

Evaluate Habitat Use and Population Dynamics of Lampreys in Cedar Creek

**Annual Report
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Evaluate Habitat Use and Population Dynamics of Lamprey in Cedar Creek

BPA Project No. 2000-014-00

Annual Report for 2003 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 fourth year of this project. Adult (n = 156), metamorphosed (n = 460), transforming (n = 0), and ammocoete (n = 518) stages of Pacific and western brook lamprey were examined in 2003. Lamprey were captured using an adult fish ladder, lamprey pots, rotary screw traps, and a lamprey electrofisher. In addition, fifty-three spawning ground surveys were conducted during which 109 Pacific lamprey and 22 western brook lamprey nests were identified. Stream gradient of spawning grounds was surveyed to better understand spawning habitat requirements. Backpack electrofisher efficiency and the 70% depletion model were also examined in a controlled field study.

Introduction

Three lamprey species (*Lampetra tridentata*, *L. richardsoni*, and *L. ayresii*) 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. ayresii*) 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 recovery of Pacific lamprey populations in the CRB (Close et al. 1995).

Identifying the biological and physical factors that are limiting lamprey 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 lamprey and western brook lamprey in Cedar Creek, Washington since 2000. Data collected during 2000, 2001 and 2002 are summarized in three annual reports (Stone et al. 2001, Stone et al. 2002, and Pirtle et al. 2003). This annual report summarizes results of research and analytical activities conducted during 2003. 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 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 macrophthmia in July to October. The macrophthmia 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 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 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 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. 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 kilometer 139. The Cedar Creek drainage is 89.3 km² 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 4).

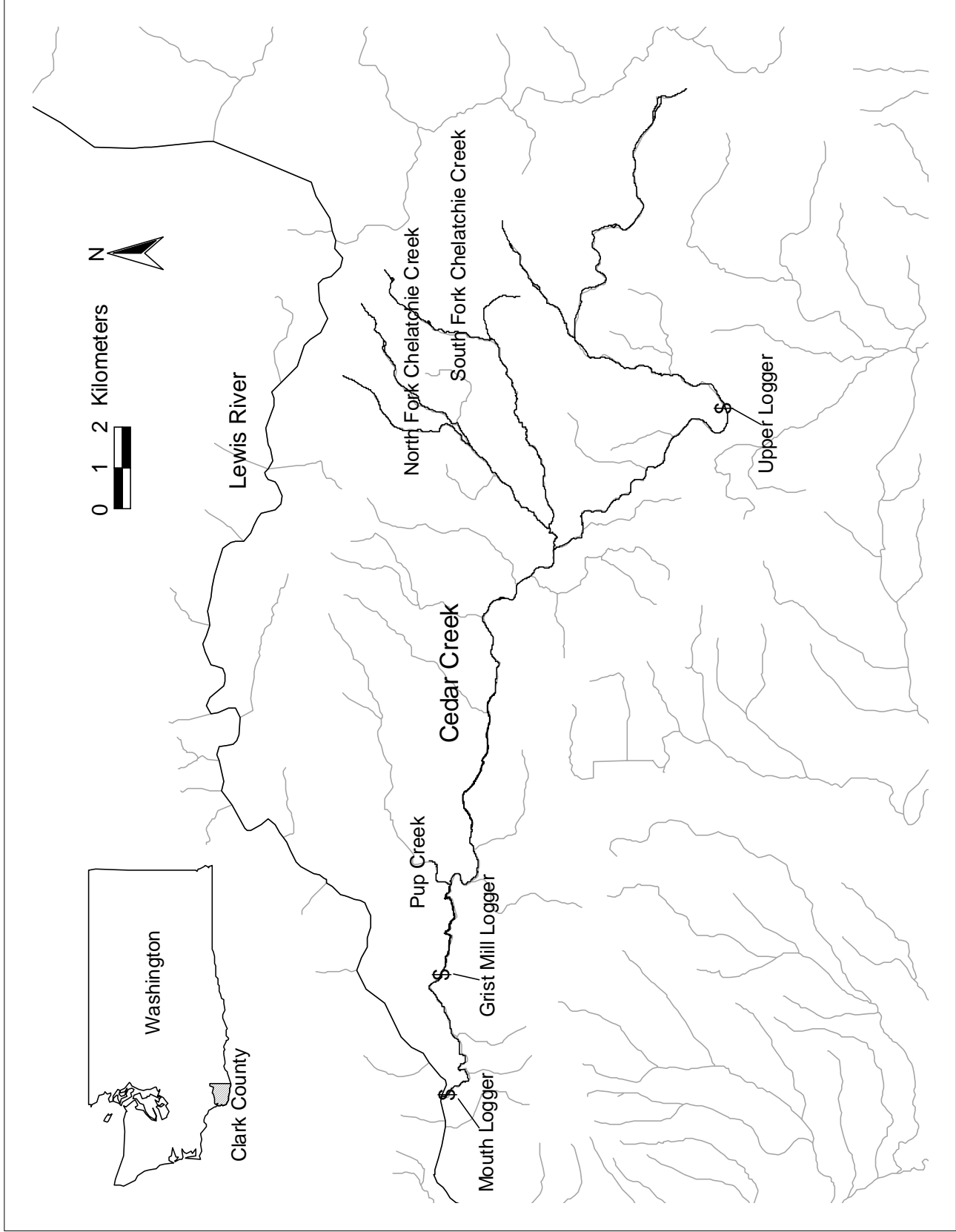


Figure 1. Cedar Creek in Clark County, Washington depicting the location of USFWS temperature loggers.

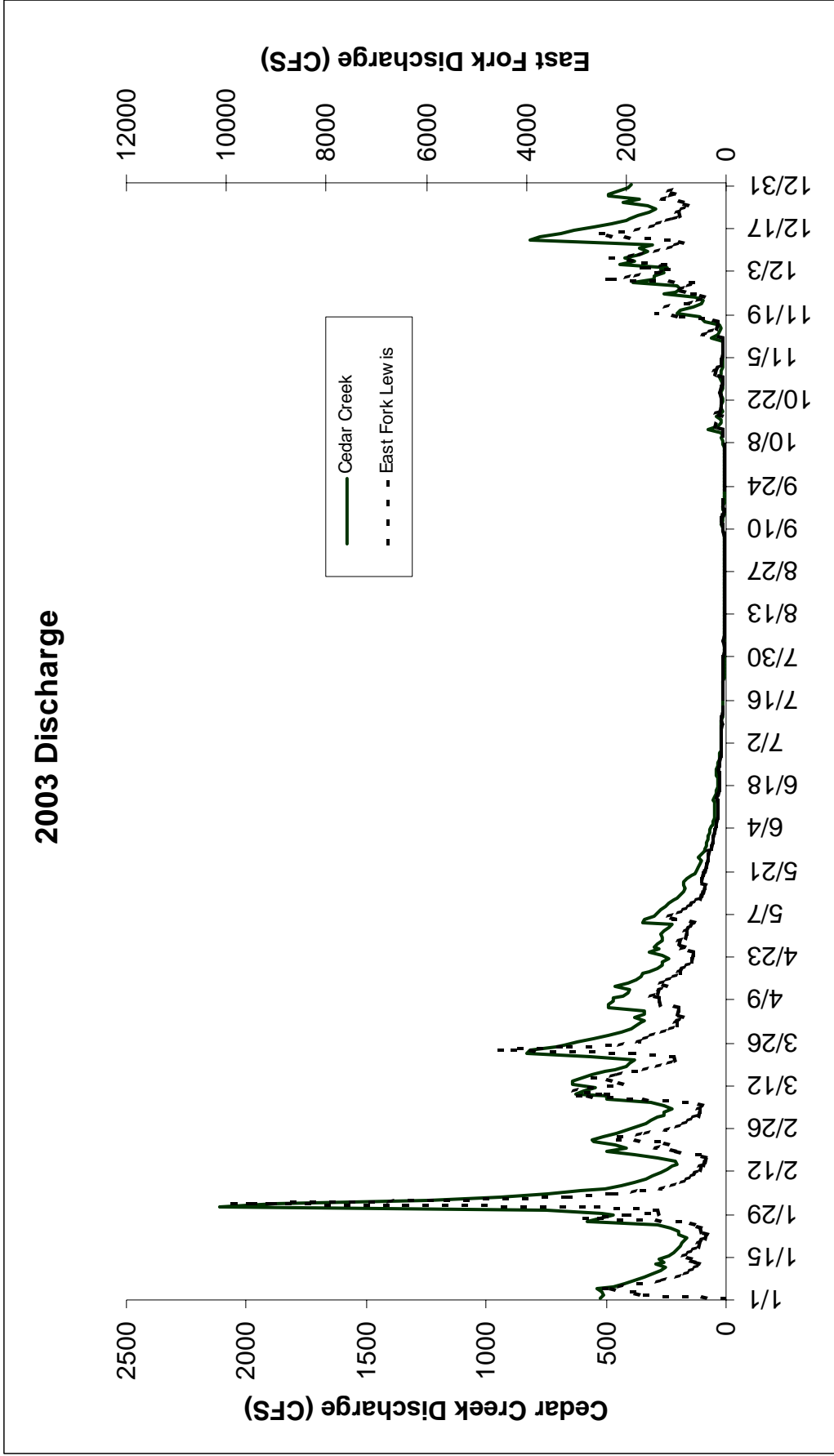


Figure 2. Discharge for East Fork Lewis River, Heisson Station (USGS) and Cedar Creek (Washington Department of Ecology), 2003.

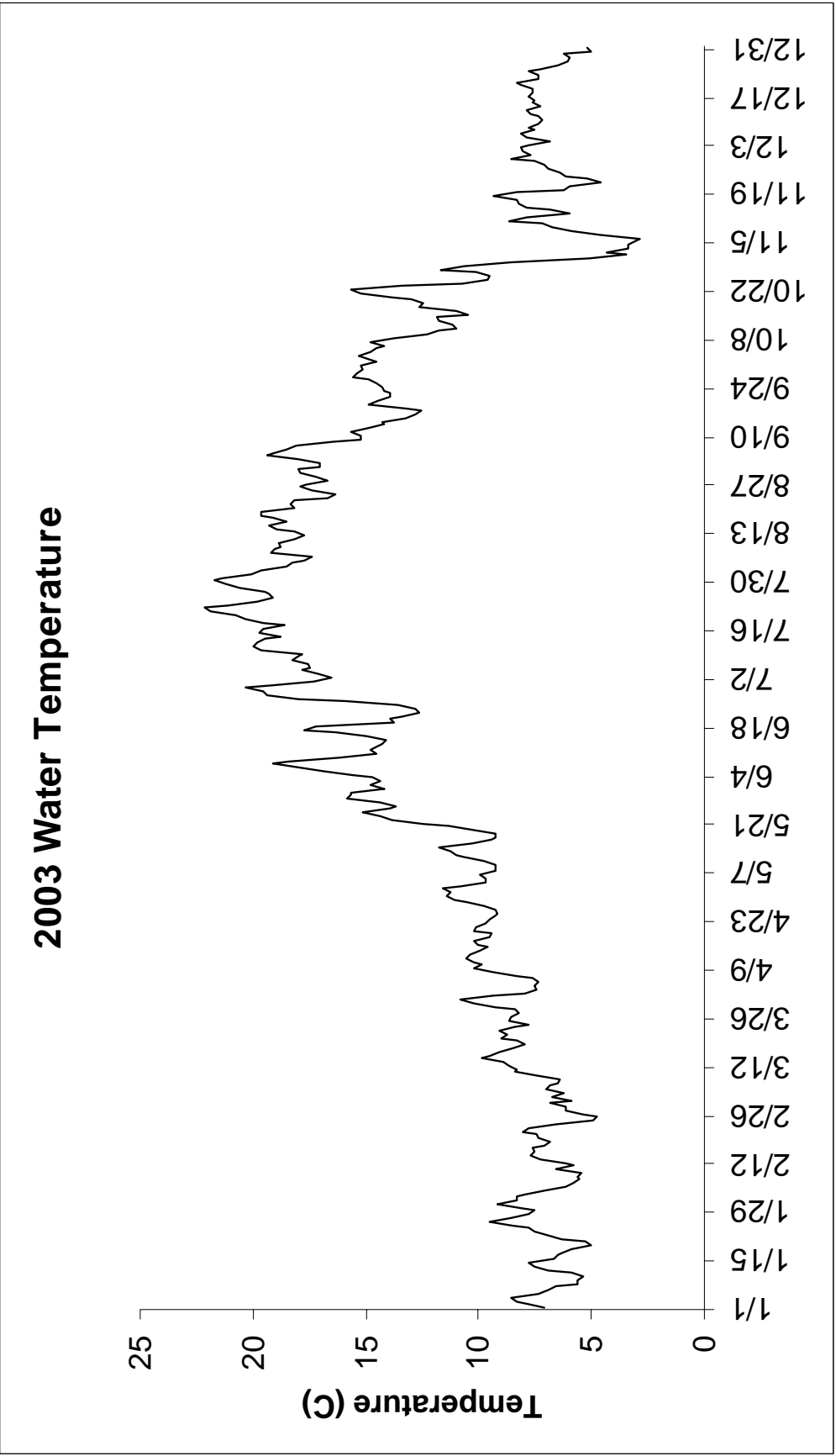


Figure 3. Water temperatures recorded on Cedar Creek at the Grist Mill using an Onset Hobo® temperature logger, 2003. Temperature data from 1/1/03 to 3/13/03 was provided by the Washington Dept. of Ecology.

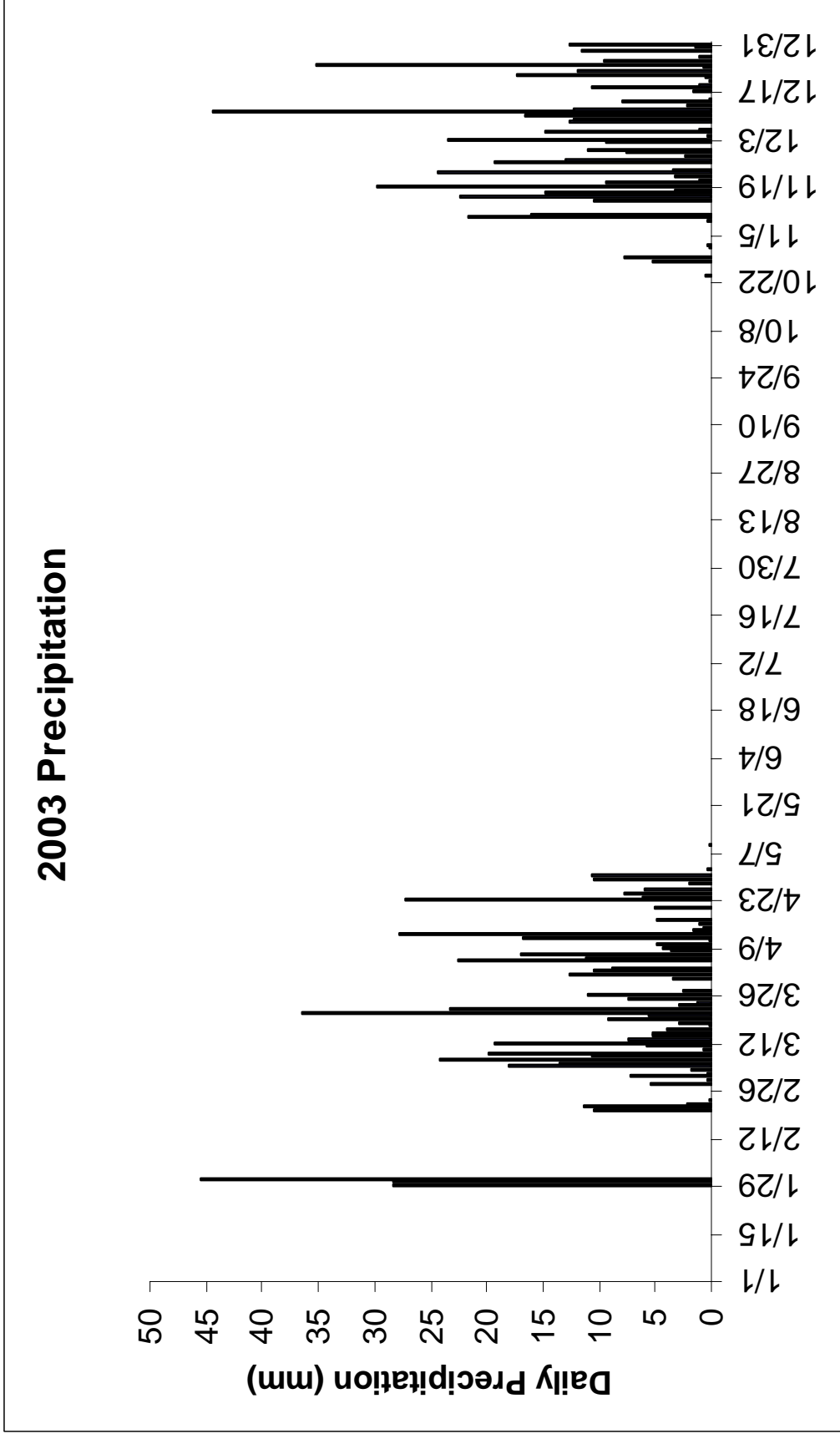


Figure 4. Precipitation recorded on Cedar Creek at the Grist Mill using an Onset Hobo® rain gage, 2003.

Methods

Larval Lamprey Density

In previous years, spatial distribution and habitat association of larval lamprey in Cedar Creek were studied using a stratified systematic point-sampling technique. After 3 years of field activities, this technique has been applied to the entire Cedar Creek drainage. However, results have yielded highly variable abundance estimates and removal efficiency has been unreliable due to violation of assumptions, species behavior, and environmental logistics. In lieu of reapplying this sampling design to Cedar Creek in 2003, a pilot study was conducted to assess backpack electrofisher removal efficiency and to validate the 70% depletion protocol (Pajos and Weise 1994) used for juvenile Pacific lamprey (*L. tridentata*). An additional objective of the pilot study was to investigate developing a correction factor to reduce highly variable abundance estimates.

The controlled field study consisted of “engineered” sample points using net pen enclosures (Figure 5) placed in Cedar Creek (Figure 5). 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 the creek. Known numbers of lamprey in two size categories (>60mm, <60mm) were added to two net pen enclosures and were allowed to equilibrate for 24 hours before sampling occurred. An effort was made to maintain a 1:1 size ratio for each trial (i.e., a trial with 60 fish total had 30 fish <60mm and 30 fish >60mm). 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. 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). Once larvae emerged, 30 pulses/second was applied to stun the larvae. Each point 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 study will allow us to assess the efficiency of our electrofishing gear and the 70% depletion model (Pajos and Weise 1994) under varying habitat conditions, densities, and sizes of fish. A correction factor could then be developed and applied to the lamprey density data from previous years with hopes of clarifying our juvenile distribution and abundance estimates.



Figure 5. Net-pen enclosures used to assess backpack electrofisher efficiency and the 70% depletion model on Cedar Creek, WA 2003.

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 was deployed and operational from January 3 through the end of the calendar year with periods of non-operation due to high or insufficiently low flow. When fishing, the trap was checked daily and during high flows, the trap was checked as many times as necessary to ensure safe and efficient operation. On January 31, 2003 the screw trap was damaged due to high flows and large debris. The trap was removed from Cedar Creek, repaired and re-deployed on March 19th. In late summer 2002, an experimental battery-powered motor was attached to the trap during low flow conditions but it was concluded that operations were not cost-effective, committing a high number of worker hours during a period when emigrant activity was lowest. Furthermore, battery operations were only sufficient to operate the screw trap at 5 rpm (revolutions per minute), which at this rate, could not guarantee trap retention. Therefore, on June 26th, 2003 during low flow conditions, the trap was removed with plans for redeployment in mid-September. Uncharacteristically dry weather in the fall (Sept-Nov) resulted in continued low flows similar to late summer and was insufficient for screw trap operation. The screw trap operated intermittently throughout the fall when flows were sufficient for operation but continuous sampling did not begin again until December 2003.

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. 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 macrophthmia and western brook adults were marked with fin clips removed from the upper or lower caudal fin. Elastomer marks in ammocoetes and fin clips in macrophthmia were made according to a pre-determined marking schedule. First-time captures were released upstream of the trap (ammocoetes approximately 50 m and macrophthmia and western brook adults 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.

To estimate trap retention, half of the daily total captured macrophthmia 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 macrophthmia 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.

Adult Pacific Lampreys

Adult Pacific lamprey 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). In mid-March, 2003, six adult pot traps were deployed downstream from the falls near the base of the ladder and four pots were placed at the mouth of Cedar Creek. Two additional pots were placed inside the adult ladder.



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

Captured lamprey were anesthetized with MS-222, measured for length and weight, and marked with a PIT tag and a dorsal fin clip. 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.

In 2003, a radio telemetry pilot study was conducted to examine the movements of returning adult Pacific lamprey. Lamprey were captured using

adult pot traps. Fish meeting pre-determined size (at least 10cm mid-girth measurement) requirements were anesthetized and then fitted (surgically implanted) with radio tags. After full recovery, tagged fish were released at their point of capture. A fixed receiver with bi-directional aerial antennas was installed at the mouth of Cedar Creek to determine if Pacific lamprey leave the drainage. Another fixed receiver with bi-directional aerial antennas was installed at the upstream end of suitable lamprey spawning habitat. A final receiver with underwater antennas was installed above and below the Grist Mill falls. In addition to tracking lamprey movement through the falls, this receiver was intended to provide information as to the efficacy of calculating population abundance using the salmonid fish ladder as the sole source for mark-recapture estimates. At least once a week, mobile tracking was conducted and fixed stations were downloaded to locate lamprey in Cedar Creek.

Spawning

Lamprey nests were identified by foot surveys during the spawning period. Foot surveys began April 16th and continued until the end of June. Based on 2000-2002 nest density (Figure 7), the areas surveyed in 2003 were divided into seven index reaches in high nest density areas and two 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. When possible, locations of each nest were recorded with global positioning system (GPS) technology. 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 laser 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.

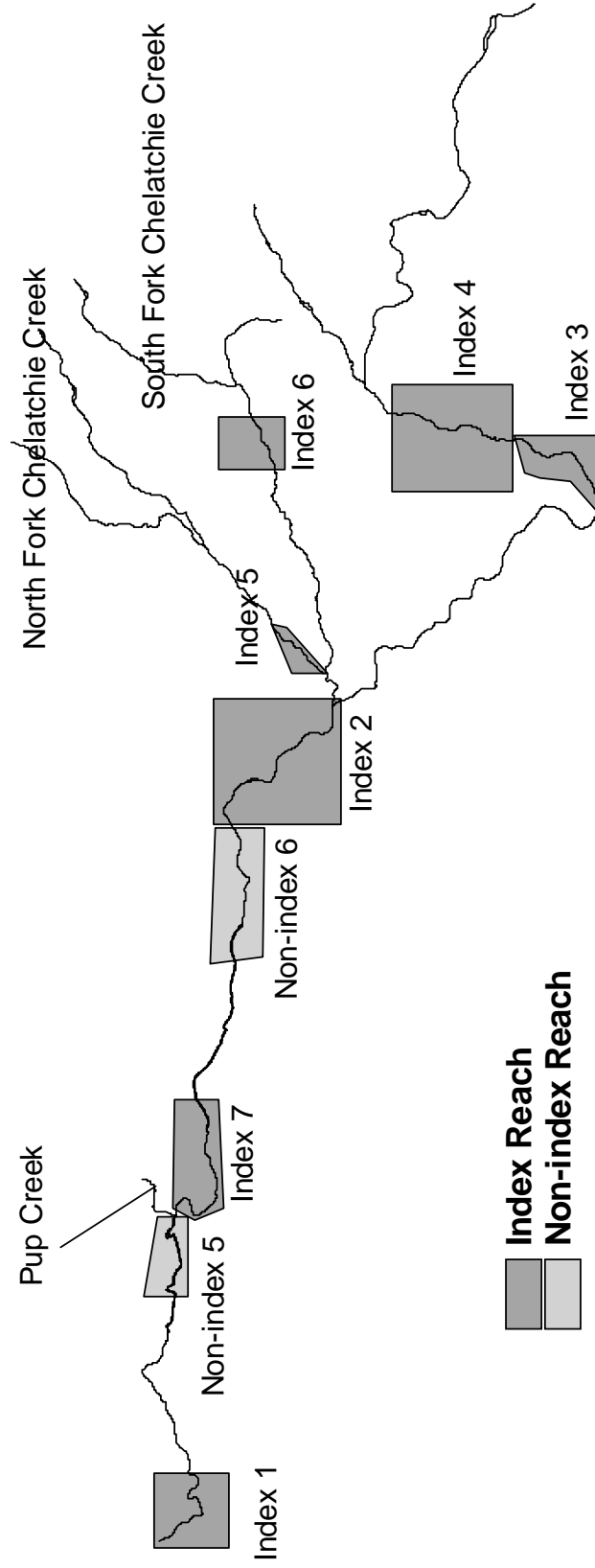


Figure 7. Areas routinely surveyed for Pacific lamprey and western brook lamprey nests. Areas in between were surveyed once during the spawning season, Cedar Creek, WA, 2003.

Results

Larval Lamprey Density

The controlled field study was conducted from August 10, 2003 to September 7, 2003. A total of 16 trials were completed in 2003 to examine the efficiency of the backpack electrofisher and to validate the 70% depletion model (Pajos and Weise 1994) that was used to estimate lamprey density in previous years. A minimum of 24 and a maximum of 130 juvenile Pacific lamprey were used in the trials. To satisfy the requirements of the 70% depletion model, 2-pass trials were required once, 3-pass trials were required 3 times, 4-pass trials were required 8 times, and trials where all 5 passes were necessary, occurred 4 times. Temperature and conductivity were consistent between trials and throughout the study period. Average temperature inside and outside of the net pens was 17.55°C and 17.56°C, respectively. Average conductivity inside and outside of the net pens was 97.86 μ s and 98.19 μ s, respectively. During the study, visibility within net pens was clear and did not impair sampling.

The 70% depletion model (Pajos and Weise 1994) had an associated error for individual size groups and both size groups combined (Table 1). Furthermore, for small fish at higher densities, the 70% depletion model produced a bias that overestimated abundance. For both size groups combined, the depletion model had an 8% mean error and 28% absolute mean error in predicting abundance. For fish >60mm, the depletion model had a -6% mean error and 17% absolute mean error. For fish <60mm, the depletion model had a 28% mean error and 32% absolute mean error (Table 1). In order to correct for the depletion model error, a regression was applied to all treatments (both size groups, only fish >60mm, and only fish <60mm) (Appendix 1). For each treatment, regression analysis using depletion model estimates provided a decrease in mean error. Regression analysis yielded abundance estimates with mean errors of 2%, 13%, and 2% for both size groups combined, only fish <60mm, and only fish >60mm, respectively. Regression analysis provided abundance estimates with absolute mean errors of 14%, 31%, and 14% for both size groups combined, only fish <60mm, and only fish >60mm, respectively. This was an improvement from using only the 70% depletion model estimates. The largest improvement was for fish <60mm where mean error was reduced from 28% to 13%. The regression equation for both size groups is $Y=1.77X_1+0.18X_2+4.07$ with an $R^2=0.923$. The regression for fish <60mm is $Y=.48X_1+13.43$ with an $R^2=0.689$ and $Y=1.01X_1+1.76$ with an $R^2=.911$ for fish >60mm (Table 2). X_1 and X_2 are defined as the 70% depletion model estimates for fish greater than 60mm and less than 60mm, respectively.

Table 1. Data collected to assess the efficiency of the backpack electrofisher on juvenile Pacific lamprey in Cedar Creek, WA, 2003 using a 70% depletion model and the mean error produced by regression analysis.

70% Depletion Model		mix size groups				>60 mm				<60 mm				no. passes			
date	actual	predict	% error	%error	actual	predict	% error	%error	actual	predict	% error	%error	actual	predict	% error	%error	
14-Aug	65	53	-18%	18%	32	25	-22%	22%	33	31	-6%	6%	5	31	-6%	6%	5
14-Aug	64	44	-31%	31%	32	30	-6%	6%	16	16	0%	0%	4	16	0%	0%	4
15-Aug	32	43	34%	34%	16	23	44%	44%	16	28	75%	75%	4	28	75%	75%	4
15-Aug	32	30	-6%	6%	16	15	-6%	6%	16	16	0%	0%	4	16	0%	0%	4
18-Aug	63	82	30%	30%	31	36	16%	16%	32	53	66%	66%	4	53	66%	66%	4
18-Aug	60	135	125%	125%	30	36	20%	20%	30	29	-3%	3%	5	29	-3%	3%	5
19-Aug	24	21	-13%	13%	14	9	-36%	36%	10	13	30%	30%	4	13	30%	30%	4
19-Aug	28	13	-54%	54%	13	8	-38%	38%	15	18	20%	20%	2	18	20%	20%	2
20-Aug	100	95	-5%	5%	50	53	6%	6%	50	46	-8%	8%	3	46	-8%	8%	3
20-Aug	100	90	-10%	10%	50	43	-14%	14%	50	48	-4%	4%	4	48	-4%	4%	4
21-Aug	100	87	-13%	13%	50	47	-6%	6%	50	44	-12%	12%	3	44	-12%	12%	3
21-Aug	100	94	-6%	6%	50	42	-16%	16%	50	58	16%	16%	5	58	16%	16%	5
22-Aug	130	142	9%	9%	65	63	-3%	3%	65	90	38%	38%	4	90	38%	38%	4
22-Aug	130	193	48%	48%	65	56	-14%	14%	65	121	86%	86%	5	121	86%	86%	5
25-Aug	80	113	41%	41%	40	39	-3%	3%	40	91	128%	128%	4	91	128%	128%	4
25-Aug	80	81	1%	1%	40	34	-15%	15%	40	47	18%	18%	3	47	18%	18%	3
mean % error			8%	28%			-6%	17%			28%	32%				32%	
mean abs % error																	
<u>Regression Correction</u>																	
mean % error			2%	14%			2%	14%			13%	31%				31%	
mean abs % error																	

Emigrants

The floating rotary screw trap fished for 89 days during sampling year 2003. A decrease in total days fished (in comparison to previous years) was due to a variety of factors such as trap damage and inoperability (February-mid March), no battery powered operation during low flow months (July-mid Sept), and an uncharacteristically dry fall (mid September-December) providing insufficient flows. Despite fewer days fished, an increase in catch (compared to 2002) was observed for all life history stages of both Pacific lamprey and western brook lamprey. A total of 518 Pacific lamprey ammocoetes, 460 Pacific lamprey macrophthalmia, 7 western brook lamprey ammocoetes, and 18 western brook lamprey adults were captured via the rotary screw trap (Table 3). In 2003, trap efficiency marks were given to 321 and 329 Pacific lamprey ammocoetes and macrophthalmia, respectively. Marks were given to 6 and 5 western brook lamprey ammocoetes and adults, respectively (Table 3). Eight Pacific lamprey ammocoetes, 30 macrophthalmia, and one western brook ammocoete were subsequently recaptured. Average trap efficiencies were estimated to be 2% for Pacific lamprey ammocoetes and 9% for Pacific lamprey macrophthalmia (Table 3). Due to low captures of western brook lamprey, trap efficiencies were not calculated for ammocoetes or adults. Population estimates were not calculated in 2003 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 January, March-April, June, and December (Figure 9). Ammocoete movement during January, late March-April, and December was associated with discharge and movement from May-June was not (Figure 9). Recaptured ammocoetes were low relative to the number of fish marked (Table 3).

Peaks in macrophthalmia movement were more isolated, occurring only in January (Figure 10). However, activity was also recorded from April-June and in December. Macrophthalmia movement was associated with discharge in January and December but movement from April to June was not (Figure 10). Relative to the number of macrophthalmia marked, recaptures in 2003 were low (Table 3).

Adult Pacific Lampreys

A total of 156 adult Pacific lampreys were captured in Cedar Creek in 2003 (Figure 11). Adults were captured between April 1 and December 3, 2003. Lamprey pot traps in various locations on the creek captured 67 adults. Sixty-five adult Pacific lamprey were captured in the ladder and 19 were captured in a pot placed inside the ladder. Two were captured in the screw trap and 2 were found out of water. These 2 fish appeared to be a product of trap vandalism but fortunately, both fish survived. All but 3 adult lamprey captured were in pre-spawning condition. Of the 156 adults captured, 153 were marked with PIT tags and 43 of these fish were later recaptured. Capture efficiency for

Table 3. Data collected from juvenile lampreys captured in the rotary screw trap at the Grist Mill, Cedar Creek, Washington, in 2003.

	<u>Pacific Lamprey</u>		<u>Western Brook Lamprey</u>	
	<u>Ammocoete</u>	<u>Macrophalmia</u>	<u>Ammocoete</u>	<u>Adult</u>
Minimum Length (mm)	43	97	107	98
Average Length (mm)	96.4	131.7	123.9	112.9
Maximum Length (mm)	146	178	135	127
Minimum Weight (g)	0.1	1	1.2	2.1
Average Weight (g)	1.5	3.1	2.8	2.7
Maximum Weight (g)	4.8	7.7	3.8	3.9
Total Captured	518	460	7	18
Trap Efficiency Marks	321	329	6	5
Number Recaptured	8	30	1	0
Average Trap Efficiency (%)	2	9		

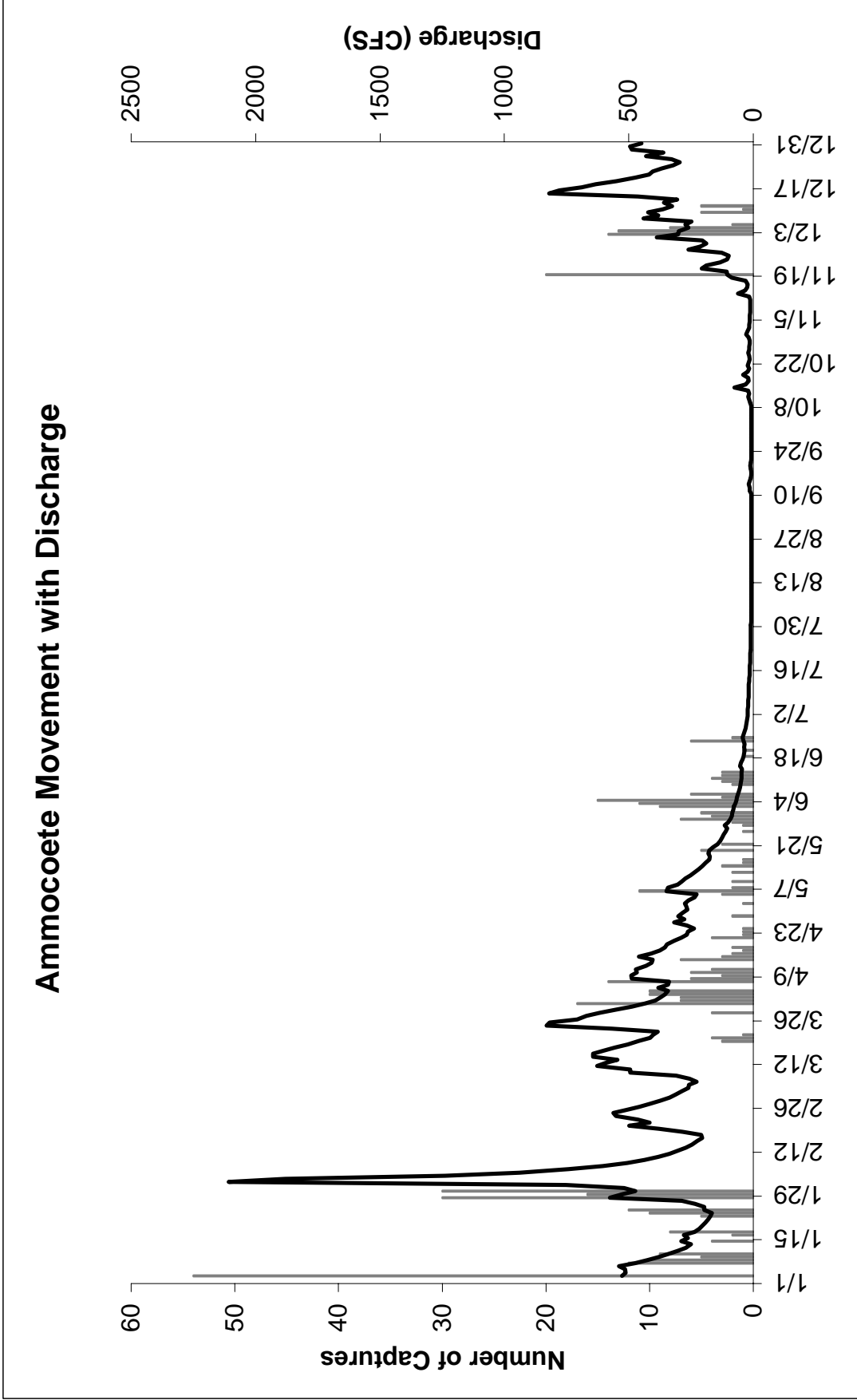


Figure 9. Ammocoete captures and discharge, Cedar Creek, WA, 2003.

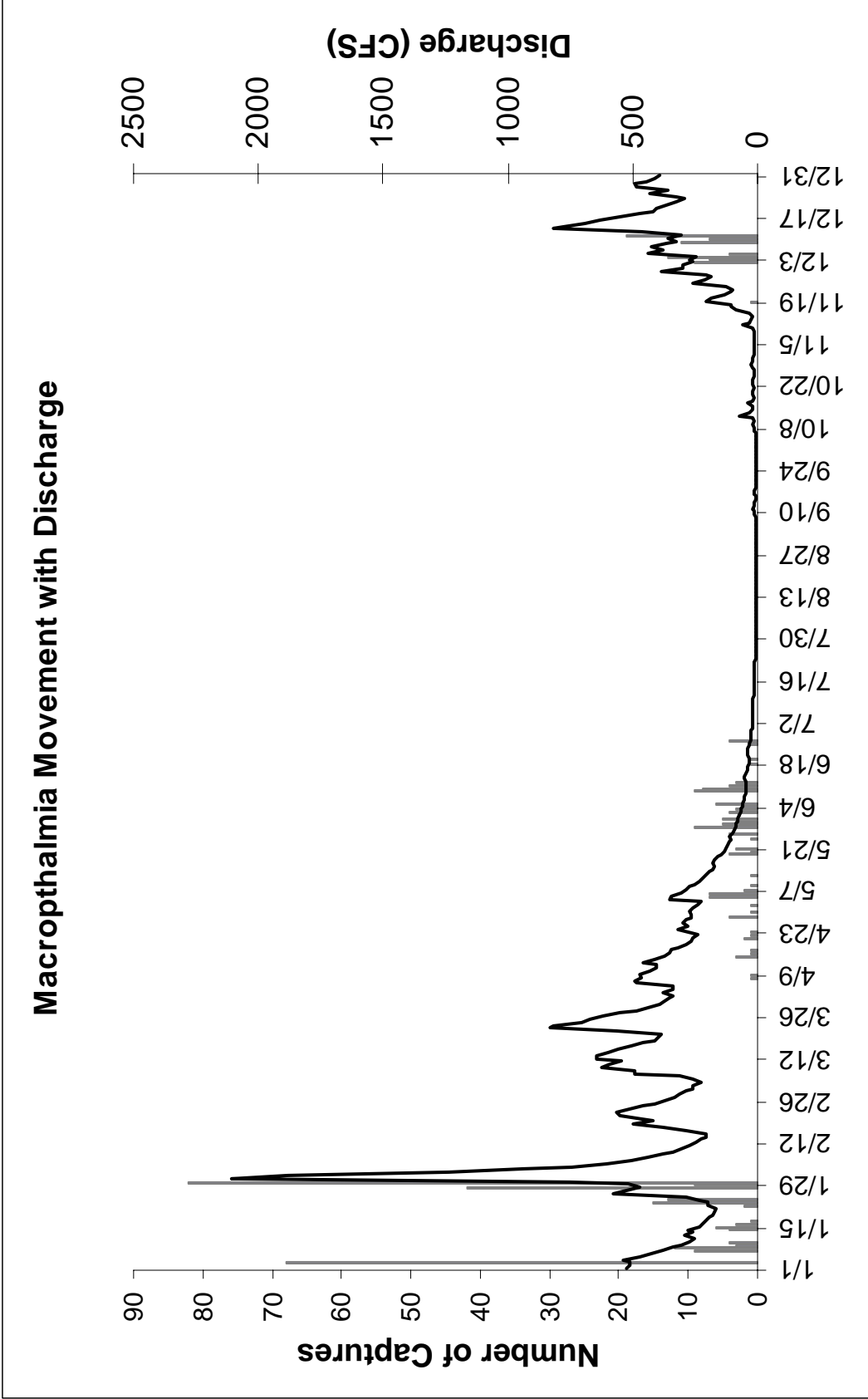


Figure 10. Pacific lamprey macrophthalmia captures and discharge, Cedar Creek, WA, 2003.

adults using lamprey pots and the ladder were 8% and 21%, respectively. A rough population estimate was calculated to be 693 ± 153 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 637, 522, and 421 mm, respectively. Maximum, mean, and minimum Pacific lamprey adult weights were 361, 244, and 135 g, respectively. The length to weight relationship can be described by $y = 0.9943x - 276.34$ with $R^2 = 0.7153$. Girth measurements were recorded from 115 fish. Average anterior girth was 92 mm, average medial girth was 91 mm, and average posterior girth was 74 mm respectively. It should be noted that body circumference measurements were recorded for adults in an effort to identify lamprey meeting size requirements for radio telemetry. Therefore, averages are representative of Pacific lamprey adults on the larger end of the distribution for Cedar Creek.

Spawning

Fifty-three spawning ground surveys were conducted during the spawning period (April 16, 2003 through July 14, 2003). A total of 109 Pacific lamprey nests and 22 western brook lamprey nests were identified and locations were assigned coordinates with a GPS. Temperatures during this time ranged between 10 and 22 °C.

The two species of lamprey in Cedar Creek utilize different areas of the drainage to spawn (Figure 12). Pacific lamprey nests were most abundant near the mouth of Cedar Creek. Western brook lamprey nests were most abundant on the Chelatchie forks, but infrequently occurred on Pup Creek and on mainstem Cedar Creek.

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 lamprey 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).

Pacific lamprey spawning activity was observed twice during spawning ground surveys. A pair of lamprey (1 male, 1 female) were observed constructing a nest and digging in areas around the nest near the mouth of Cedar Creek. Another event was witnessed with two females and one male constructing nests and actively spawning, also near the mouth of Cedar Creek. Both sexes participated in nest construction. Multiple spawning events were observed with the male spawning with both females in what appeared to be an uncharacteristically large nest. Video of this spawning event and a detailed description of spawning behavior observed will be available on the CRFPO webpage (<http://columbiariver.fws.gov>) in early 2004.

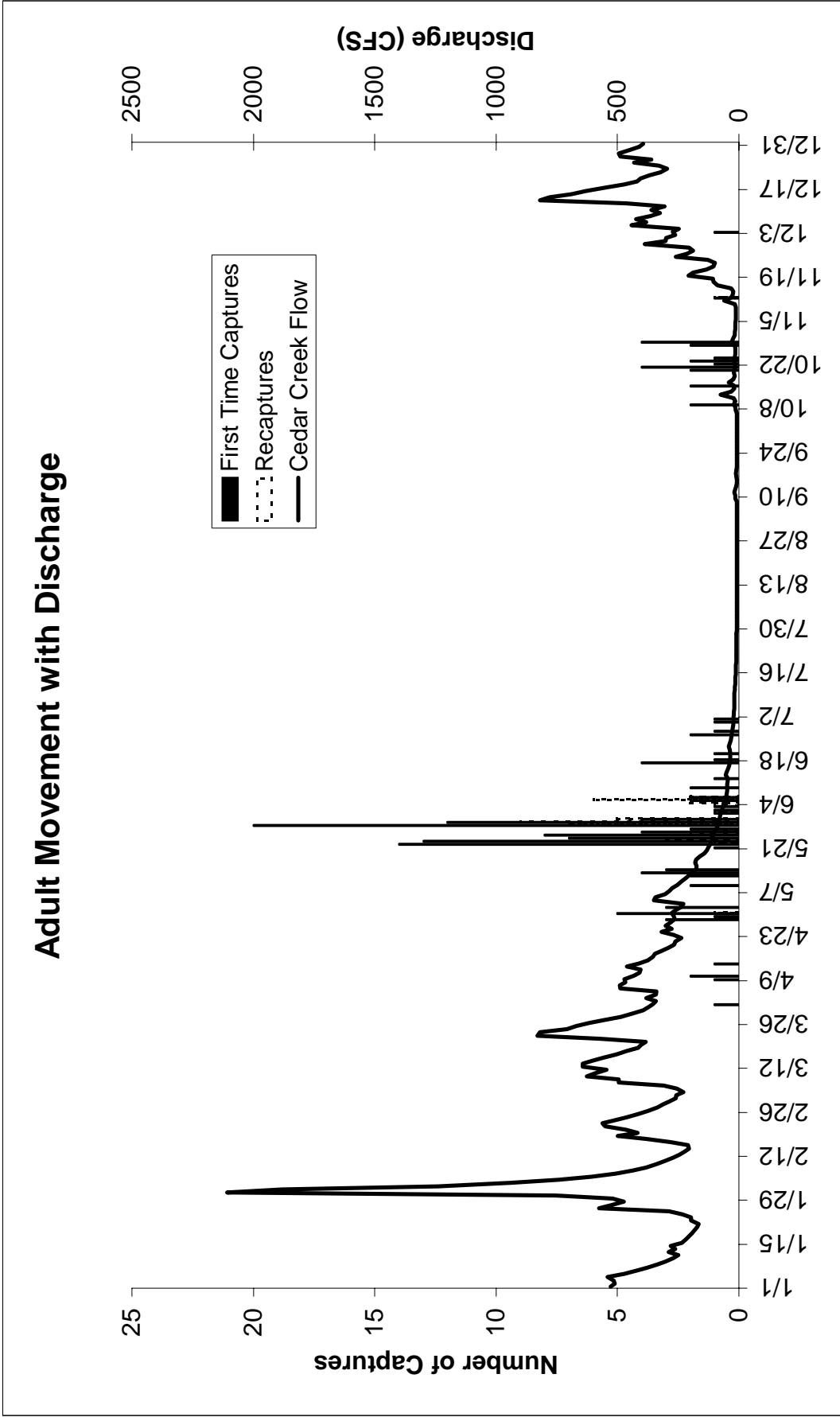


Figure 11. Pacific lamprey adult movement and recaptures with discharge on Cedar Creek, WA 2003.

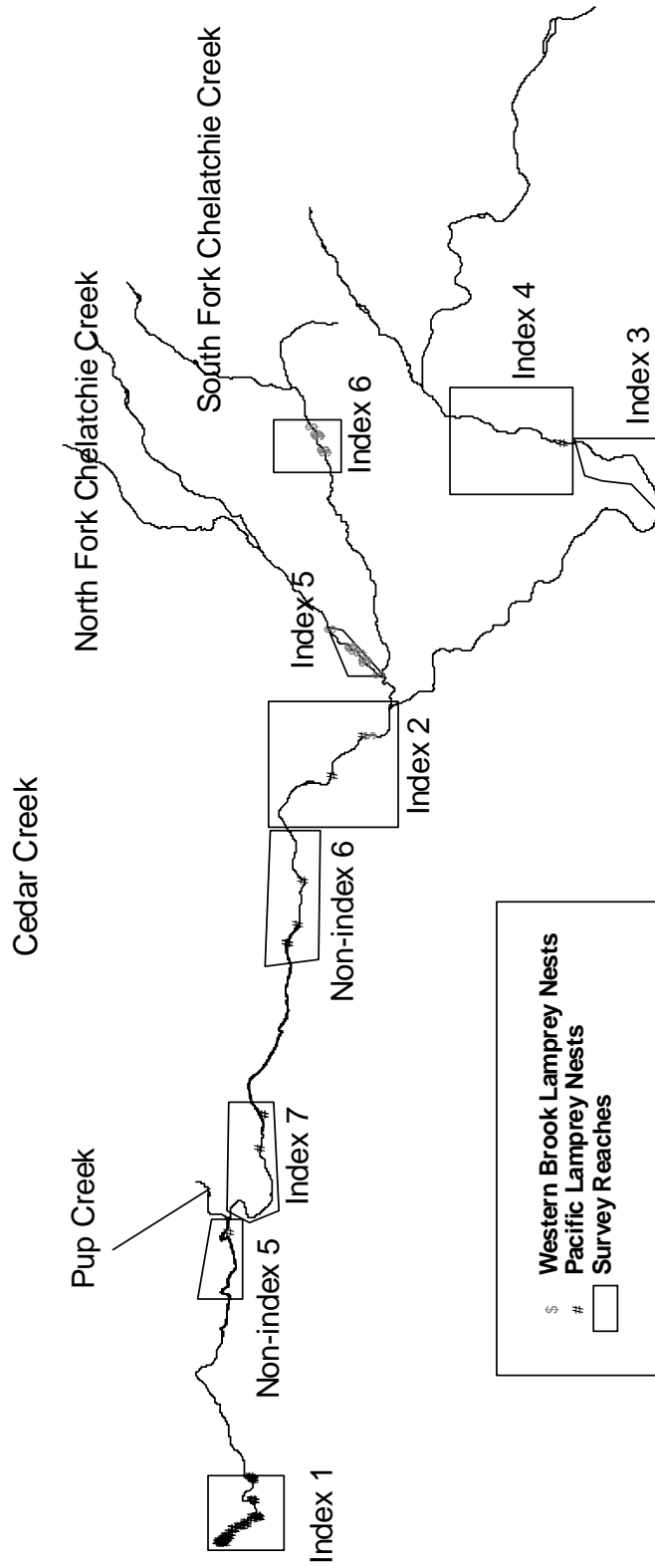


Figure 12. Locations of Pacific and western brook lamprey nests on Cedar and Chelatchie Creeks, WA 2003.

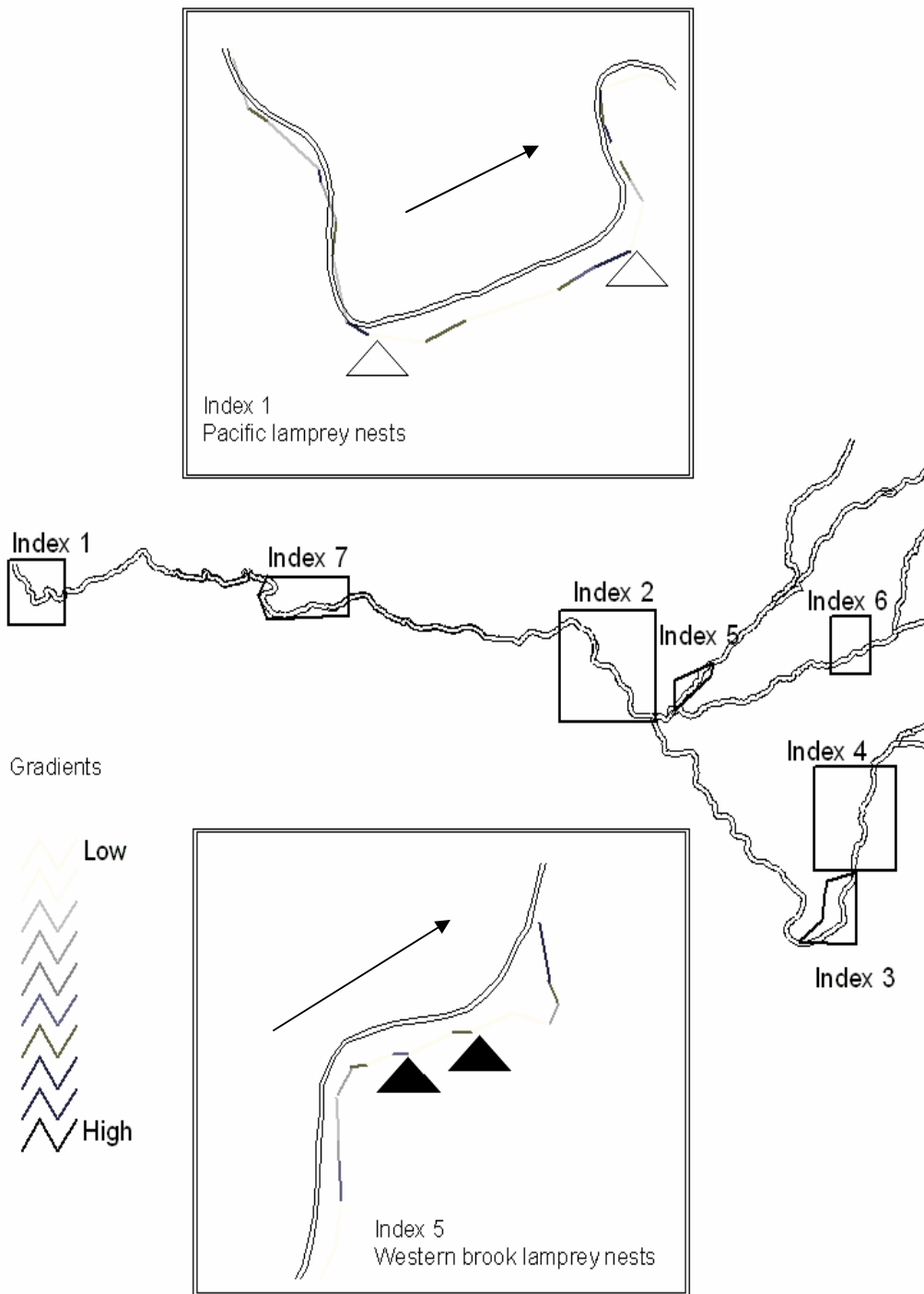


Figure 13. Location of Pacific lamprey and western brook lamprey nests with gradient, Cedar Creek, WA, 2003. Arrows indicate upstream direction. Triangles indicate location of nest clusters.

Four Pacific lamprey carcasses were found during spawning ground surveys in 2003. 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. The other two carcasses were found at the bottom of deep pools and could not be retrieved to assess sex, condition, or previous capture. All carcasses were found on Index Reach-1 near the mouth of Cedar Creek.

Western brook lamprey spawning activity was observed on several occasions during the spawning period. These lamprey were not easily scared away and close observation of spawning behavior was possible using an aquascope. A minimum of one and a maximum of seven lampreys were observed at each nest. Behavioral observations included, lamprey cooperatively moving pebbles outside of the nest, each sucking on to a spot on larger rocks, collectively moving them out of the way.

Ten Pacific lamprey adults were radio tagged in 2003. Lamprey were tagged from April 29 to June 17 with tag life varying from 61 to 230 days. Of the ten lamprey tagged, 8 were male and 2 were female. Two lamprey adults were captured at the mouth of Cedar Creek and 8 were captured at the Grist Mill. After radio tags were surgically implanted, tagged fish were released back at the site of capture.

Lamprey movement in Cedar Creek was minimal. Five tagged lamprey at the Grist Mill site remained within 100 meters of the release site, holding in large, deep pools. One male lamprey moved downstream from the Grist Mill to the mouth and was detected within several meters of two nests. On July 2, two radio tagged males were tracked within several feet of a nest. At the mouth of Cedar Creek, two radio tagged lamprey were released and immediately left the drainage entering the North Fork Lewis River. Neither fish was detected re-entering Cedar Creek and no mobile tracking was done outside of the Cedar Creek system to relocate these fish.

Discussion

An electrofisher specifically designed for removing larval lamprey was used in this study to determine larval presence/absence and density at both the reach and subreach (1 m² sample point) scales. The ability to effectively detect larval lamprey is dependent upon our gear efficiency. One of the challenges of the project has been to calculate reliable population estimates of the larval life history stage. To address this challenge, the efficiency of the sampling gear and the 70% depletion model (Pajos and Weiss 1994) at the sample point scale were examined using a controlled field study. Our preliminary results suggest that although we are detecting presence within the first two passes, the 70% depletion model has an error for large (>60mm), small (<60mm), and mixed groups of fish. Although regression analysis does correct for some of the error with the 70% depletion model, the nature of the controlled field study is representative of “ideal” sampling conditions where fish are in enclosures and

have higher probabilities of capture after being extracted from the substrate. Furthermore, sampling crews are aware of fish presence during each trial, which likely affects sampling effort. Both aspects of the experimental design would suggest that the error associated with the depletion method is a minimum error and that we should expect to see higher error in our field sampling where enclosures are not used and presence is not known. In 2004, trial densities will be kept unknown to sampling crews in an effort to create an environment similar to field sampling.

Our gear efficiency data suggests that if lamprey are present within a sample point, we are likely to detect it within the first two passes. Therefore, our "sample point" classifications from past years' field data for fish presence are probably accurate. In 2002, half of the sites resampled for larval presence/absence contained lamprey when surveys 1-2 years previous had determined that larval lamprey were absent. This discrepancy could indicate that our sample design is unable to accurately determine presence/absence under very low larval densities or patchy habitat. It is important to note that our gear efficiency study used net pens with preferred habitat conditions and relatively high densities representative of preliminary core samples from the field. In order to address this discrepancy and to increase our confidence in detecting presence over varying densities, future trials of the controlled field study will include lower densities than were tested in 2003 and lamprey densities similar to those found in patchy habitat on Cedar Creek. All data collected from future trials will be integrated into the existing regression correction. Another goal of the gear efficiency study in 2004 will be to build density probability curves from our data to address the challenges in estimating abundance with high levels of certainty.

In 2003, larval abundance and habitat use data were not collected. Instead, gear efficiency and testing of the 70% depletion model were investigated. In 2004, the sample design for assessing larval abundance and habitat use will be modified and if workload allows, implemented. One problem that we encountered with the stratified systematic sampling approach was that not enough (approximately 30% in 2000, 12% in 2001, and 32% in 2002) points sampled, contained lamprey. Multivariate statistics rely on "successes" to model relationships between lamprey occurrence/density (if possible) and habitat. Sample design modifications will increase the chances of "successes" in lamprey occurrence/density in an effort to develop a more reliable habitat use model.

Ammocoete movement, as observed through screw trap operations, occurs throughout the year and is associated with both discharge patterns and transformation. In January, March to April, and November through December, ammocoetes moved during high discharge periods that were likely scouring events. In May and June, during periods of decreasing discharge, ammocoetes captured were significantly larger (ANOVA, $p < .05$) than ammocoetes captured in winter months. It is likely that the larger ammocoetes are starting their transformation further downstream and that these captures are characteristic of active movement versus displacement from scouring events. Beamish and Levings (1991) also documented an increase in the abundance of larger ammocoetes moving during macrophthalmia migration. In 2003, capture of larger

ammocoetes coincided with the spring macrophthalmia migration. In previous sample years ammocoetes were only recaptured during these periods, which suggested active migration (Stone et al. 2002). However, in 2003, recaptures occurred during all months ammocoetes were captured, which does not support that only older individuals nearing transformation are actively moving. As more data is collected, it may be possible to distinguish between captures from active movement versus displacement as well as temporal trends related to transformation.

Macrophthalmia outmigrate with high water during late fall-winter and also in late spring and summer, regardless of flow. Beamish and Levings (1991) observed that macrophthalmia emigration was almost always associated with high discharge events. In Cedar Creek, peak movement occurred in May-June when discharge was decreasing and in January, and November-December when discharge was increasing. Marked macrophthalmia were also recaptured during these periods. 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 in 2002, we found that only a small portion of fish that make it into the livebox are retained. In 2003, modifications were made to the debris wheel and livebox with the addition of compression rings as both areas were identified as sources of escapement from the retention study in 2002. Retention for the livebox in 2002 was 64% (7 out of 11) for macrophthalmia and 51% (28 out of 55) for ammocoetes. In 2003, after structural modifications had been made, retention was 74% (64 out of 87) for macrophthalmia and 45% (48 out of 106) for ammocoetes. Although, percent retained did not significantly improve after modification, our results suggest that there may be some improvement for livebox retention considering we operated the screw trap with less effort in 2003 (89 days) versus 2002 (263 days) yet were still able to observe as much as an 8-fold increase in catch for macrophthalmia and a two-fold increase for ammocoetes. However, this modification should not improve our trap efficiencies (assuming that marked fish escape at a rate that is equal to unmarked fish). 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 macrophthalmia.

Cedar Creek is a flashy system that responds to rain events with high flows and high transport of large woody debris. In past years, screw trap operation at the Grist Mill (2.4 miles upstream of the mouth of Cedar Creek) has posed challenges due to its stream morphology, which concentrates discharge into a fraction of the stream's wetted width. This has resulted in flow conditions that compromise safety, sampling and consistent operation during the winter, when heavy rainfall is characteristic and catch is relatively high. Furthermore, information from our spawning ground surveys suggest that a large proportion of adult Pacific lamprey spawning activity is occurring downstream of our current screw trap location. Although we will continue to operate the screw trap at the current location, we will begin the section 10 permitting process with the NOAA Fisheries to begin operating the screw trap at the mouth of Cedar Creek in the fall of 2004. The new location provides flows sufficient for safe operation, continuous sampling, and will enable us to characterize emigrant activity for the entire Cedar Creek drainage.

Adult Pacific lamprey enter the creek between May and November and are detected through capture in the adult ladder and pot traps deployed at various locations in Cedar Creek. Movement is divided into an early pulse of spawners (April-July) and a late pulse of upstream migrants (September-November) (Stone et al. 2001, Stone et al. 2002). It is uncertain whether early migrants immediately spawn or if they overwinter as do the late migrants. 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.

In 2004, more effort will be expended on capturing adult Pacific lamprey. A systematic sampling design will be implemented that establishes index and non-index pots, documents fishing effort, and generates data that is compatible with available multi-mark recapture software. This will allow us to address questions regarding trap catchability and to calculate population estimates without assumption violations. Additional trap pots will be placed in various locations on Cedar Creek in order to increase adult catch, marked fish, and chances of recapture.

Observed movement of radio tagged lamprey in Cedar Creek was minimal in 2003. Tagged lamprey either left the Cedar Creek drainage and were no longer monitored or were found holding in deep, slow moving pools within 100m downstream of their release site. When movement was detected, it was sporadic and did not provide sufficient information to characterize pre-spawning behavior of adult lamprey. Unfortunately, insufficient resources were dedicated to this pilot study in 2003 as other activities directly related to project objectives took priority. Mobile radio tracking during the adult spawning season was erratic and focused strictly on known locations of tagged lamprey. Exploratory tracking for "lost" fish did not occur and was unrealistic given the existing workload. Furthermore, locations for fixed tracking stations (3) in the Cedar Creek drainage were based

on observations made during 2002 spawning ground surveys. In 2003, spawning activity shifted downstream due to drastic changes in upstream spawning habitat suitability. This resulted in the upstream fixed station recording no movement, spatially unbalanced coverage for fixed stations in Cedar Creek, and little movement data collected via fixed stations.

Adult radio telemetry in Spring 2004 will not be pursued due to changes and increased effort in existing objectives. Future work may include testing the hypothesis whether the fall pulse of adult Pacific lamprey in Cedar Creek are overwintering, winter movements, and habitat use. Implementation will be dependent upon the feasibility of a sampling design/schedule that is compatible with the existing winter workload.

Pacific lamprey and western brook lamprey spawned in different sections of the Cedar Creek drainage. Of the areas surveyed (Cedar, Pup, and Chelatchie creeks), Pacific lamprey were observed spawning only within mainstem Cedar Creek. Western brook lamprey spawning was concentrated in the Chelatchie creeks and Pup Creek tributaries, and rarely was observed in Cedar Creek. This separation is likely due to habitat preferences. Pacific lamprey prefer to spawn in larger substrate and faster water velocities than western brook lamprey.

A large proportion of the Cedar Creek drainage is privately owned. Land-use practices such as logging and cattle farming have created areas of degraded habitat throughout the system. Coupled with high flow and scour events during the winter, suitable spawning habitat within Cedar Creek is dynamic and changes can be observed from year to year. In 2002, 28 nests (27 Pacific lamprey, 1 western brook) were observed in index reaches 3 and 4 in upper Cedar Creek. During 2003 spawning ground surveys, only one nest was observed in these same reaches. The entire spawning area had become clogged with fine sediment creating habitat not conducive to spawning Pacific lamprey. It was discovered later that logging had occurred on land adjacent to these reaches. It is probable that winter rains caused sediment loading into Cedar Creek making once available spawning habitat for Pacific lamprey, unsuitable.

During 2004, the design for spawning ground surveys will be modified to create a more spatially and temporally balanced sampling regime. Index and non-index sampling reaches that maximize coverage for the entire drainage will be identified. Nest longevity data will be used to determine the frequency at which reaches need to be surveyed. This will increase survey efficiency and reduce the chances of oversampling particular reaches. Exploratory dusk surveys will be implemented during the peak of spawning. Surveyors will carry digital video equipment to record the spawning behavior of both species. A rigorous observer variance study will be conducted to evaluate individual's difference in nest identification. After spawning ground surveys are completed, habitat characterization of non-use areas for spawning adult lamprey will be investigated.

Several modifications will be made during the 2004 sampling year. The current sample design will be adjusted and expanded to allow us to better meet the various objectives of the study. Furthermore, these modifications will allow

us to provide more technical information to other agencies and the public. Sampling efforts on Cedar Creek will continue for 2004 and an annual report, similar to this, will be delivered during the early months of 2005.

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Appendix 1. Regression correction output for the backpack electrofisher efficiency study using 70% depletion on juvenile Pacific lamprey in Cedar Creek, WA. 2003.

Regression Output

All Fish

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	4.06675299	6.305747856	0.64492794	0.530191
*X1	1.76664066	0.259128171	6.81763259	1.23E-05
*X2	0.18074743	0.135361574	1.33529347	0.204691

Regression Statistics

Multiple R	0.96077585
R Square	0.92309023
Adjusted R Square	0.91125796
Standard Error	10.229884
Observations	16

Fish <60mm

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	13.4324607	4.838277956	2.77628958	0.014857
X Variable 1	0.48475384	0.087116983	5.56440118	6.97E-05

Regression Statistics

Multiple R	0.82983723
R Square	0.68862983
Adjusted R Square	0.66638911
Standard Error	10.4134635
Observations	16

Fish >60mm

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	1.76466345	3.233982291	0.54566268	0.593886
X Variable 1	1.01210266	0.084512462	11.9757801	9.6E-09

Regression Statistics

Multiple R	0.95449754
R Square	0.91106555
Adjusted R Square	0.90471309
Standard Error	5.27708257
Observations	16

* X1=The depletion model estimate for fish >60mm. X2=The depletion model estimate for fish <60mm.