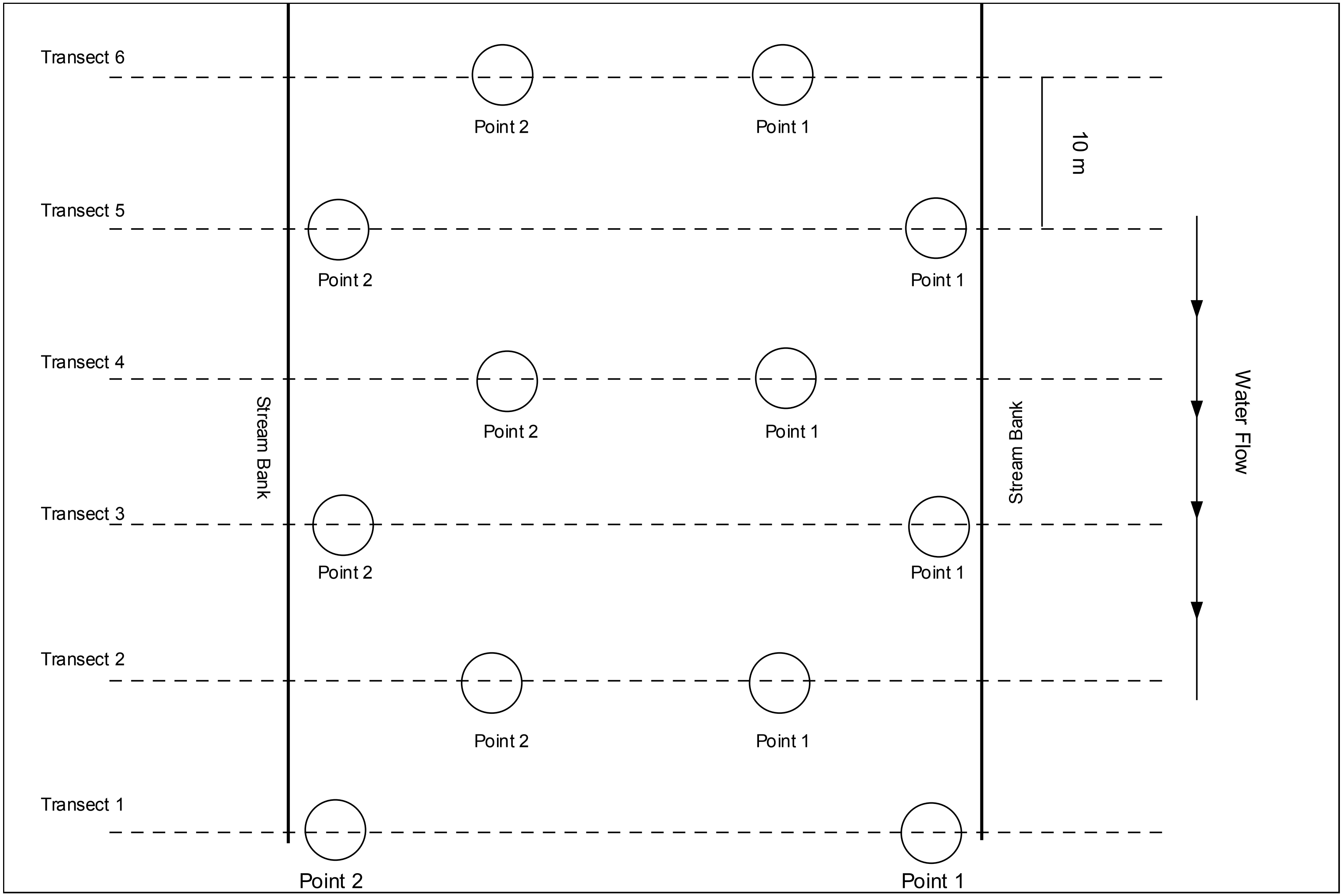

Figure 5. Transect and point layout for each sample reach during the electrofishing survey, Cedar Creek, WA, 2001.

Table 1. Habitat characteristics measured at each electrofishing sample reach Cedar Creek, Washington, 2001.

Habitat Characteristic	Sample Reach	Transect	Point
Water Temperature	X		
pH	X		
Dissolved Oxygen (%)	X		
Dissolved Oxygen (mg/L)	X		
Conductivity	X		
Specific Conductivity	X		
Gradient	X		
GPS Waypoint	X		
Wetted Width		X	
Densiometer		X	
Depth			X
Velocity			X
Percent Substrate*			X
Fine Substrate Depth			X
Bycatch			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)

Institute 1999). In addition, classification and regression tree (CART) analyses (Gini separation) were conducted (Steinberg and Colla 1997, Brieman et al 1984).

Emigrants

Emigrating lamprey 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 January 1, 2001 until November 14, 2001, when it was pulled due to high flow. When fishing, the trap was checked daily during high flows and approximately every other day during low flow conditions.

Captured lamprey were anesthetized, identified to species, and measured for length and weight. Trap efficiency and emigrant abundance were estimated through mark/recapture (Thedinga et al. 1994) using the program SPAS (Arnason et al. 1996). Ammocoetes were marked using colored elastomer injections and macropthalmia and adults were marked with fin clips. First-time captures were released upstream of the trap (ammocoetes approximately 50 m, and macropthalmia approximately 2 km) and recaptured individuals were released approximately 50 m downstream of the trap. Lamprey measuring less than 50 mm and all wounded lamprey were released downstream without a mark.

Pacific Lamprey Adults

Adult Pacific lamprey were captured in the adult ladder at the Grist Mill falls. In addition, an adult pot trap was deployed at the base of the adult ladder (Figure 6). The pot trap consisted of a 95 cm length of 25 cm diameter PVC pipe with funnels on each end. Funnel openings measured 5 cm in diameter.

Captured lamprey were anesthetized, measured for length and weight, and marked with a PIT tag and a dorsal fin clip. First-time captures were released approximately 100 m downstream of the trap and recaptured individuals were released approximately 100 m upstream of the trap.

Population estimates were calculated using the mark/recapture method and SPAS analysis software (Arnason et al. 1996). This method assumes that marked individuals will mix uniformly with unmarked fish, that the population is closed during the time of estimation, and that marked and unmarked lamprey have equal probabilities of capture. These assumptions could be violated if marked lamprey behave differently than unmarked fish, if marked lamprey experience higher mortality than unmarked fish, or if marked fish do not pursue upstream movement.

Figure 6. Photo of lamprey pot trap used to catch adult Pacific lampreys in Cedar Creek, WA, 2001.

Spawning

Lamprey nests were identified by foot surveys during the spawning period. When possible, physical characteristics of nests were measured, including: habitat type (Hawkins 1993), nest dimensions, substrate (pebble counts), and flow. GPS waypoints were collected at each nest when possible. As western brook nests look similar to animal hoof prints, only those nests containing adults were counted. Nests were not capped because it was impossible to determine the exact time they were created, the number of animals participating in the reproductive effort, and the fecundity of the individuals.

Diagnostic Characteristics and PIT tags

The USGS Biological Research Division at Columbia River Research Laboratory in Cook, Washington conducted this portion of the project. Methods are not available for dissemination at this time.

Results

2000 Lamprey Density

Lamprey were not evenly distributed among sample sites (Figure 7). Dissolved oxygen was positively associated with lamprey presence at the reach scale ($P= 0.0431$). At the sub-reach scale, water velocity ($P= <0.0001$) and percent bedrock substrate ($P= 0.0259$) were negatively associated with lamprey presence and percent clay/silt had a positive association ($P= 0.0005$). CART analysis evaluated gradient as the primary predictor of lamprey presence at the reach scale (Figure 8) and water velocity at the sub-reach scale (Figure 9). For a code key and a general explanation of CART results, refer to Appendix 1.

2001 Lamprey Density

Only one lamprey species was identified during the 2001 electrofishing survey, and that was the Pacific lamprey. However, genetic samples were not taken this year, nor were they analyzed last year, so the level of misidentification is unknown.

Fifty-four ammocoetes and one macropthalmia were collected. Estimated population, probability of capture, standard error, and density were not calculated because too few fish were captured. Twelve percent of the points sampled had at least one lamprey and the mean number of lamprey in these points was four. The maximum number of lamprey captured at a single point was 17.

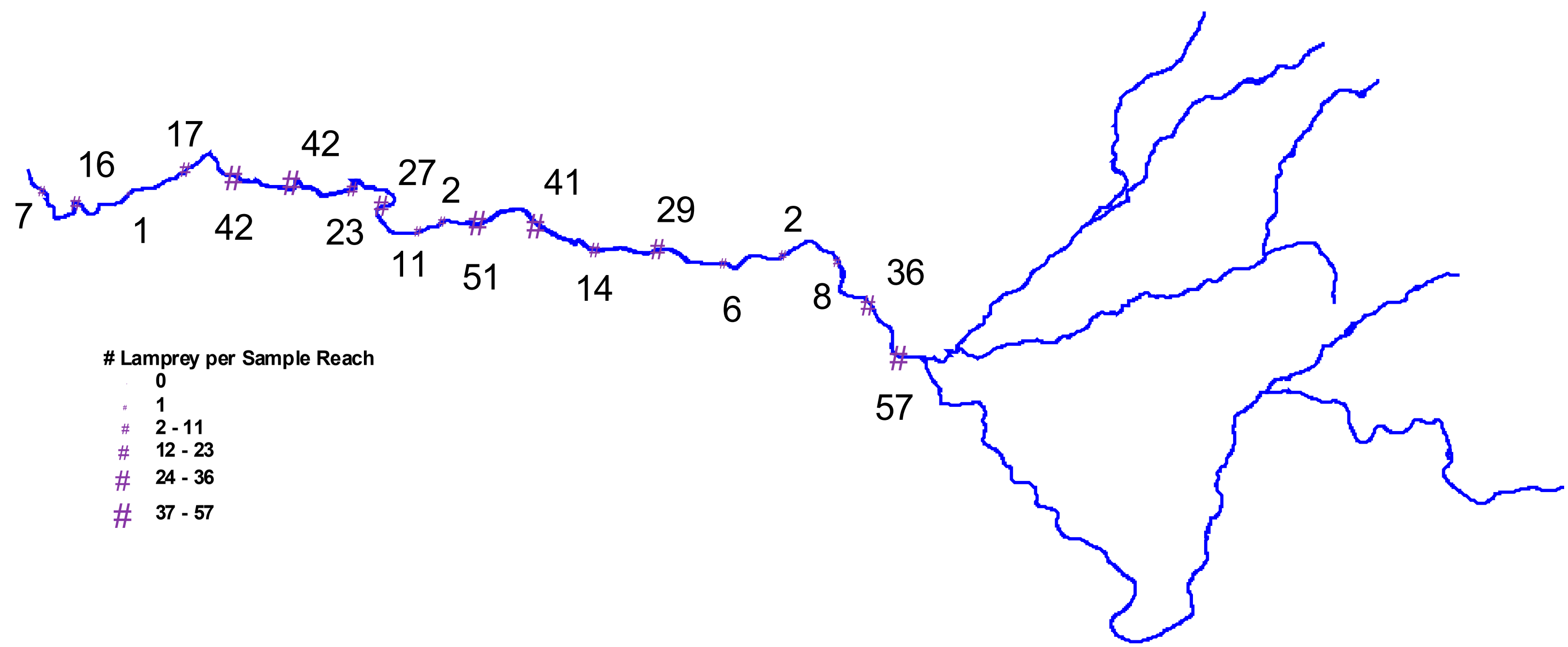

Figure 7. Number of larval lamprey captured at each sample site during the electrofishing survey, Cedar Creek, WA, 2000. Point size is relative to the number of lamprey captured.

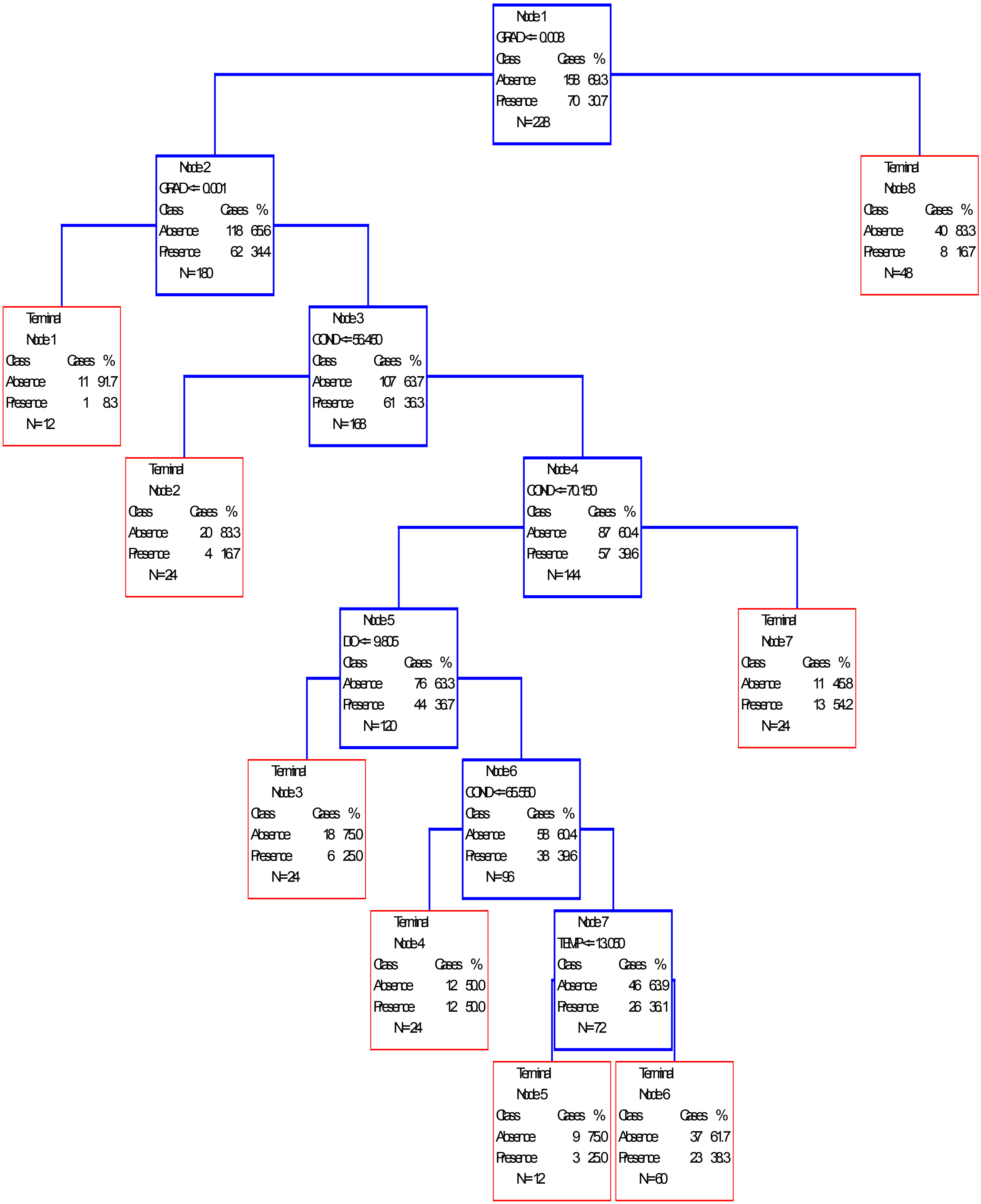

Figure 8. CART results representing habitat use at the reach scale for lamprey captured during the 2000 electrofishing survey on Cedar Creek, WA.

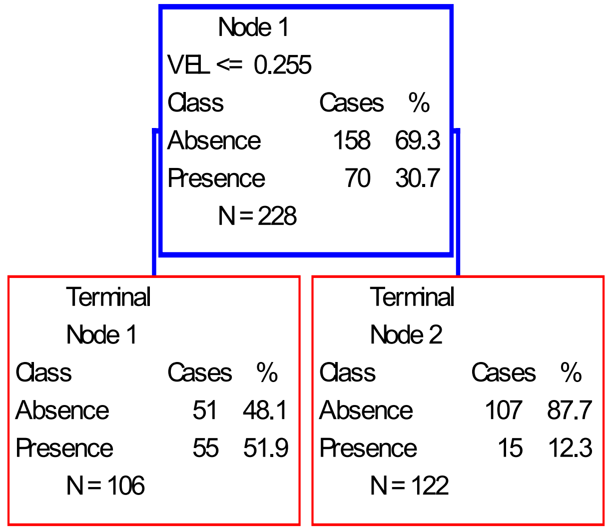

Figure 9. CART results representing habitat use at the sub-reach scale for lamprey captured during the 2000 electrofishing survey on Cedar Creek, WA.

Maximum, mean, and minimum lengths of ammocoetes collected were 142, 57, and 9 mm, respectively. Maximum, mean, and minimum weights of ammocoetes collected were 4.9, 0.54, and 0.1 g, respectively. The macropthalmia that was captured was 118 mm and weighed 3 g. Sex was impossible to determine during field examinations.

Lamprey were not evenly distributed among sample sites (Figure 10). Gradient was negatively associated with lamprey presence at the reach scale (P= 0.0333). At the sub-reach scale, percent fine substrate (P= <0.0013) was positively associated with lamprey presence and percent large gravel substrate (P= 0.0117) was negatively associated with lamprey presence. CART analysis evaluated temperature as the primary predictor of lamprey presence at the reach scale (Figure 11) and percent fine substrate at the sub-reach scale (Figure 12).

Combined (2000 and 2001) Lamprey Density

Data collected during 2000 and 2001 were combined for analyses. Dissolved oxygen was positively associated with lamprey presence at the reach scale (P= 0.0002). At the sub-reach scale, percent fine substrate (P= <0.0001) was positively associated with lamprey presence and water velocity (P= <0.0001) was negatively associated with lamprey presence. CART analysis evaluated gradient as the primary predictor of lamprey presence at the reach scale (Figure 13) and water velocity at the sub-reach scale (Figure 14).

Longitudinal stream profiles of mean larval lengths were calculated (Figure 15). There were no observed trends in abundance and length as related to distance from the creek's mouth.

Emigrants

The floating rotary screw trap fished for approximately 306 days during sampling year 2001. Three hundred and thirty-three Pacific lamprey ammocoetes, 4 Pacific lamprey transformers, 246 Pacific lamprey macropthalmia, 17 western brook adults, and 5 western brook ammocoetes were captured (Table 3). Thirty-one ammocoetes, 48 macropthalmia, and 1 adult western brook lamprey were subsequently recaptured. Yearly trap efficiencies were estimated to be approximately 11% for ammocoetes and 21% for macropthalmia.

Population estimates were calculated using a Pooled Peterson estimate. The population estimate for ammocoetes is 3799 with a standard error of 633. The 95% confidence intervals are 2559 and 5039. The population estimate for macropthalmia is 1408 with a standard error of 162. The 95% confidence intervals are 1091 and 1725.

Ammocoetes were captured during all months the trap was fishing except September (Figure 16). Peak ammocoete captures occurred in February, March-

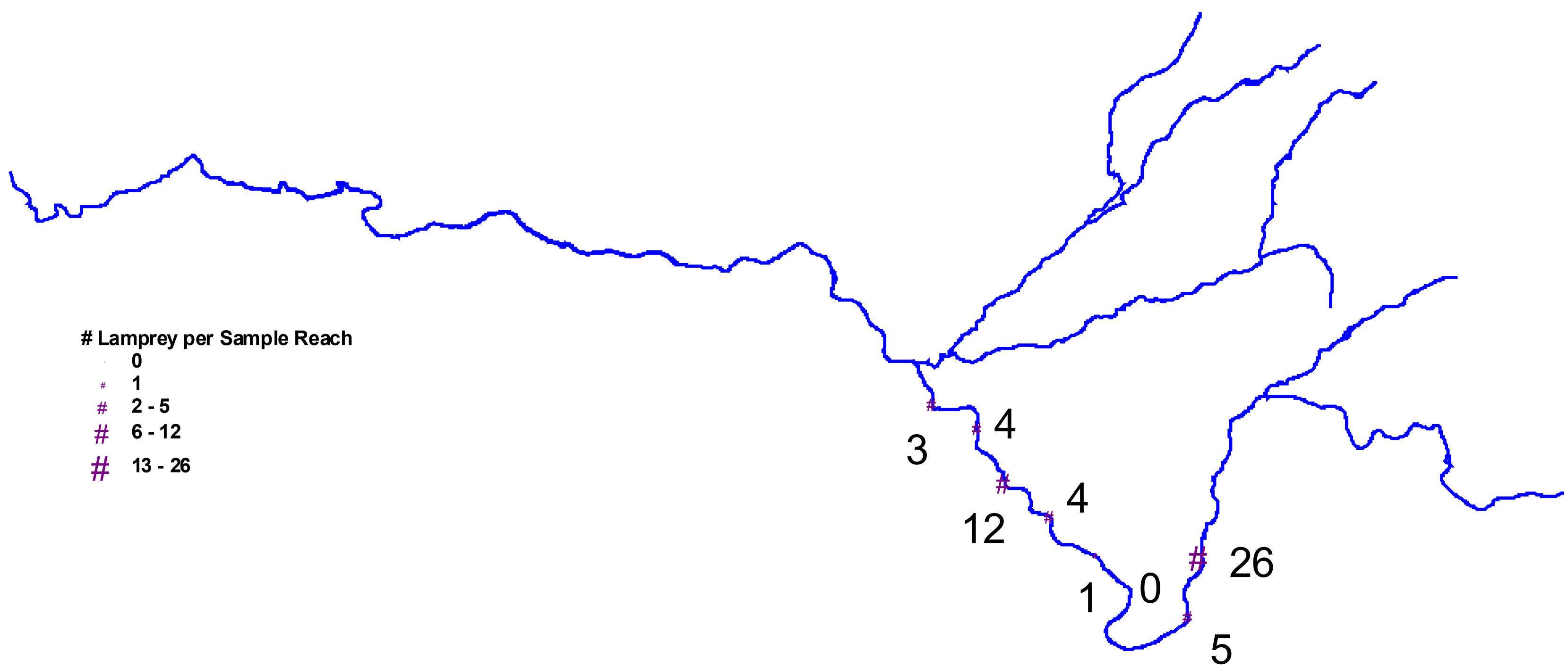

Figure 10. Number of larval lamprey captured at each sample site during the electrofishing survey, Cedar Creek, WA, 2001. Point size is relative to the number of lamprey captured.

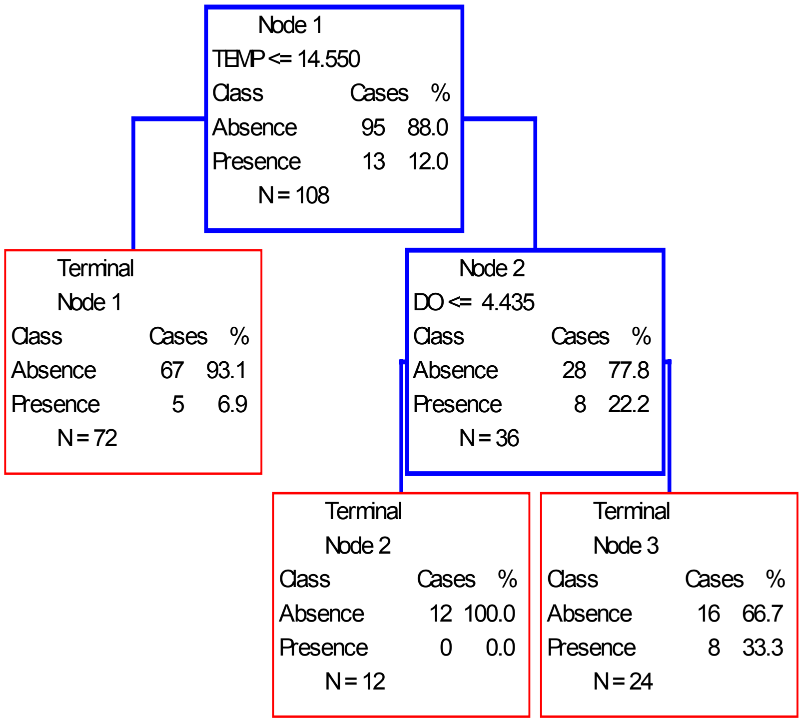

Figure 11. CART results representing habitat use at the reach scale for lamprey captured during the 2001 electrofishing survey on Cedar Creek, WA.

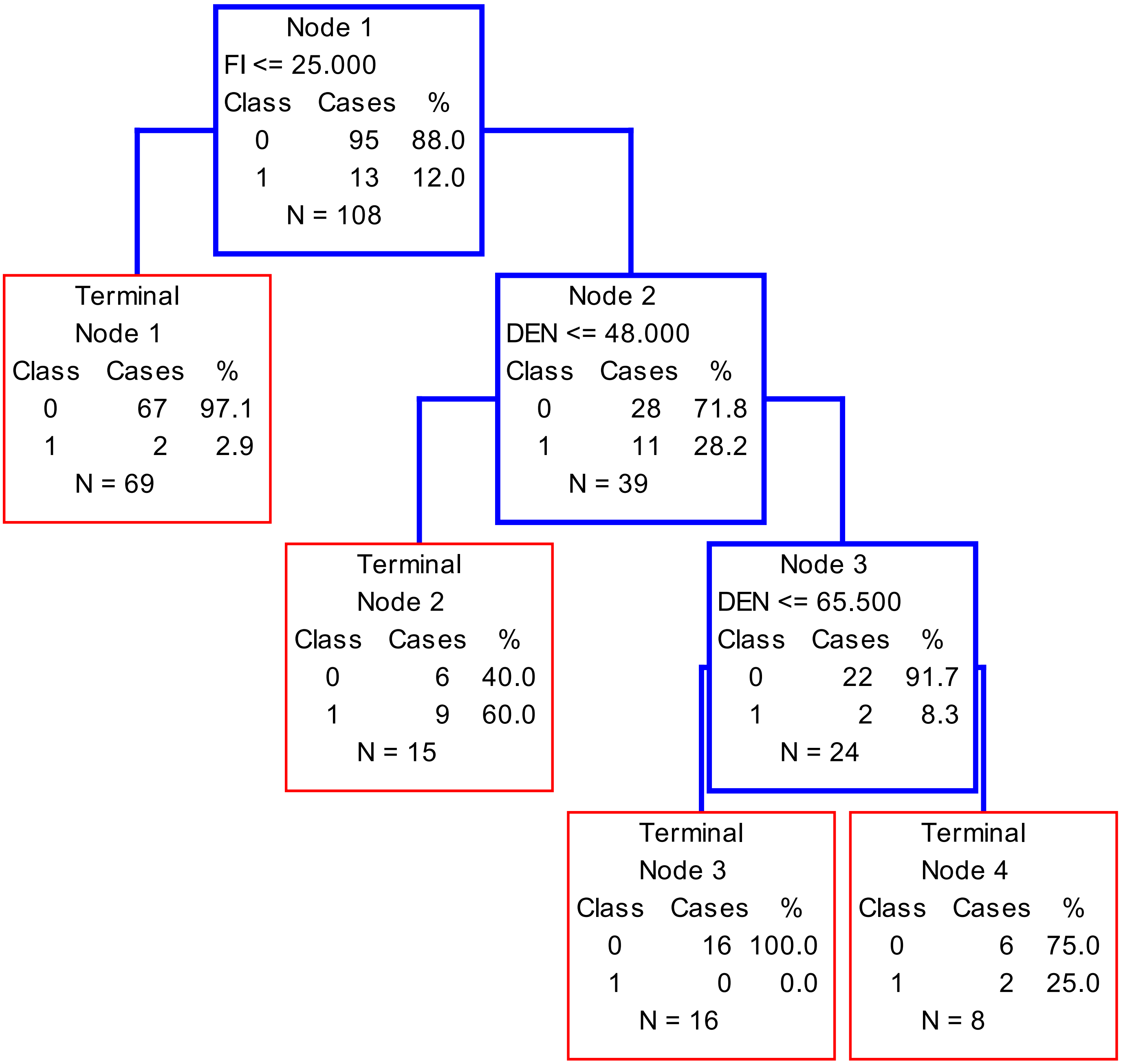

Figure 12. CART results representing habitat use at the sub-reach scale for lamprey captured during the 2001 electrofishing survey on Cedar Creek, WA.

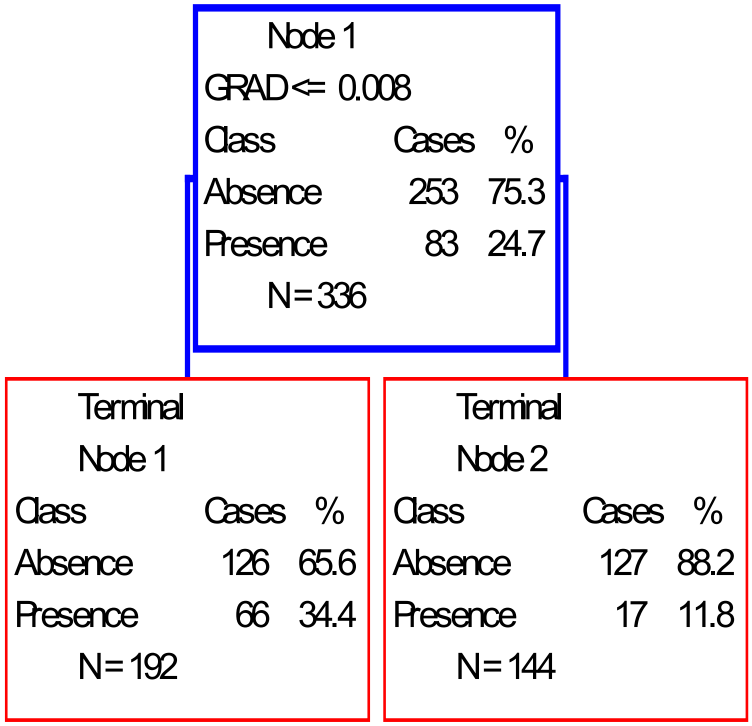

Figure 13. CART results representing habitat use at the reach scale for lamprey captured during the 2000 and 2001 electrofishing survey on Cedar Creek, WA.

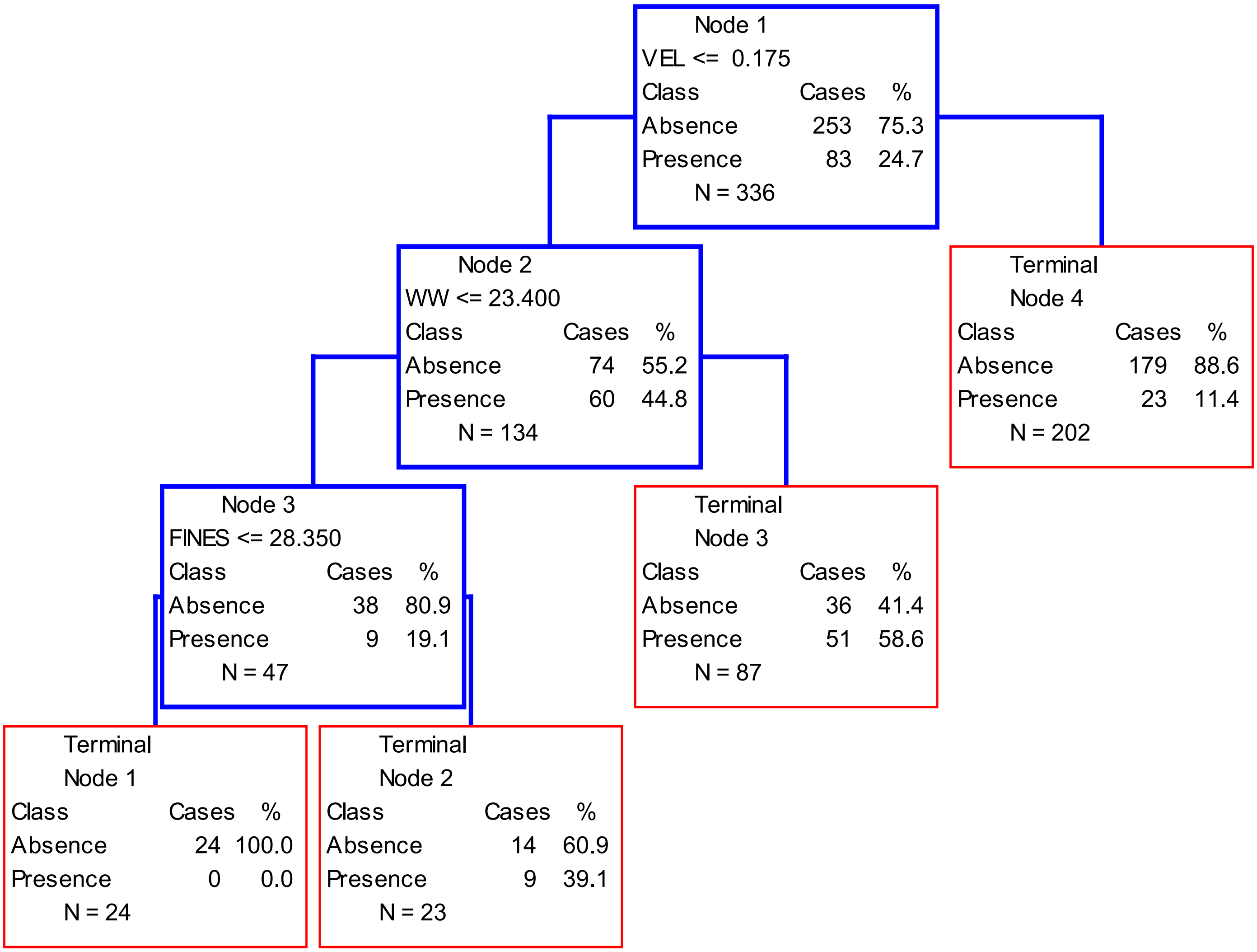

Figure 14. CART results representing habitat use at the sub-reach scale for lamprey captured during the 2000 and 2001 electrofishing survey on Cedar Creek, WA.

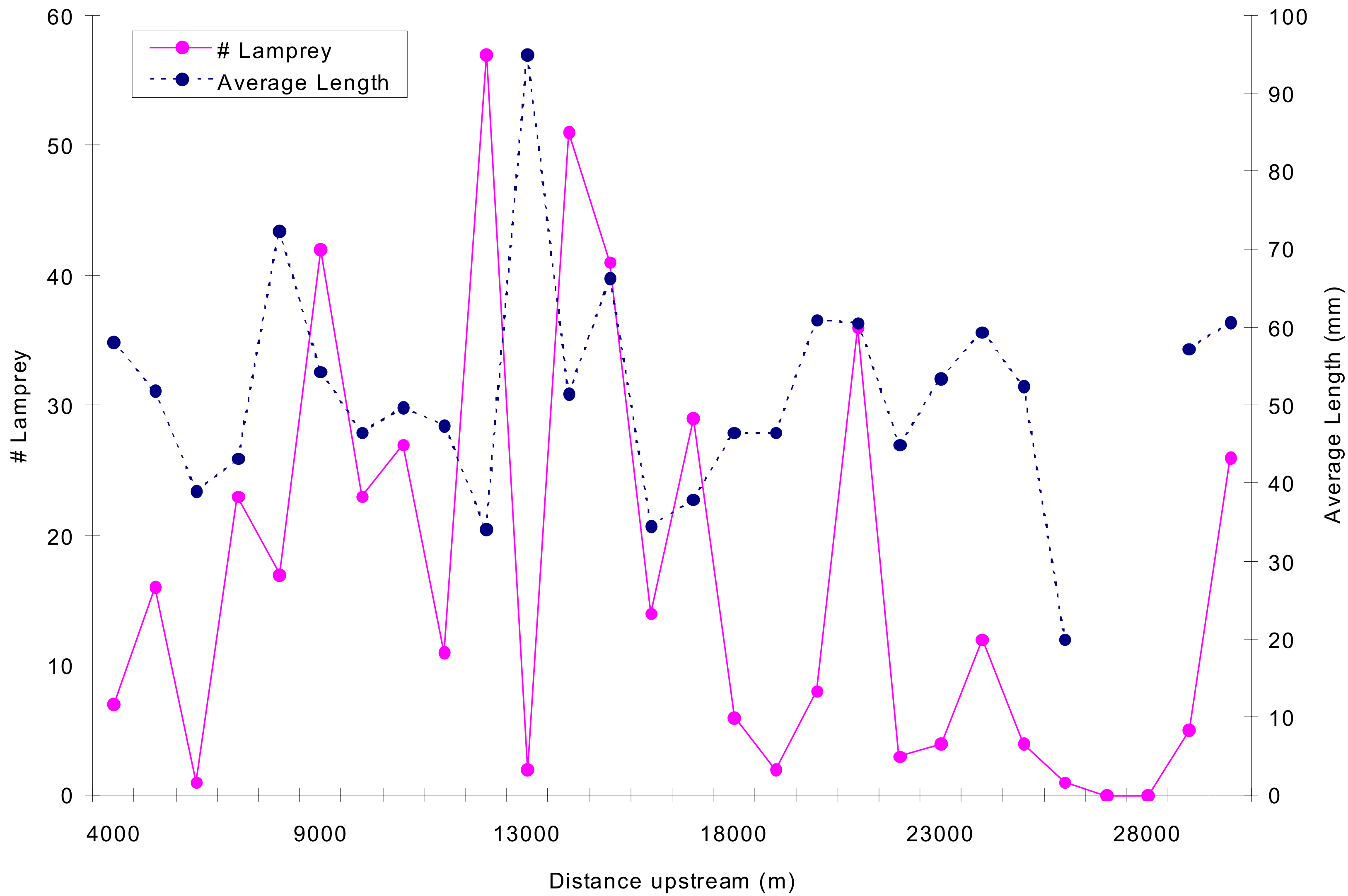

Figure 15. Average length and number of lamprey captured during the 2001electrofishing survey on Cedar Creek, WA.

Table 2. Data collected from juvenile lamprey that were captured in the rotary screw trap at the Grist
Mill, Cedar Creek WA, in 2001.

	Ammocoete	**Macropthalmia**	**Adult (Western Brook)**
Minimum Length (mm)	37.0	94.0	100.0
Average Length (mm)	97.3	119.1	111.4
Max Length (mm)	150.0	156.0	125.0
Minimum Weight (g)	0.2	1.4	1.6
Average Weight (g)	1.9	2.6	3.0
Max Weight (g)	7.1	5.2	4.7
Number Captured	338*	246	17
Number Recaptured	31	48	1
Trap Efficiency	11	21	-

*includes five western brook ammocoetes

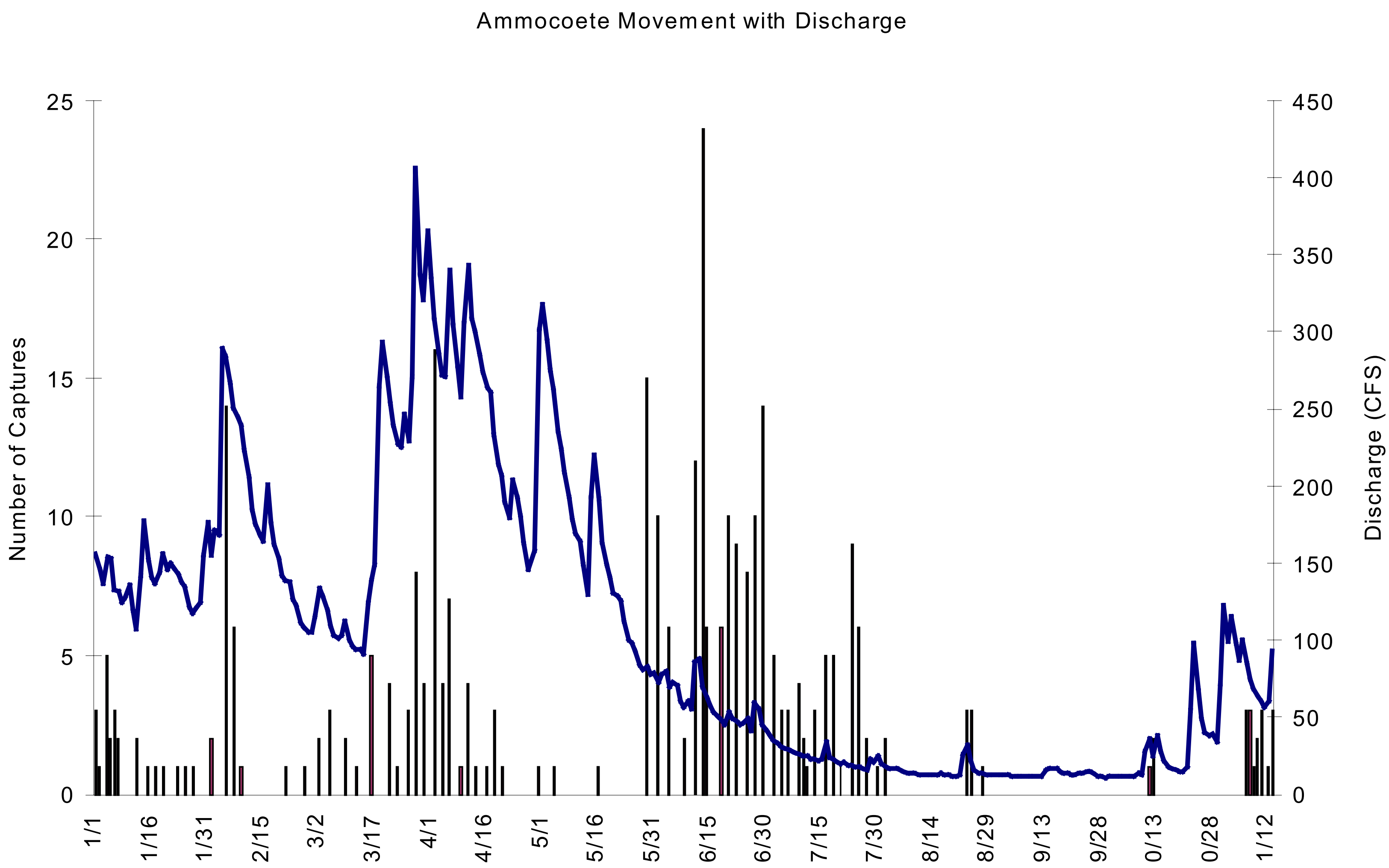

Figure 16. Ammocoete movement patterns as they are associated with discharge, Cedar Creek, WA, 2001.

April, and June-July. Ammocoete movement during February and March-April was associated with discharge and movement during June-July was not. Though ammocoetes were marked year-round, recaptures occurred only during June-August. Transforming lamprey were captured during August.

We separated ammocoetes into two groups: those that moved with peak discharge events (mean length 90 mm) and those that moved regardless of discharge (mean length 102 mm). The fish that moved with discharge were significantly smaller than those that moved regardless of discharge (P=<0.000). When ammocoetes greater than (102) mm were removed from the capture distribution, the movement pattern followed the discharge peaks (Figure 17).

Peaks in macropthalmia movement were more isolated, occurring in February and June-July. Macropthalmia movement in February was associated with discharge and June-July movement was not (Figure 18). Though fish were marked year-round, recaptures occurred only during May-September.

Pacific Lamprey Adults

Twenty-four Pacific lampreys were captured in the adult ladder and an additional six were captured in the lamprey pot trap. Adults were captured between June 11, 2001 and November 16, 2001. Maximum, mean, and minimum Pacific lamprey adult lengths were 605, 534, and 473 mm, respectively. Maximum, mean, and minimum Pacific lamprey adult weights were 419, 302.3, and 193 g, respectively. The length to weight relationship can be described by $y = 5E\text{-}06x^{2.8379}$ with $R^2 = 0.7523$. Eleven of these fish were later recaptured in the adult ladder. Recaptures, with one exception, were all originally marked within fall 2001. Average “time at large” was 15 days, with a minimum of 1 day and a maximum of 61 days.

Adults moved in two pulses, one during late spring-early summer, and the other in late summer-early fall. Captures often occurred during peak discharge events (Figure 19). Temperature and daylength did not seem to affect movement, but a longer time series is needed to be sure.

Spawning

Twenty-nine spawning ground surveys were conducted during the spawning period (April 16, 2001 through July 2, 2001). Twenty Pacific lamprey nests and 24 western brook lamprey nests were identified and many of them were GPSed (Figure 20). Temperatures during this time ranged between 8.6 and 17.4°C.

The two species of lamprey in Cedar Creek use different parts of the drainage to spawn. Pacific lamprey nest density was most abundant downstream of the Chelatchie forks and upstream of Cedar Creek’s “boot”. The

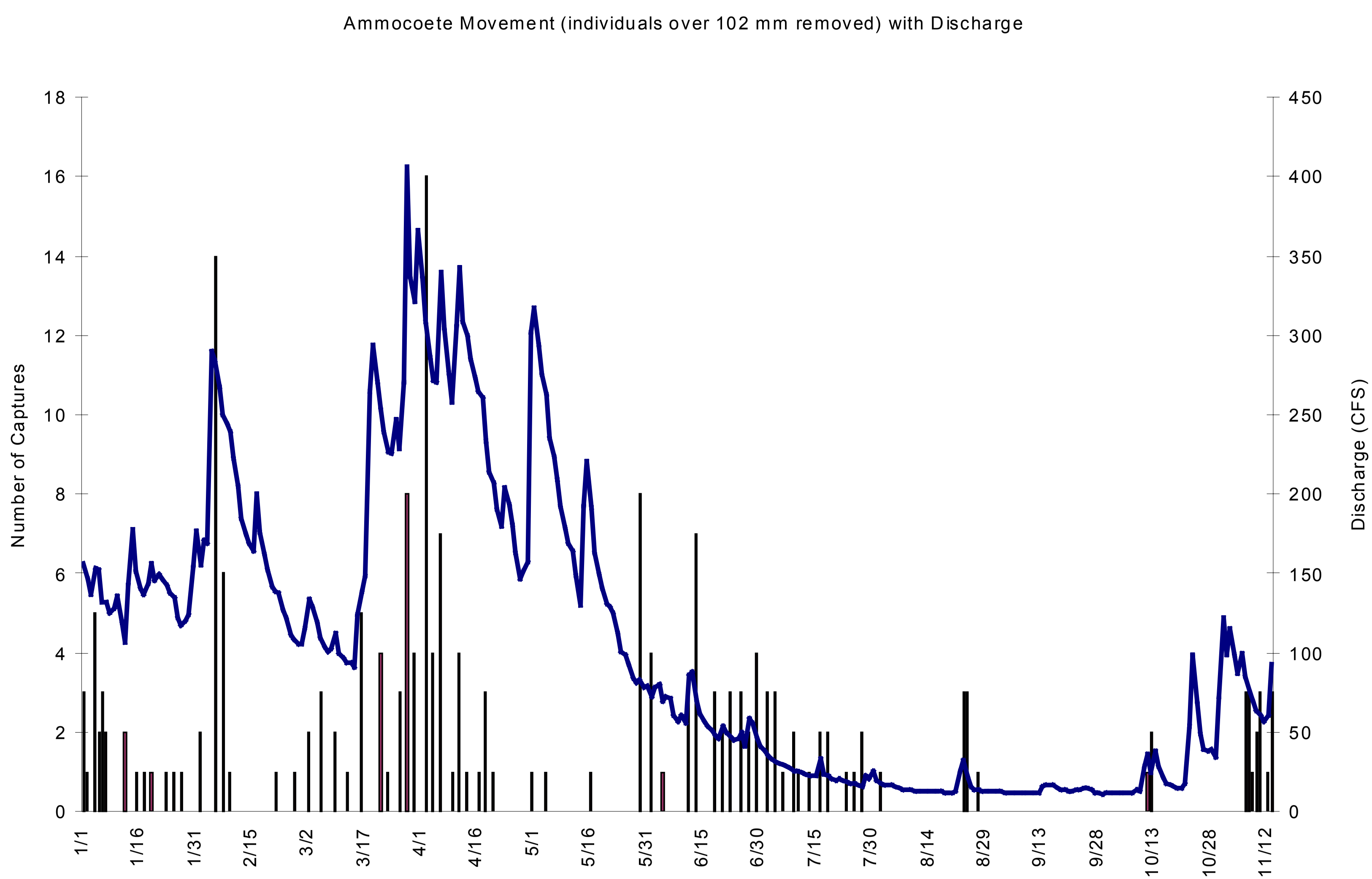

Figure 17. Ammocoete movement patterns as they are associated with discharge, Cedar Creek, WA, 2001. In this graph, all fish over 102 mm were removed.

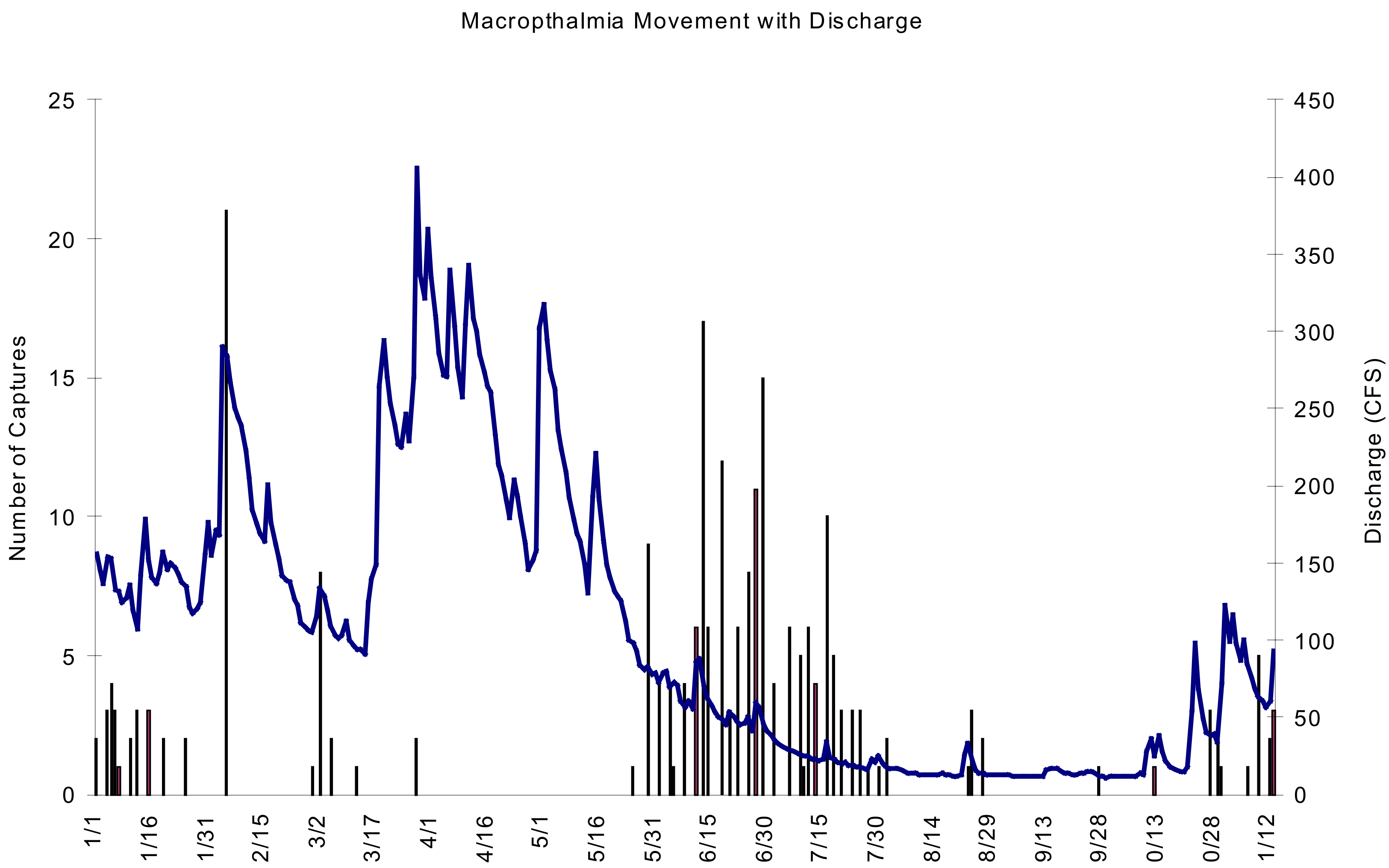

Figure 18. Macropthalmia movement patterns as they are associated with discharge, Cedar Creek, WA, 2001.

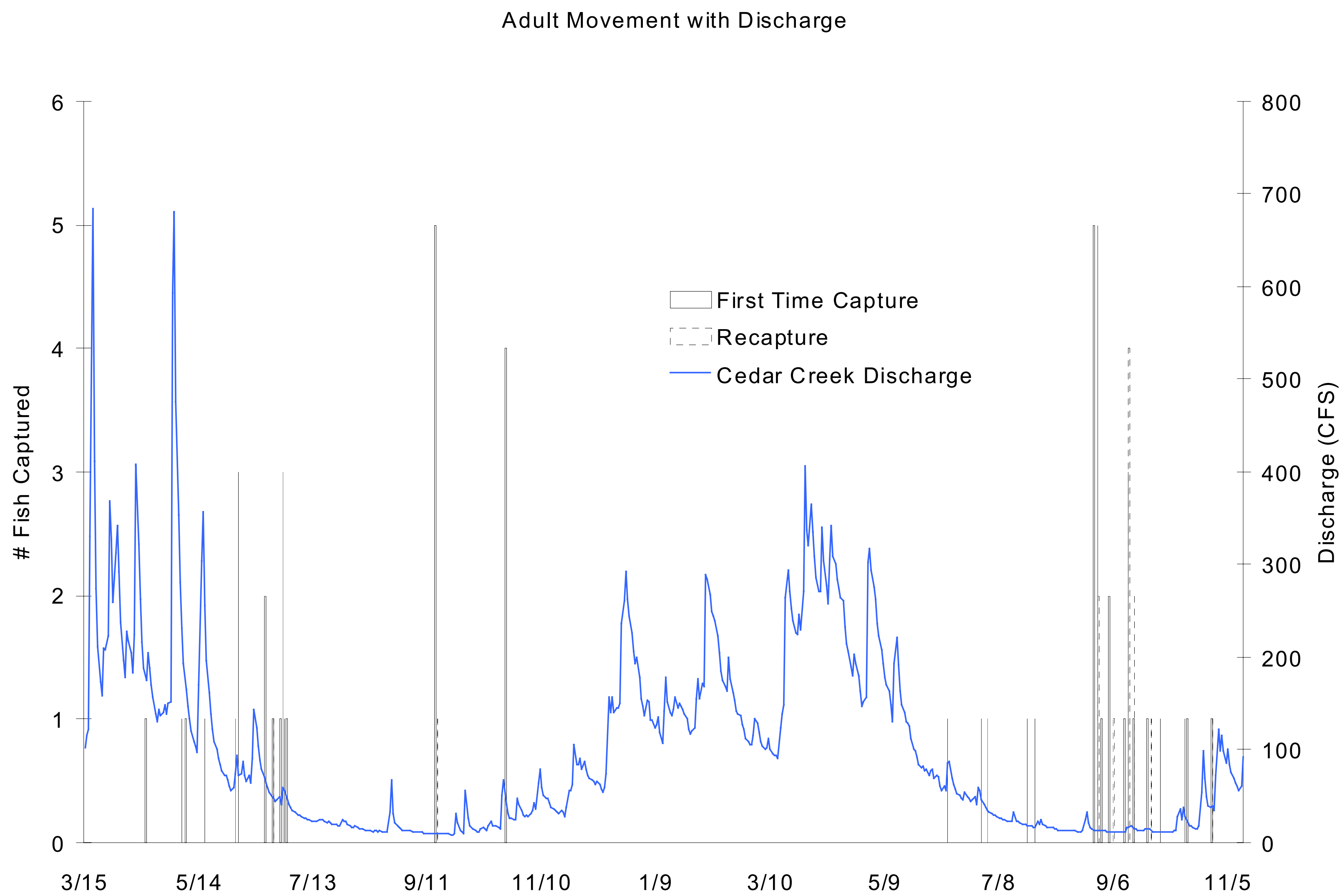

Figure 19. Adult Pacific lamprey movement patterns as they are associated with discharge, Cedar Creek, WA, 2001.

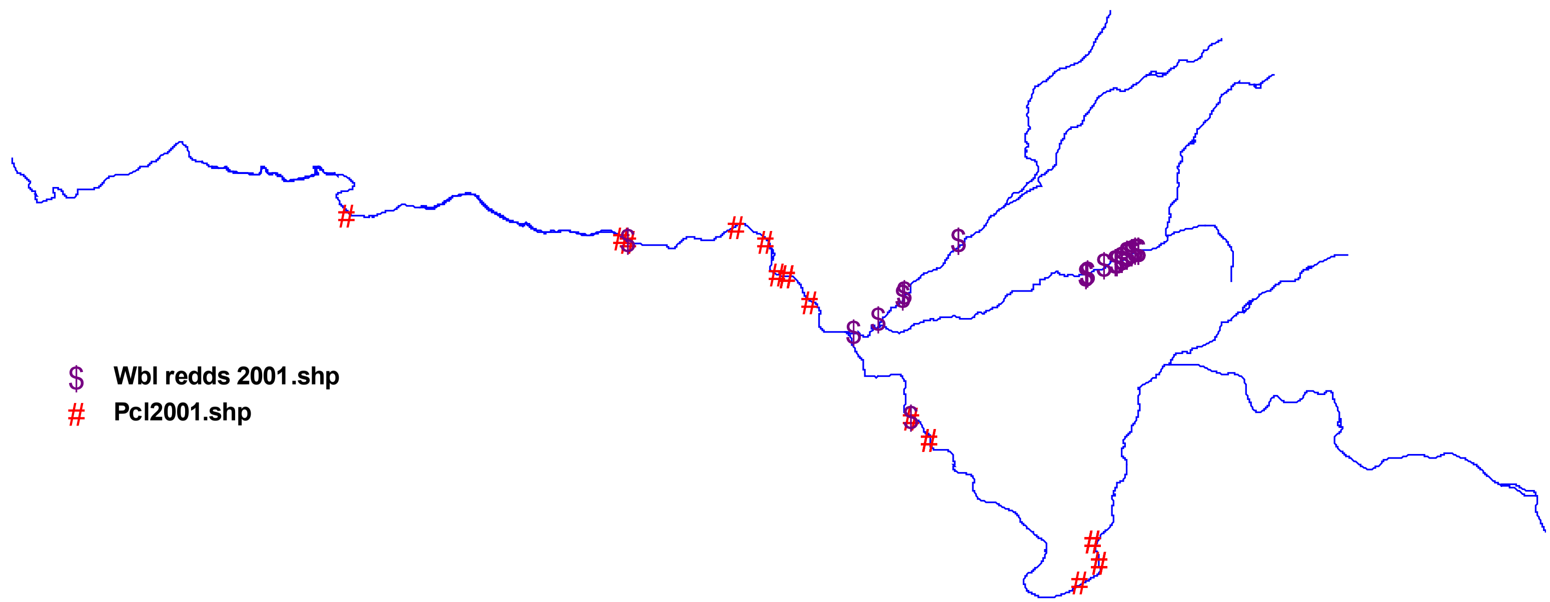

Figure 20. Location of Pacific lamprey and western brook lamprey nests, Cedar Creek, WA, 2001. Not all nests are represented.

mouth of Cedar Creek was not surveyed this year due to access concerns. Western brook nests were most abundant on the Chelatchie forks.

Habitat parameters were recorded for Pacific and western brook lamprey nests (Table 3). Pacific lamprey spawned in pool tail out habitats having large gravel substrate. Western brook lamprey spawned in runs with small gravel substrate.

Pacific lamprey spawning activity was not observed. One female was seen guarding a nest. This fish was marked with a dorsal fin clip, likely from the previous year.

Western brook spawning activity was observed. A minimum of three and a maximum of twelve lampreys were observed at each nest. The lamprey 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 lamprey were not easily scared away and close observation of individuals with an aquascope was possible. One nest contained one live female Pacific lamprey (the female mentioned above) and three live western brook lamprey. The western brooks were observed spawning in the center of the Pacific lamprey nest.

Discussion

Pacific and western book lamprey are active in Cedar Creek through much of the year. Adult Pacific lampreys enter the creek between June 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 lamprey are distributed throughout much of the creek, with greatest densities in habitats having slow water velocity 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 high flows.

There seems to be more Pacific lamprey than western brook lamprey, but this may be a result of incorrect field identifications. Studies are currently being conducted with USGS Biological Research Division at Cook, Washington to quantify the level of misidentification. This trend also may be a result of sample location, migratory behavior, and spawning distribution.

Larval lamprey are distributed throughout Cedar Creek and their presence at any particular sample point is determined by habitat variables at the reach and sub-reach scales. At the reach scale, lamprey presence is negatively associated with stream gradient and positively associated with temperature and dissolved oxygen. At the sub-reach scale, lamprey presence is negatively associated with velocity, percent bedrock, percent large gravel, and positively associated with percent fine substrate. The relationship of larval abundance to water velocity and

Table 3. Summarized data collected at nest sites during spawning ground surveys on Cedar Creek, WA, 2001.

Year	Beginning	End	Species	# Nests	# Males	# Females	# Unknown	Average Velocity (ft/sec)	Average Substrate (mm)	Habitat
2001	4/16/01	7/2/01	PCL	20	0	1	0	2.44	34.6	11 Pool Tail-out 8 Run 1 Riffle
			WBL	24	3	3	66	1.2	13.3	14 Run 3 Riffle 2 Pool Tail-out 3 Mid-channel Scour 2 Eddy

fine substrate also was observed in the Middle Fork John Day River (Torgersen 2002). Lamprey abundance in Cedar Creek did not decrease with increasing distance from the mouth of the creek, as has been observed in other systems (Close 2001).

Larval presence/absence information should be viewed as conservative until gear efficiencies can be tested. It is presumptive to make the conclusion that lamprey are absent when none are collected from a sample point. There were several occasions when larval lamprey were observed fleeing a sample point but were not captured. When lamprey were captured from a sample point, a capture almost always occurred during the first pass, and always occurred by the second pass. For this reason, two-pass sampling is probably very effective in determining lamprey presence/absence in most substrate types, but further testing is required.

Larval presence/absence criteria should be evaluated for biological importance. If we define “good” lamprey habitat using the presence of one fish, does the presence of 10 lamprey indicate “great” lamprey habitat? Do habitats have a carrying capacity for larval lamprey? Do larger lamprey competitively exclude smaller lamprey from prime habitats as do other species of fish? Do different length classes of larval lamprey occupy different habitats? These questions will be addressed when more sites containing lamprey are sampled and a length to age relationship can be determined.

Larval population estimates were not made at sample points containing few larvae. Population estimates are considered questionable when proper depletions are not achieved. Too few fish were sampled in 2001 to make any valid estimates and many of the 2000 estimates were based on poor depletions.

Average larval length was highly variable throughout Cedar Creek. This pattern was observed in main stem John Day River (Close 2001). In the North and Middle forks of the John Day River (Close 2001), average length decreased with increasing distance from the mouth. If recruitment were to stop entirely, after time we would expect to find the largest (and oldest) larvae in the downstream sections of the creek. This is because larvae are not good swimmers and are moved with the water current. Therefore, it is possible that streams that have a significant length to RKM relationship have poor recruitment or recruitment is isolated to a certain section of the stream.

Macropthalmia move throughout the year. High flow events may dislodge macropthalmia, causing them to move outside their normal migration period. Peak movement occurred in June-July when discharge was low. This also was the period when marked macropthalmia were recaptured. These macropthalmia are actively emigrating out of Cedar Creek during low flow periods. In contrast, Beamish and Levings (1991) observed that macropthalmia movement was almost always associated with high discharge events.

Ammocoete movement is associated with discharge and transformation. Ammocoetes moved involuntary during high flow periods that were likely scouring events. Larger ammocoetes moved during low flow periods, coinciding with peak macropthalmia migration. This also is the period when all ammocoete recaptures occurred. Beamish and Levings (1991) documented an increase in the abundance of larger ammocoetes moving during macropthalmia migration. If length is an indication of age, the larger ammocoetes are older and ready to transform. Therefore, these larger ammocoetes are voluntarily emigrating and are transforming downstream from the screw trap. Age analysis would give further insight to length relationships and transformation.

Our juvenile population estimates may inaccurately represent the actual population of lamprey moving past the screw trap. One of the assumptions of this population estimate is that trap efficiencies are equal among the pooled marking periods. Recaptures were limited to May-September, so trap efficiencies were higher during those months than all other months, thereby violating this assumption. Another assumption of this estimate is that downstream movement is intentional. In our study, we observed that movement was intentional only during May-July. Population estimates can only be made during those periods of active juvenile movement. However, these population estimates will underestimate the population in systems where juveniles are involuntarily moved due to high discharge events.

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

Adult Pacific lamprey recapture data suggest that movement is more upstream directed during the late migration pulse. All recaptures occurred within the later movement pulse and ten of the eleven recaptures were originally marked within this pulse. The early migrants either spawned and died downstream of the release site or are holding over in the creek until the following year. One of the early migrants was recaptured 61 days after release. This fish will likely hold over in the creek and spawn next year.

Mark/recapture data were used to generate an adult Pacific lamprey spawning population estimate for Cedar Creek (above the Grist Mill). We assume that tagged fish had similar behavior and mortality rates as did untagged fish. USGS-BRD used similar tagging techniques (PIT tags and dorsal fin clips) to identify their fish during laboratory swimming performance studies and have not noted any behavioral changes or an increase in mortality as a result of tagging. (Jen Bayer, USGS-BRD, Cook WA, pers. comm.). We also assume that marked fish pursued movement in the upstream direction (over the course of the year). Vella et al (2001) conducted a radio telemetry study at Bonneville Dam and noted that 88% of the tagged fish released below the dam continued to move upstream.

Survival, ocean residence, and homing fidelity will not be assessed and will be removed from the original objectives. Coded wire tags (CWT) will not be used with juvenile outmigrants until we can investigate mark retention and survival in a controlled laboratory or natural environment. Until more agencies are involved in a collaborative effort involving CWT implantations and recoveries, an objective such as this is unobtainable.

Pacific lamprey and western brook lamprey spawn in different sections of the Cedar Creek drainage. Of the areas surveyed (Cedar and Chelatchie Creeks), Pacific lamprey were observed spawning only within mainstem Cedar Creek. Western brook spawning was concentrated in Chelatchie Creek and rarely was observed in Cedar Creek. This separation is due to habitat preferences. Pacific lamprey prefer larger substrate and faster water velocities than western brooks. There was one instance when three western brooks were observed spawning in a Pacific lamprey nest, occupied by a female Pacific lamprey. 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 Gibbons Creek (Scott Barndt, U. S. Forest Service, Bozeman MT, pers. comm.).

Interannual variation was observed between the data collected in 2000 and in 2001. These differences may be a result of monitoring lamprey populations across two very different water years, differences in year-class strength, or sampling techniques. It is necessary to gather more data to clarify trends.

Higher abundances of lamprey were observed during the electrofishing survey in 2000 (Stone et al. 2001) than in 2001. The 2001 survey sampled nine points that were higher in the drainage than those points surveyed during 2000. These nine points averaged a higher overall gradient and a lower average lamprey density than those points sampled in 2000. These data support the idea that lamprey prefer lower gradient habitats (Torgersen 2002). However, differences in the flow regime, capture efficiency, and sampling technique also may reflect interannual differences in lamprey abundance.

Assessing interannual variation for outmigrants is somewhat difficult because sampling periods varied across years. Sampling did not begin until March 15 of 2000 (Stone et al. 2001), but continued through the end of December. Sampling during 2001 was cut short in November due to high water in Cedar Creek. However, if we examine only the data collected between March 15 and November 15 for each year, several patterns emerge.

The relative proportion of life stages captured in the screw trap differed between years. Ammocoetes accounted for 87% of the catch in 2000 (Stone et al. 2001), and 58% in 2001. Macropthalmia accounted for 10% of the catch in 2000, and 39% in 2001. This may reflect differences in year-class strength or timing of transformation. Another explanation for this difference may be a mechanical phenomenon. Macropthalmia are often observed sucking onto flat surfaces inside the live box and we hypothesize that they can also attach to parts of the debris drum (which is situated at the stern of the live box). When the debris drum is spinning, an attached lamprey may be removed from the live box. Conversely, a spinning debris drum may cause ammocoetes to avoid the stern of the live box. There is a small gap between the live box and the debris drum and this gap may allow ammocoetes to escape. In 2001, the debris drum of the screw trap was often malfunctioning, preventing the drum from spinning. The higher numbers of macropthalmia and lower numbers of ammocoetes captured in 2001 may simply be a result of the debris drum malfunctioning.

Adult Pacific lamprey abundance was consistent between years, however capture efficiencies were far greater in 2001 (37%) than in 2000 (9%) (Stone et al. 2001). This may be a result of decreased handling mortality (unknown factor at this time), increased mark-retention, density dependence (availability of spawning and overwintering habitat downstream of the trap), or discharge.

Pacific lamprey timing was not consistent between years. In 2001, the first pulse in adult movement occurred approximately two months later than in 2000 (Stone et al. 2001). If this delay is real, it is likely due to discharge. 2001 is considered a drought year and the high discharge events that typically occur in Cedar Creek during early spring were muted or non-existent. This could have delayed fish cuing into the stream or created access barriers. It is conceivable that lamprey were moving, but the low flow conditions provided them the opportunity to go over the falls and avoid the traps.

Lamprey spawned within the same relative areas during 2001 as in 2000. The 2000 data reflects that more nests of both species were created within those areas (Stone et al. 2001). However, it is likely that surveyors were a little more liberal in 2000 and more conservative in 2001. In addition, we were not able to survey the mouth of Cedar Creek in 2001, which had a high occurrence of Pacific lamprey nests in 2000.

Modifications will be made during the 2002 sampling year. Sample design will be adjusted to allow us to better meet the objectives of our contract and to provide general information to other agencies and the public.

The sampling design for assessing larval abundance will be modified. One problem that we encountered with the stratified systematic sampling approach was that too few (approximately 30% in 2000, and 12% in 2001) of the points sampled contained lamprey. Multivariate statistics rely on “successes” to model relationships between lamprey abundance (or presence/absence) 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).

Gear efficiency for the lamprey electrofisher needs to be tested. A pilot study will be attempted either in the field or perhaps at Abernathy Fish Technology Center. If possible, efficiency will be assessed by placing a known number of juveniles in a variety of substrates having a known area. This will help us determine the accuracy of our density estimates based on depletion electrofishing, the number of passes needed to make these estimates, and the accuracy of our presence/absence delineations based on one and two pass electrofishing.

Several modifications will be made to our rotary screw trap sampling protocol. The trap will be fished more regularly during high flow periods. This may require modifying the trap (increasing the buoyancy), or moving it to another location during months of high discharge. Short term handling mortality and mark retention will be assessed by holding marked fish for a period of 24-72 hours. An estimate of short-term survival will be used to better calculate population size. USGS-BRD used similar elastomer injections to identify their fish during a species verification study and have not noted an increase in mortality as a result of tagging (Jen Bayer, pers. comm.). Additionally, a screw trap retention study will be conducted over various environmental and mechanical conditions. We will adjust the trap to minimize escapement or adjust our population estimates if escapement is unavoidable.

More effort will be expended on capturing adult Pacific lamprey. A series of lamprey pots will be placed on the substrate at the mouth of Cedar Creek. This sampling technique will not likely affect the migration of salmon and trout and will hopefully allow us to capture those fish that enter the creek and spawn or overwinter below the Grist Mill. In addition, the proportion of the population that moves upstream using the Grist Mill falls (instead of the trapping facilities) will be determined by placing several pots above the falls. These will be fished throughout the year to encompass various water levels, as it is likely that the lamprey's ability to navigate the fall depends on discharge. Finally, lamprey pots will be placed 100 m downstream of our release site to determine if marked fish are moving downstream.

Spawning ground surveys will be conducted more systematically. Index reaches will be chosen, based on 2000 and 2001 data, and will be surveyed regularly. Additionally, non-index reaches will be surveyed randomly to cover more area.

Sampling efforts on Cedar Creek will continue for 2002 and an annual report, similar to this, will be delivered during the first months of 2003.

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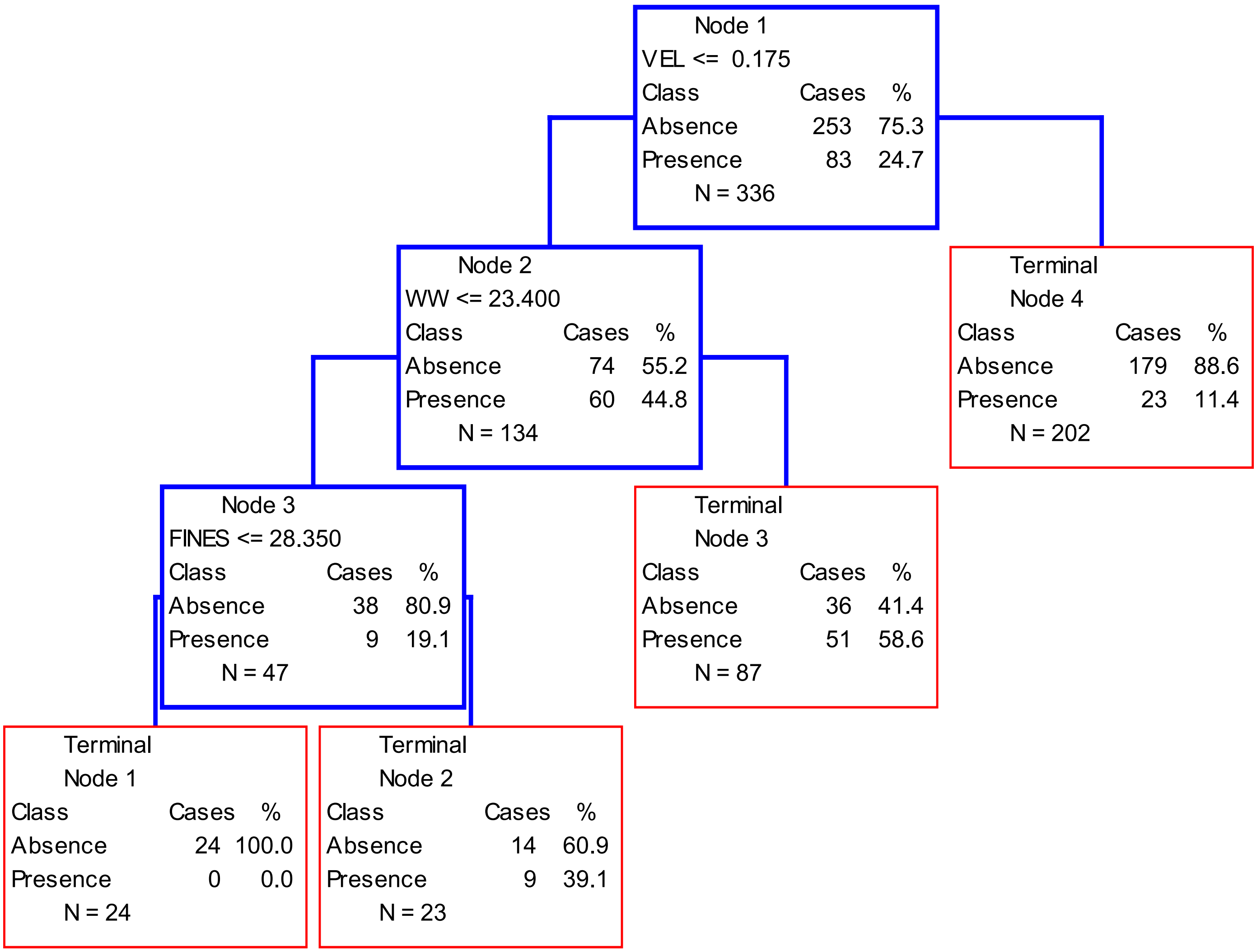
Appendix 1. Explanation of CART analysis using an example derived from data collected during the 2000 and 2001 larval distribution electrofishing surveys on Cedar Creek, WA.



These results would read as follow: Node 1--Of the 83 sample points that contained at least one lamprey, 60 were found in habitats having water velocities less than 0.175 ft/sec (Node 2). Twenty-three sample points containing larvae were in habitats having water velocities greater than 0.175 ft/sec (Terminal Node 4). Node 2—Of the 60 remaining sample points that contained at least one larvae, 51 were found in habitats having a wetted width greater than 23.4 m (Terminal Node 3). Nine sample points containing larvae were in habitats having a wetted width less than 23.4 m (Node 3). Node 3—Of the 9 remaining sample points that contained larvae, all nine were located in habitats having percent fine substrates greater than 28.35% (Terminal Node 2).

Key: GRAD=gradient; COND=conductivity; DO=dissolved oxygen (mg/l); TEMP=temperature (C); VEL=water velocity (ft/sec); FI or FINES=fine substrate (%); DEN=densiometer reading (canopy); and WW=wetted width (m).