U.S. Fish and Wildlife Service

Occurrence, Detection, and Habitat Use of Larval Lamprey in Columbia River Mainstem Environments: The Dalles Pool and Deschutes River Mouth.

FY 2012 Annual Report

Jeffrey C. Jolley, Gregory S. Silver, and Timothy A. Whitesel

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
Vancouver, WA 98683

On the cover: *The Dalles Pool on the Columbia River and deepwater electrofishing bell. Photo taken in October 2012 by Jeff Jolley.*

The correct citation for this report is:

Jolley, J.C., G.S. Silver, and T.A. Whitesel. 2013. Occurrence, detection, and habitat use of larval lamprey in Columbia River mainstem Environments: The Dalles Pool and Deschutes River Mouth. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, WA. 21 pp.

Occurrence, Detection, and Habitat Use of Larval Lamprey in Columbia River Mainstem Environments: The Dalles Pool and Deschutes River Mouth.

Study funded by

U.S. Fish and Wildlife Service

and authored by

Jeffrey C. Jolley
Gregory S. Silver
Timothy A. Whitesel

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
1211 SE Cardinal Court, Suite 100
Vancouver, WA 98683

Final
April 4, 2013

Disclaimers

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

The mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use by the federal government.

Occurrence, Detection, and Habitat Use of Larval Lamprey in Columbia River Mainstem Environments: The Dalles Pool and Deschutes River Mouth.

Jeffrey C. Jolley, Gregory S. Silver, and Timothy A. Whitesel

U.S. Fish and Wildlife Service
Columbia River Fishery Program Office
1211 SE Cardinal Court, Suite 100
Vancouver, WA 98683

Abstract – Pacific lamprey *Entosphenus tridentatus* are declining in the Columbia River Basin and larval lamprey use of large, mainstem river habitats is unknown. Their use of shallow depositional areas associated with tributary inputs is equally unknown. We used a deepwater electrofisher to explore occupancy, detection, and habitat use of larval Pacific lamprey and *Lampetra* spp. in The Dalles Pool and Deschutes River mouth of the Columbia River. We used a generalized randomized tessellation stratified (GRTS) approach to select sampling quadrats in a random, spatially-balanced order and used a deepwater electrofisher to collect larval lamprey. We did not detect any lamprey in our sampling and larval lampreys are likely at a density too low to detect. Substrates in The Dalles Pool were unsuitable for larval lamprey burrowing at many sites. Substrates appeared suitable for larval lamprey burrowing in The Deschutes River mouth and the lack of detection in this area was unexpected. We also conducted capture efficiency experiments with a deepwater electrofisher and found high capture efficiency (>70%) and survival after 96-h (nearly 100%). A deepwater electrofisher is effective for capturing larval lamprey and poses little risk to bodily injury.

Page intentionally left blank

Table of Contents

List of Tables

List of Figures

Introduction

Pacific lamprey *Entosphenus tridentatus* in the Columbia River Basin and other areas have experienced a great decline in abundance (Luzier et al. 2011). They are culturally important to Native American tribes, are ecologically important within the food web, and whose decline provides insight into the impact of human actions on ecological function (Close et al. 2002). Information is lacking on basic biology, ecology, and population dynamics required for effective conservation and management.

Pacific lampreys have a complex life history that includes multiple year larval (ammocoete), migratory juvenile, and adult marine phases (Scott and Crossman 1973). Larvae and juveniles are strongly associated with stream and river sediments. Larvae live burrowed in stream and river sediments for multiple years after hatching, where they filter feed detritus and organic material (Sutton and Bowen 1994). Larvae metamorphose into juveniles from July to December (McGree et al. 2008) and major migrations are made downstream to the Pacific Ocean in the spring and fall (Beamish and Levings 1991). The sympatric western brook lamprey *Lampetra richardsoni* does not have a major migratory or marine life stage although adults may locally migrate upstream before spawning (Renaud 1997). For both species, the majority of the information on habitat preference of larvae comes from Columbia River Basin tributary systems (Moser and Close 2003; Torgersen and Close 2004; Stone and Barndt 2005; Stone 2006) and coastal systems (Farlinger and Beamish 1984; Russell et al. 1987; Gunckel et al. 2009).

Lamprey ammocoetes are known to occur in sediments of shallow streams but their use of larger river (i.e., >5th order [1:100,000 scale]; Torgersen and Close 2004) habitats in relatively deeper areas is less known. Downstream movement of larvae, whether passive or active, happens year-round (Nursall and Buchwald 1972; Gadomski and Barfoot 1998; White and Harvey 2003). The numerous hydroelectric dams on the Columbia River mainstem have transformed this river into a series of low velocity reservoirs. Anecdotal observations exist regarding larval lamprey occurrence in large river habitats mainly at hydropower facilities or in downstream bypass reaches (Hammond 1979; Moursund et al. 2003; Dauble et al. 2006; CRITFC 2008), impinged on downstream screens, or through observation during dewatering events. Occurrences at hydropower facilities are generally thought to be associated with downstream migration and specific collections of presumably migrating ammocoetes have been made in large river habitats (Beamish and Youson 1987; Beamish and Levings 1991). Sea lamprey *Petromyzon marinus* ammocoetes have been documented in deepwater habitats in tributaries of the Great Lakes, in proximity to river mouths (Hansen and Hayne 1962; Wagner and Stauffer 1962; Lee and Weise 1989; Bergstedt and Genovese 1994; Fodale et al. 2003*b*), and in the St. Marys River, a large river that connects Lake Superior to Lake Huron (Young et al. 1996). References to other species occurring in deepwater or lacustrine habitats are scarce (American brook lamprey *Lampetra appendix*; Hansen and Hayne 1962). Previous studies of larval Pacific lamprey and *Lampetra* spp. use of mainstem river habitats (Silver et al. 2008; Jolley et al. 2012c) indicated larvae of both Pacific lamprey and *Lampetra* spp. across a wide size range occupy broad areas of the Willamette River and the Columbia River mainstem (Jolley et al. 2011a, 2011b, 2012a, 2012b).

We continued our mainstem Columbia River larval occupancy work in 2012, by expanding our sampling effort upriver into The Dalles Pool, the next mainstem reservoir upstream from Bonneville Reservoir, where previous sampling has taken place (Jolley et al. 2011a, 2012a). In addition we continued to investigate occupancy at tributary mouths within

mainstem reservoir habitats by sampling the Deschutes River mouth within The Dalles Pool. Tributaries have been speculated to be the source of larvae; they often form alluvial fans of fine-grained rearing substrate, and thus may have a higher density of larvae. In general, we documented presence or absence of larval Pacific and *Lampetra* spp. throughout the The Dalles Pool and compared that to information from previous mainstem work and determined detection probabilities using a deepwater electrofisher. Our specific objectives were as follows:

1) Determine occupancy of lamprey larvae in The Dalles Pool.
2) Determine the occupancy and detection probability of larval lamprey at a tributary mouth (Deschutes River) within The Dalles Pool, with a deepwater electrofisher, given it was occupied.
3) Compare proportion of sites occupied to other habitat patches from previous surveys (i.e. Bonneville Reservoir, tailwater, Lower Willamette).
4) Describe the size distribution of larval lamprey.
5) Describe the species composition of larval lamprey.
6) Experimentally evaluate the capture efficiency of a deepwater electrofisher and larval lamprey survival.

The long-term objectives of the project are to: 1) determine if occupancy and detection of larval lamprey decline with distance upstream and increasing number of migratory obstructions, 2) Identify habitats that may be positively related to larval lamprey detection, and 3) determine effect of reservoir and water management operations on larval lamprey.

Methods

The Dalles Pool (Lake Celilo) is impounded by The Dalles Dam (RKm 309) and John Day Dam (RKm 348) is the next upstream hydropower project. The reservoir is 39 km long, 3,805-ha at full pool and is 48.8 m above sea level (Figure 1). The Deschutes River is the only significant tributary input of The Dalles Pool and enters at RKm 330. The pool was sampled on 11 October and 18 October 2012 and The Deschutes River mouth was sampled 12 July and 7 September 2012. The Deschutes River flows from the Lava Lake in the central Oregon Cascade Range and has a basin covering 27,200 km^2. There is a shallow depositional area at the mouth with presumably appropriate silty/sandy substrates suitable for larval lamprey rearing. Sampling occurred in summer and early fall when water velocities were the lowest and most conducive to sampling.

We estimated occupancy of larval lamprey in The Dalles Pool and Deschutes River mouth (within The Dalles Pool; Figure 2) by adapting an approach used by Peterson and Dunham (2003) and refined by the U.S. Fish and Wildlife Service (USFWS 2008) to evaluate patch occupancy and detection probability for bull trout *Salvelinus confluentus*. The approach was further applied to studies of larval lamprey in the Willamette and Columbia rivers (Jolley et al. 2011a, 2011b; 2012a, 2012b). The approach has several requirements: 1) a site- and gear-specific detection probability (assumed or estimated); 2) the probability of presence at a predetermined acceptably low level (given no detection); and 3) random identification of spatially-balanced sample sites that allow estimation of presence and refinement of detection probabilities. A reach-specific probability of detection, d_{reach}, was calculated as the proportion of quadrats (i.e., 30 m x 30 m sampling quadrat) occupied (i.e., larvae captured) by larval lamprey

in the Lower Willamette River, an area known to be occupied. The posterior probability of reach occupancy, given a larval lamprey was not detected, was estimated as:

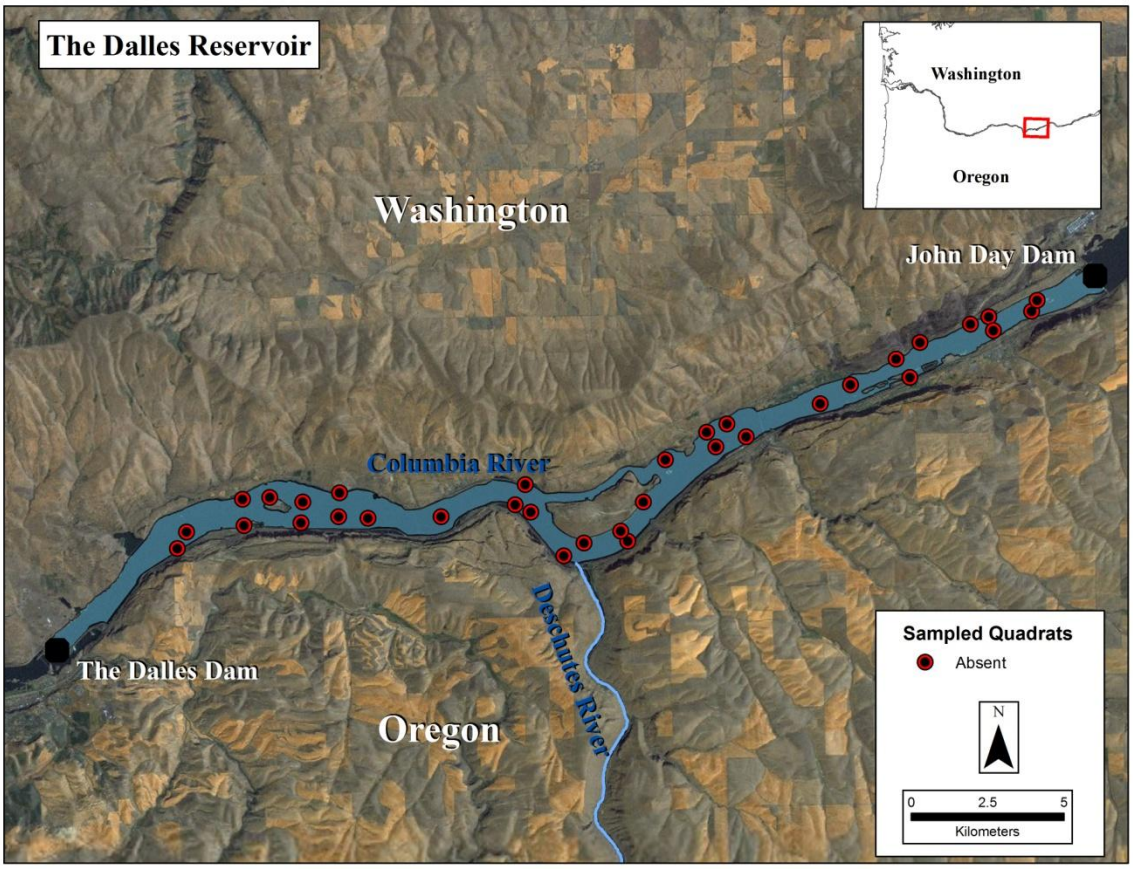

Figure 1. Sampling sites for larval lamprey on The Dalles Pool of the Columbia River

$$(1)\ \mathrm{P}(F|C_o) = \frac{\mathrm{P}\ C_o\ F\ \cdot \mathrm{P}(F)}{\mathrm{P}\ C_o\ F\ \cdot \mathrm{P}\ F\ +\ \mathrm{P}\ C_o\ \sim F\ \cdot \mathrm{P}\ \sim F},$$

where P(F) is the prior probability of larval lamprey presence. Although we knew the reach was occupied with larval lamprey, P(F) of 0.5 (uninformed) was used for future study design (i.e., P[$F|C_o$]) in areas where larval lamprey presence is unknown. P(~F), or 1 – P(F), is the prior probability of species absence, and P($C_o|F$), or 1 – d, is the probability of not detecting a species when it occurs (C_0 = no detection; Peterson and Dunham 2003). Patterns of occupancy by river were compared using the Chi-square test for differences in probabilities (Conover 1999).

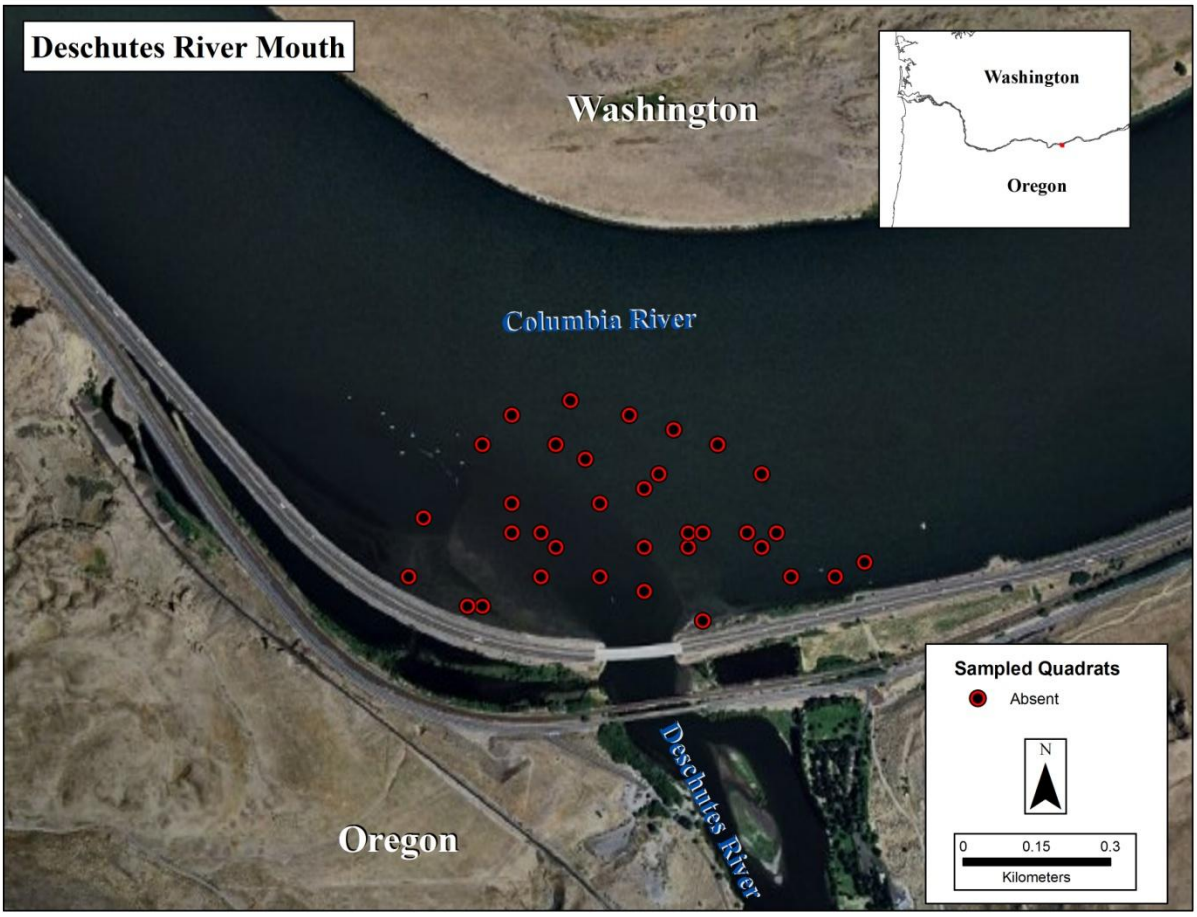

Figure 2. Sampling sites for larval lamprey at the Deschutes River mouth in The Dalles Pool of the Columbia River in 2012.

A sampling event consisted of using a deepwater electrofisher (Bergstedt and Genovese 1994) in a 30 m x 30 m quadrat. This quadrat size was selected based on the previous experience of sea lamprey researchers in the Great Lakes (M. Fodale, USFWS, personal communication) as their sampling approach evolved from a systematic to adaptive approach (Fodale et al. 2003*a*). A description of the complete configuration of the deepwater electrofisher is given by Bergstedt and Genovese (1994). The bell of the deepwater electrofisher was lowered from a boat to the river bottom. The electrofisher delivered three pulses DC per second at 10% duty cycle, with a 2:2 pulse train (i.e., two pulses on, two pulses off). Output voltage was adjusted at each quadrat to maintain a peak voltage gradient between 0.6 and 0.8 V/cm across the electrodes. Suction was produced by directing the flow from a pump through a hydraulic eductor, prohibiting ammocoetes from passing through the pump. Suction began approximately 5 seconds prior to shocking to purge air from the suction hose. Shocking was conducted for 60 seconds, and the suction pump remained on for an additional 60 seconds after shocking to ensure collected ammocoetes passed through the hose and emptied into a collection basket (27 x 62 x 25 cm; 2 mm wire mesh). The sampling techniques are described in detail by Bergstedt and Genovese (1994) and were similar to those used in the Great Lakes region (Fodale et al. 2003*b*) and the Willamette River (Jolley et al. 2012c).

We used a Generalized Random Tessellation Stratified (GRTS) approach to select sampling quadrats in a random, spatially-balanced order (Stevens and Olsen 2004). We developed a layer of 30 m x 30 m quadrats using ArcMap 9.3 (Environmental Systems Research Institute, Redlands, California) which was overlaid on each lower river section (Figure 3). There were 41,547 and 423 quadrats in The Dalles Pool and Deschutes River Mouth, respectively (Table 1). The Universal Trans Mercator (UTM) coordinates representing the center point of each quadrat were determined. The GRTS approach was applied to all quadrats to generate a random, spatially balanced sample design for these areas. This approach was used to generate an unbiased sample design that would allow the quantification of detection probabilities.

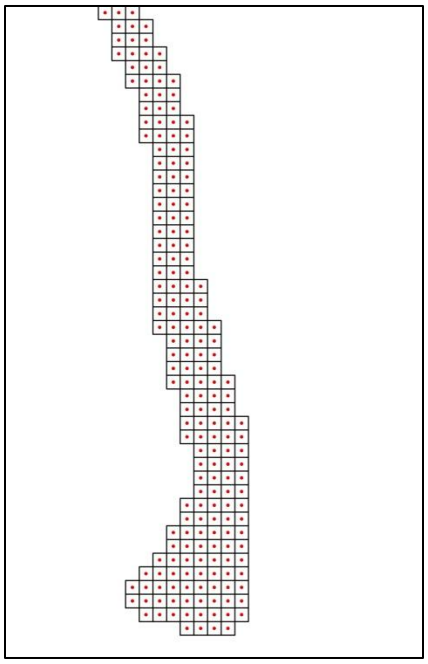

Figure 3. A schematic showing a hypothetical section of a river divided into 30 m x 30 m quadrats and associated UTM center points.

The quadrats were ordered sequentially as they were selected in the GRTS approach and the lower numbered quadrats were given highest priority for sampling. Based on previous occupancy sampling in a variety of areas, with detection rates ranging from 0.02 to 0.32, we used a relatively low to moderate detection rate of 0.07 (given an area was occupied). A minimal sampling effort of 17 quadrats is therefore necessary to achieve 80% certainty of lamprey absence when they are not detected (see Jolley et al. 2012c). To be conservative, we doubled that sampling rate to 34 quadrats. The GRTS approach allows increasing the sample effort, while maintaining a random and spatially-balanced design, when warranted (i.e., low detection). Quadrats that were not feasible due to dewatered conditions or excessive velocity (Table 1)

Table 1. Total number of quadrats delineated, visited, sampled, and occupied and species present in 2012. Unidentified larval lampreys are noted as "Unid".

	Quadrats								
Reach	Total	Visited	Sampled	Occupied	*d*	Pacific lamprey	*Lampetra* spp.	Unid	Total
The Dalles Pool	41,547	39	34	0	0.000	0	0	0	0
Deschutes River mouth	423	38	38	0	0.000	0	0	0	0

were eliminated from the sample and all subsequent quadrats were increased in priority.

Collected lampreys were anesthetized in a solution of tricaine methanesulfonate (MS-222), identified as Pacific lamprey or *Lampetra* spp. according to caudal pigmentation (Goodman et al. 2009), and classified according to developmental stage (i.e., ammocoete, macrophthalmia, or adult). Lampreys were measured (TL in mm), placed in a recovery bucket of fresh river water, and released after resuming active swimming behavior. Length-frequency histograms were constructed for each species to describe size structure.

Concurrent to each sampling event a sediment sample was taken from the river bottom by using a Ponar bottom sampler (16.5 cm x 16.5 cm). A 500 mL sample was labeled, placed on ice, and returned to the lab. Samples were oven-dried for 12 hours at 100°C to remove all water. Sediment size was characterized by weighing the component portions of the sample that collected on a set of sieves (opening sizes: 37.5 mm, 19 mm, 9.5 mm, 1 mm, 0.5 mm, and remainder less than 0.5 mm). Percent organic content of replicate samples was determined using loss-on-ignition methods (Heiri et al. 2001) by combusting organic material at 500-550 C for six hours.

Capture efficiency experiments

Capture efficiency trials were conducted at Eagle Creek National Fish Hatchery (ECNFH) using fiberglass troughs seeded with known numbers of larval Pacific lamprey. Larval Pacific lampreys were collected from the North Fork Eagle Creek on 17 October 2011 using an AbP-2 backpack electrofisher (ETS Electrofishing, Verona, WI), and separated into the experimental groups. Experimental troughs (4.9 m long x 1.0 m wide x 0.8 m deep) were divided into 5 chambers with wood dividers fitted with screen openings that allowed water to flow among chambers (Figure 4). Individual chambers (86 cm x 74 cm) allowed the deepwater electrofishing bell to fit snugly in each chamber (Figure 5). Landscape cloth lined each chamber to further prevent larval lamprey from moving between chambers. Sediment was added to each chamber to a depth of 5-7 cm; the source was a spoil pile excavated from the presettling pond below the ECNFH intake and contained natural Eagle Creek sediments. The trough was filled with water from ECNFH (sourced by Eagle Creek).

We conducted experimental trials using two densities of larvae, 5 or 10 individuals , and two size classes, <70 mm or >80 mm total length (Table 2). In each trial, a prescribed density (5 or 10) of one size class of larvae was seeded into an experimental chamber and allowed to burrow and acclimate for 24-h prior to electrofishing. The electrofishing trials were conducted identical to field protocols (described above). Trials were replicated five or six times (one trial was omitted due to containment failure of experimental chamber). The deepwater electrofisher was lowered into each chamber and allowed to rest on the sediment. Suction was produced by directing the flow from a pump

Table 2. Mean capture efficiency of larval lamprey and temperature and conductivity in experimental trials using a deepwater electrofisher. Standard errors are in parentheses.

Size (mm)	Density	Number of trials	Mean capture efficiency	Temperature (^{o}C)	Conductivity (µS/cm)
<70	10	5	71 (3)	8.7 (0.1)	48.2 (0.3)
<70	5	6	83 (10)	7.5 (0.1)	48.6 (1.1)
>80	10	6	68 (9)	11.0 (0.1)	45.6 (0.5)
>80	5	6	65 (9)	10.0 (0.1)	45.0 (0.2)

through a hydraulic eductor, prohibiting larvae from passing through the pump. Water was recycled to the far end of the trough to prevent the entire trough from dewatering. Suction began approximately 5 seconds prior to shocking to purge air from the suction hose. Shocking was conducted for 60 seconds, and the suction pump remained on for an additional 60 seconds after shocking to ensure collected larvae passed through the hose and emptied into a collection basket (27 x 62 x 25 cm; 2 mm wire mesh). Collected larvae were counted and immediately placed into

plastic recovery tanks (61.5 x 41.2 x 22.4 cm) containing two large rocks for cover, a lid, and aerated water. Larvae were monitored for survival in the recovery tanks for a minimum of 96-h and maximum of 240-h. Larvae were examined daily for normal swimming behavior. In addition, control tanks were also used each containing five larvae from one size class (either < 70 mm or >80 mm). Six replicates for each size class were set up, for a total of 12 control tanks. These larvae were collected concurrently with the experimental larvae from the North Fork Eagle Creek and placed directly into the tanks. Mortalities were enumerated and immediately removed from the recovery tanks. Capture efficiency was expressed as the number of larvae captured/total number of larvae in each trial. Mean capture efficiency was examined for potential differences using a two-way analysis of variance (ANOVA), data satisfied the assumptions of ANOVA, and all statistical tests were conducted using SAS 9.2 software (SAS 2002).

Figure 4. Experimental chambers used for deepwater electrofishing capture efficiency trials in 2011.

Figure 5. Deepwater electrofishing bell in an experimental chamber (without sediment) used in capture efficiency trials in 2011.

Results

We visited 39 quadrats in The Dalles Pool and sampled 34 and visited and sampled 38 quadrats in the Deschutes River mouth. The feasibility of being able to sample a given quadrat ranged from 85% to 100% (Table 1). Some quadrats were not sampled because they were not feasible (dewatered conditions or excessive depth). Larval lampreys were not detected at any quadrat. Depths sampled ranged from 0.6 to 17.1 m.

The Dalles Pool in-general had coarser substrate and many areas (24 quadrats) with bedrock or substrate too large for the dredge (73% of quadrats sampled; Figure 6). Mean percent organic content ranged from 0.4% to 1.3% and was significantly higher in The Dalles Pool than at the Deschutes River mouth (ANOVA, F=11.46, df=1, P<0.01; Table 3). Fine sediments were present in both areas but the Deschutes River mouth had a higher percentage of the smaller-sized sediments (Figure 6) with the exception of sediments <0.5 mm.

Capture efficiency experiments

Overall average capture efficiency was 71.6% (SE ± 4.1) and ranged from 33 to 100% (Table 2). No differences were detected by size or density and the density*size interaction was not significant (two-way ANOVA, F=0.47, df=3, P>0.05). Capture efficiencies were 70% or greater in 61% of trials. Mean survival over 96-h was 99%; one individual died and no control

fish died. Survival did not differ by size or between control and treatment groups (two-way ANOVA, F=0.7, df=1, P>0.05).

Table 3. Mean percent organic content in sediment in The Dalles Pool and Deschutes River mouth 2012.

Reach	Mean percent organic content	Number	Standard error
Deschutes mouth	0.4	24	0.1
The Dalles Pool	1.3	9	0.3

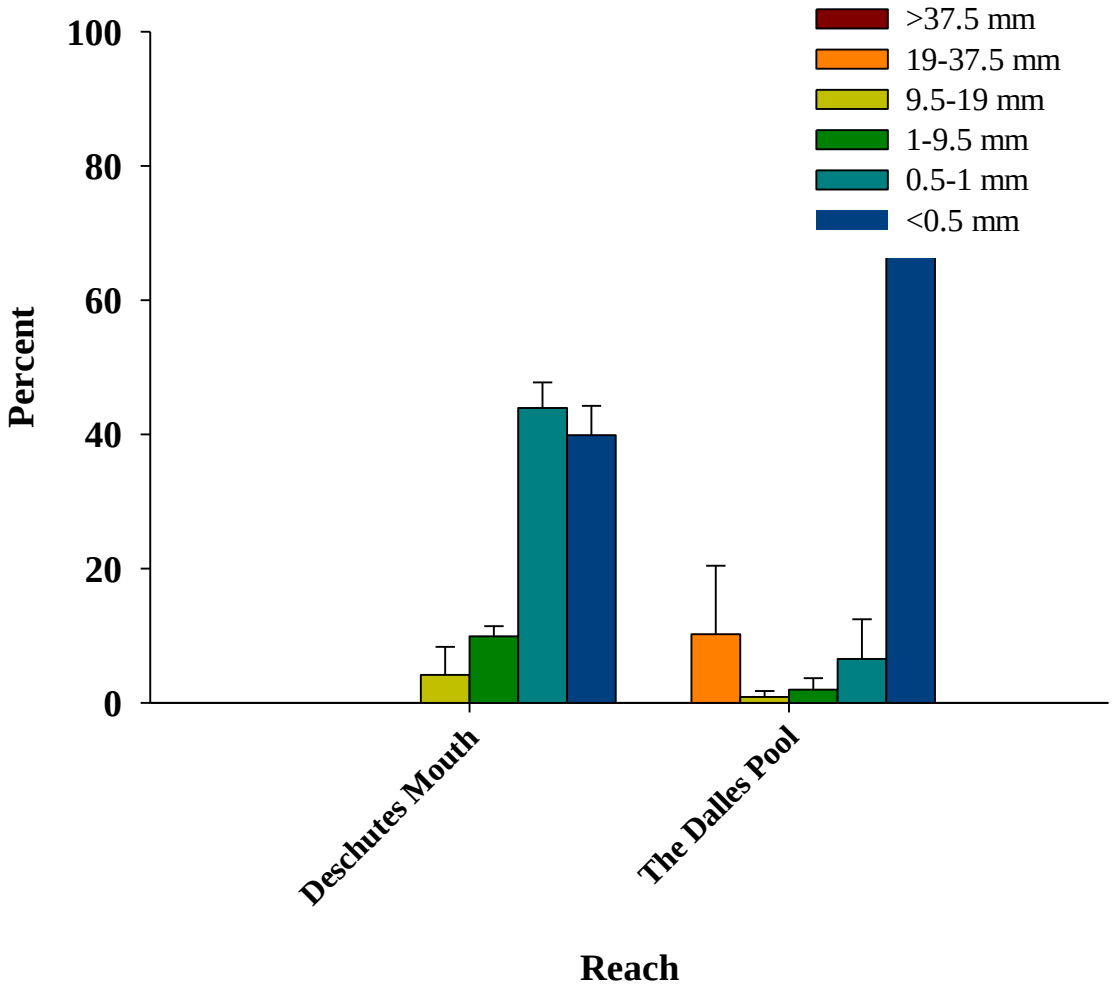

Figure 6. Mean percent of sediment in different size categories (mm) in river reaches in 2012. Large cobble and bedrock categories not included. Bars denote standard errors.

Conclusions

Larval lampreys were not detected in these surveys. Either larval lampreys are not rearing in the pool or they are at a level too low to detect. The Deschutes River, a relatively unaltered tributary, is known to have a population of Pacific lamprey (Gadomski and Barfoot 1998; Fox and Graham 2007; USFWS [unpublished data]). The absence of larval lamprey in the Deschutes River mouth was unexpected, especially as depositional sediments at river mouths in Bonneville Reservoir have yielded the highest detection rates observed in all of our mainstem larval lamprey surveys to date (Table 4; Jolley et al. 2012a, 2012b; 2013). At a detection rate of 0.07 our sampling effort of 34 quadrats yields an 8% chance that larval lampreys are actually present when not detected. In comparison, the detection rate for larval lamprey in Bonneville Reservoir was 0.02 in 2010 (Table 4). A sampling effort of 34 quadrats yields a 32% chance that larval lamprey are present when not detected and an effort of 63 quadrats would be necessary to achieve 80% certainty that larval lampreys are actually absent when not detected. It is possible that detection rates in The Dalles Pool may be equally low and a higher sampling effort may be required to detect larval lamprey. In addition, the Type 1 larval rearing habitat appears to be relatively scarce in The Dalles Pool as evidenced by abundance of bedrock and coarse substrates in our sediment sampling data. The banks of this reservoir are steep-sided and become confined as the river enters the Columbia River Gorge. In comparison, the upstream reach of John Day Reservoir (the next upstream) is wider and shallow with complex backwaters and side-channels, with more sandy and silty substrates (Parsley et al 1993; Gadomski and Barfoot 1998) which may be conducive to larval lamprey rearing.

We observed high capture efficiency and survival rates in our experimental trials. Our results are constrained by potential experimental chamber effects, water depth, and substrate depth. The potential effect of warmer water temperatures and capture of larvae from deeper areas is unknown although recent research has indicated that larval lamprey may not be as susceptible to barotrauma likely because lamprey lack a swim bladder (Colotelo et al. 2012). Repeated capture efficiency trials are recommended *in-situ* using enclosures.

Table 4. Summary of detection rate for all mainstem larval lamprey work to date.

Year	Reach	*d*	Pacific lamprey	Western brook lamprey	Unid	Total	Source
2009	Lower Willamette River	0.07	5	6	1	12	Jolley et al. 2012c
2010	Bonneville Reservoir	0.02	1	0	0	1	Jolley et al. 2011a
	Bonneville Tailwater	0.00	0	0	0	0	
2011	Bonneville Tailwater	0.03	0	1	0	1	Jolley et al. 2012a
	Hood River mouth	0.06	1	1	0	2	
	Klickitat River mouth	0.00	0	0	0	0	
	White Salmon River mouth	0.00	0	0	0	0	
	Wind River mouth	0.29	22	9	6	37	
	Lower Klickitat River	0.26	13	0	2	15	Jolley et al. 2012b
	Lower White Salmon River	0.29	5	11	3	19	
	Lower Wind River	0.32	13	9	4	26	
2012	Klickitat River mouth	0.12	3	0	2	5	Jolley et al. 2013
	White Salmon River mouth	0.03	1	0	0	1	
	Wind River mouth	0.29	6	15	16	37	
	Lower Klickitat River	0.03	1	0	0	1	
	Lower White Salmon River	0.09	0	4	0	4	
	Lower Wind River	0.24	4	10	1	15	

Relationship to the Fisheries Program Strategic Plan

Implementation of this project demonstrates application of the Pacific Region's 2009-2013 Fisheries Program Strategic Plan. The following National goals (NG) and Regional objectives (RO) have been addressed by this project:

NG1 Open, interactive communication between the Fisheries Program and its partners.

RO1.1 Develop and maintain relationships with partners throughout the Pacific Region. **We participated, coordinated, and cooperated with the White Salmon River Working Group (a partnership of federal, state, tribal, and NGOs) throughout this project.**

NG2 America's streams, lakes, estuaries, and wetlands are functional ecosystems that support self-sustaining communities of fish and other aquatic resources.

RO2.1 Facilitate management of aquatic habitats on national and regional scales by working with Tribes, States, partners and other stakeholders. **We regularly coordinated and communicated with the Columbia River Inter-Tribal Fish Commission and Yakama Nation throughout this project regarding potential management issues.**

RO2.4 Expand opportunities to connect people with nature, engage citizen scientists and volunteers, and temporarily employ youth in the aquatic habitat conservation and monitoring programs and activities we lead or support. **We**

employed two undergraduate STEP students to conduct field work on this project.

NG3 Self-sustaining populations of native fish and other aquatic resources that maintain species diversity, provide recreational opportunities for the American public, and meet the needs of tribal communities.

RO3.3 Support the research and fish culture needed to prevent listing or to recover native species listed or proposed for listing under ESA. **This research provides important information on the ecology of Pacific lamprey that will be useful in conserving this important trust species.**

NG8 Assistance is provided to Tribes that results in the management, protection, and conservation of their treaty-reserved or statutorily defined trust natural resources, which help Tribes develop their own capabilities.

RO8.1 Recognize and promote the Service's distinct obligations toward Tribes. **Pacific lampreys are a trust species and research into the conservation of ecologically and culturally tribal species fulfills this obligation.**

Acknowledgements

We thank S. Hansen, J. Harrison, D. Allard, and J. Archibald for field assistance with deepwater electrofishing surveys. We thank D. Grugett, R. Miller, S. Lazzini, D. Allard, and B. Silver for assistance with capture efficiency experiments. Staff of Eagle Creek National Fish Hatchery provided technical assistance and space for the capture efficiency experiment. K. Steinke (USFWS) provided the oscilloscope. Funding for the this project came from the U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, and through the U.S. Fish and Wildlife Service, Region 1, Flexible Funding.

Literature Cited

Beamish, R.J., and C.D. Levings. 1991. Abundance and freshwater migrations of the anadromous parasitic lamprey, *Lampetra tridentata*, in a tributary of the Fraser River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 48:1250-1263.

Beamish, R.J., and J.H. Youson. 1987. Life history and abundance of young adult *Lampetra ayresi* in the Fraser River and their possible impact on salmon and herring stocks in the Strait of Georgia. Canadian Journal of Fisheries and Aquatic Sciences 44:525-537.

Bergstedt, R.A., and J.H. Genovese. 1994. New technique for sampling sea lamprey larvae in deepwater habitats. North American Journal of Fisheries Management 14:449-452.

Close, D.A., M.S. Fitzpatrick, and H.W. Li. 2002. The ecological and cultural importance of a species at risk of extinction, Pacific lamprey. Fisheries 27:19-25.

Colotelo, A.H., B.D. Pflugrath, R.S. Brown, C.J. Brauner, R.P. Mueller, T. J. Carlson, D.Z. Deng, M.L. Ahmann, and B.A. Trumbo. 2012. The effect of rapid and sustained decompression on barotrauma in juvenile brook lamprey and Pacific lamprey: Implications for passage at hydroelectric facilities. Fisheries Research 129–130:17-20.

Conover, W.J. 1999. Practical nonparametric statistics, 3rd ed. John Wiley & Sons, Inc.

CRITFC. 2008. Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. Formal draft available: www.critfc.org/text/lamprey/restor_plan.pdf. (February 2010).

Dauble, D.D., R.A. Moursund, and M.D. Bleich. 2006. Swimming behavior of juvenile Pacific lamprey, *Lampetra tridentata*. Environmental Biology of Fishes 75:167-171.

Farlinger, S.P., and R.J. Beamish. 1984. Recent colonization of a major salmon-producing lake in British Columbia by the Pacific lamprey (*Lampetra tridentata*). Canadian Journal of Fisheries and Aquatic Sciences. 41:278-285.

Fodale, M.F., R.A. Bergstedt, D.W. Cuddy, J.V. Adams, and D.A. Stolyarenko. 2003*a*. Planning and executing a lampricide treatment of the St. Marys River using a georeferenced data. Journal of Great Lakes Research 29(Supplement 1):706-716.

Fodale, M.F., C.R. Bronte, R.A. Bergstedt, D.W. Cuddy, and J.V. Adams. 2003*b*. Classification of lentic habitat for sea lamprey (*Petromyzon marinus*) larvae using a remote seabed classification device. Journal of Great Lakes Research 29 (Supplement 1):190–203.

Fox, M., and J. Graham. 2007. Determining lamprey species composition, larval distribution and adult abundance in the Deschutes River Subbasin, Oregon. Confederated Tribes of the Warm Springs Reservation, 2007 Annual Report.

Gadomski, D. M., and C. A. Barfoot. 1998. Diel and distributional abundance patterns of fish embryos and larvae in the lower Columbia and Deschutes rivers. Environmental Biology of Fishes 51:353-368.

Goodman, D.H., A.P. Kinzinger, S.B. Reid, M.F. Docker. 2009. Morphological diagnosis of *Entosphenus* and *Lampetra* ammocoetes (Petromyzontidae) in Washington, Oregon, and California. Pages 223-232 in L.R. Brown, S.D. Chase, M.G. Mesa, R.J. Beamish, and P.B. Moyle, editors. Biology, management, and conservation of lampreys in North America. American Fisheries Society, Symposium 72, Bethesda, Maryland.

Gunckel, S.L., K.K. Jones, and S.E. Jacobs. 2009. Spawning distribution and habitat use of adult Pacific and western brook lampreys in Smith River, Oregon. Pages 173-189 *in* L.R. Brown, S.D. Chase, M.G. Mesa, R.J. Beamish, and P.B. Moyle, editors. Biology, management, and conservation of lampreys in North America. American Fisheries Society, Symposium 72, Bethesda, Maryland pp. 173-189.

Hammond, R-J. 1979. Larval biology of the Pacific lamprey, *Entosphenus tridentatus* (Gairdner) of the Potlatch River, Idaho. Master's thesis. University of Idaho, Moscow.

Hansen, M.J., and D.W. Hayne. 1962. Sea lamprey larvae in Ogontz Bay and Ogontz River, Michigan. Journal of Wildlife Management 26:237-247.

Heiri, O., A.F. Lotter, and G. Lemcke. 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. Journal of Paleolimnology 25:101-110.

Jolley, J.C., G.S. Silver, and T.A. Whitesel. 2011a. Occurrence, detection, and habitat use of larval lamprey in Columbia River mainstem environments: Bonneville Reservoir and Tailwater. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, 2010 Annual Report.

Jolley, J.C., G.S. Silver, and T.A. Whitesel. 2011b. Occurrence, detection, and habitat use of larval lamprey in Columbia River mainstem environments: The Lower Columbia River. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, 2010 Annual Report.

Jolley, J.C., G.S. Silver, and T.A. Whitesel. 2012a. Occurrence, detection, and habitat use of larval lamprey in Columbia River mainstem environments: Bonneville Tailwater and tributary mouths. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, 2011 Annual Report.

Jolley, J.C., G.S. Silver, and T.A. Whitesel. 2012b. Occurrence, detection, and habitat use of larval lamprey in the White Salmon River Basin: pre-Condit Dam Removal. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, WA, 2011 Annual Report.

Jolley, J.C., G.S. Silver, and T.A. Whitesel. 2012c. Occupancy and detection of larval Pacific lampreys and *Lampetra* spp. in a large river: the Lower Willamette River. Transactions of the American Fisheries Society 141:305-312.

Jolley, J.C., G.S. Silver, and T.A. Whitesel. 2013. Occurrence, detection, and habitat use of larval lamprey in the Lower White Salmon River and mouth: Post-Condit Dam removal U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, WA, 2012 Annual Report.

Lee, D.S., and J.G. Weise. 1989. Habitat selection of lentic larval lampreys: preliminary analysis based on research with a manned submersible. Journal of Great Lakes Research 15:156-163.

Luzier, C.W, H.A. Schaller, J.K. Bostrom, C. Cook-Tabor, D.H. Goodman, R.D. Nelle, K. Ostrand, B. Strief. 2011. Pacific lamprey (*Entosphenus tridentatus*) assessment and template for conservation measures. U.S. Fish and Wildlife Service, Portland, OR.

McGree, M., T.A. Whitesel, and J. Stone. 2008. Larval metamorphosis of individual Pacific lampreys reared in captivity. Transactions of the American Fisheries Society 137:1866-1878.

Moser, M.L., and D.A. Close. 2003. Assessing Pacific lamprey status in the Columbia River basin. Northwest Science 77:116-125.

Moursund, R. A., D. D. Dauble, and M. J. Langeslay. 2003. Turbine intake diversion screens: investigating effects on Pacific lamprey. Hydro Review 22:40-46.

Nursall, J. R., and D. Buchwald. 1972. Life history and distribution of the arctic lamprey (*Lethenteron japonicum* (Martens)) of Great Slave Lake, N.W.T. Fisheries Research Board of Canada Technical Report 304.

Parsley, M.J., L.G. Beckman, and G.T. McCabe. 1993. Spawning and rearing habitat use by white sturgeons in the Columbia River downstream from McNary Dam. Transactions of the American Fisheries Society 122:217-227.

Peterson, J.T., and J. Dunham. 2003. Combining inferences from models of capture efficiency, detectability, and suitable habitat to classify landscapes for conservation of threatened bull trout. Conservation Biology 17:1070-1077.

Renaud, C. B. 1997. Conservation status of northern hemisphere lampreys (Petromyzontidae). Journal of Applied Ichthyology 13:143-148.

Russell, J. E., F. W. H. Beamish, and R. J. Beamish. 1987. Lentic spawning by the Pacific lamprey, *Lampetra tridentata*. Canadian Journal of Fisheries and Aquatic Sciences 44:476-478.

SAS Institute, Inc. 2002. SAS/STAT user's guide, version 9.1 edition. Cary, NC, USA: SAS Institute, Inc.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Ottawa.

Silver, G.S., C.W. Luzier, and T.A. Whitesel. 2008. Investigation of larval Pacific lamprey habitat use in the mainstem Columbia River and Willamette River. 2007 Annual Report, U.S. Fish and Wildlife Service, Vancouver, Washington.

Stevens, D.L., and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

Stone, J. 2006. Observations on nest characteristics, spawning habitat, and spawning behavior of Pacific and western brook lamprey in a Washington stream. Northwestern Naturalist 87:225-232.

Stone, J., and S. Barndt. 2005. Spatial distribution and habitat use of Pacific lamprey (*Lampetra tridentata*) ammocoetes in a western Washington stream. Journal of Freshwater Ecology 20:171-185.

Sutton, T.M., and S.H. Bowen. 1994. Significance of organic detritus in the diet of larval lamprey in the Great Lakes Basin. Canadian Journal of Fisheries and Aquatic Sciences 51:2380-2387.

Torgersen, C.E., and D.A. Close. 2004. Influence of habitat heterogeneity on the distribution of larval Pacific lamprey *Lampetra tridentata* at two spatial scales. Freshwater Biology 49:614-630.

USFWS (U.S. Fish and Wildlife Service). 2008. Bull trout recovery: monitoring and evaluation guidance. Report prepared for the U.S. Fish and Wildlife Service by the Bull Trout Recovery and Monitoring Technical Group (RMEG). Portland, Oregon.

Wagner, W.C., and T.M. Stauffer. 1962. Sea lamprey larvae in lentic environments. Transactions of the American Fisheries Society 91:384-387.

White, J. L., and B. C. Harvey. 2003. Basin-scale patterns in the drift of embryonic and larval fishes and lamprey ammocoetes in two coastal rivers. Environmental Biology of Fishes 67:369-378.

Young, R. J., G.C. Christie, R.B. McDonald, D.W. Cuddy, T.J Morse, and N.R. Payne. 1996. Effects of habitat change in the St. Marys River and northern Lake Huron on sea lamprey (*Petromyzon marinus*) populations. Canadian Journal of Fisheries and Aquatic Sciences 53:99-104.

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
1211 SE Cardinal Court, Suite 100
Vancouver, WA 98683

April 2013