Captive Rearing of Pacific Lamprey

2010 Annual Report

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Introduction

Pacific lamprey *Entosphenus tridentatus* in the Columbia River Basin have declined to a remnant of their historical abundance (Close et al. 2002). Pacific lamprey populations are declining and have been given protected status within Oregon due to declines along the coast and in the Columbia River Basin (Close et al. 2002; Kostow 2002). Increased knowledge of the biology, population dynamics, ecology, and identification of Pacific lamprey will help managers understand and conserve these important species.

Pacific lampreys have a complex life history that includes a three to seven year larval (i.e., ammocoete), migratory juvenile (i.e., macrophthalmia) and adult phases (Scott and Crossman 1973). Ammocoetes and macrophthalmia are strongly associated with stream and river sediments. Ammocoetes live burrowed in stream and river sediments for periods up to seven years after hatching, where they filter feed detritus and organic material (Scott and Crossman 1973; Sutton and Bowen 1994). Ammocoetes metamorphose into macrophthalmia from July to December (McGree et al. 2008) and migrate downstream to the Pacific Ocean. The timing, duration, and habitat use at the ammocoete and macrophthalmia life stage are poorly understood.

Several critical uncertainties have been formalized regarding the basic life history and ecology of lampreys (CRBLTWG 2005; U.S. Fish and Wildlife Service 2010) and may be addressed by observation and experimentation using captive animals. For example, McGree et al. (2008) improved understanding of Pacific lamprey metamorphosis using captive animals. However, the unique life history of the lamprey poses unique challenges to rearing them in captivity. Developing appropriate holding vessels that contain rearing habitat and nutrition required for robust individuals is necessary. Animals transported to captivity from the wild may

be vectors of pathogens that can then be spread to the rest of the facility. Proper care needs to be taken to address these potential issues. Our objectives were to 1) screen various samples of Pacific lamprey ammocoetes from the Clackamas River Basin, particularly Eagle Creek, for pathogens, 2) establish a captive group of ammocoetes at Eagle Creek National Fish Hatchery (ECNFH) and the associated holding configuration, and 3) investigate salinity tolerance of ammocoetes, and 4) investigate growth responses of different feeding regimes.

Methods and Results

Health and disease screening

Pacific lamprey ammocoetes were collected from Eagle Creek at Bonnie Lure State Park (n=30) and from the mainstem of the Clackamas River at Milo McIver State Park (n=30) on 22 September 2009 (Figure 1). Fish were euthanized using an overdose of MS-222 (750 mg/L), placed on ice, and transported by Ken Lujan (USFWS, Lower Columbia Fish Health Center) for health and pathogen screening. Health screening results were negative for a variety of pathogens, including *Renibacterium salmoninarum* (causative agent of bacterial kidney disease), infectious hematopoietic virus (IHNV), and *Myxobolus cerebalis* (whirling disease), all significant Salmonid disease concerns. The bacteria *Vibrio vulnificus* was identified in these lampreys (Table 1, 2).

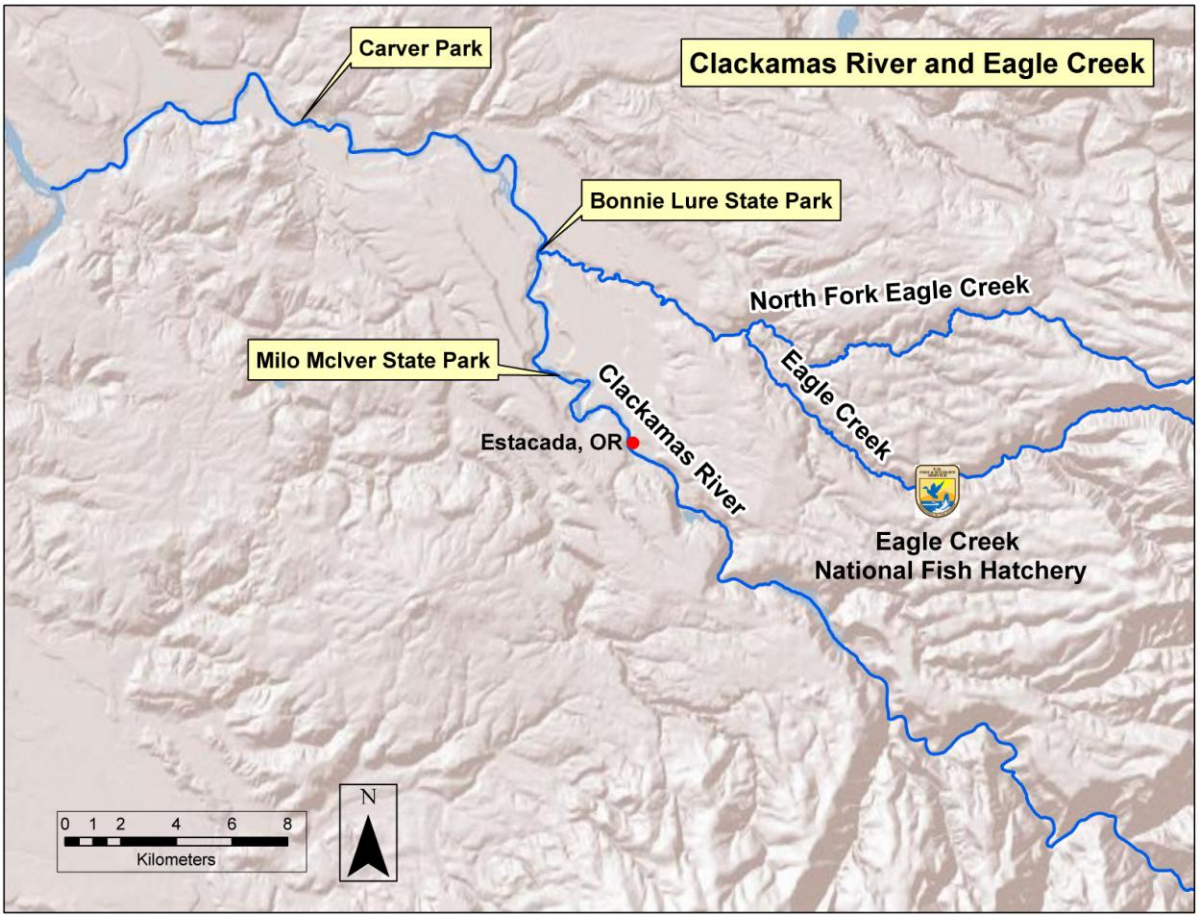

Figure 1. Map of showing Eagle Creek area including Pacific lamprey collection sites in 2009-2010.

Table 1. Results of fish health examination for Pacific lamprey ammocoetes collected from Eagle Creek, 22 September 2009 by the Lower Columbia River Fish Health Center (Ken Lujan, USFWS).

FISH HEALTH REPORT 2009

FISH SOURCE	FISH EXAMINED
Location: Eagle Creek (Bonnie Lure State Park) **County**: Clackamas **Contact Person:** Jeff Jolley **Affiliation:** USFWS **Phone:** (360) 604-2500	**Species:** Pacific lamprey **Age:** Ammocoetes **CHN:** W09-116 **Number of fish:** 30 **Date Sampled:** 9/22/2009

DISEASE AGENT [1]	SAMPLE SIZE	RESULTS	COMMENTS
IPNV	30	not detected	EPC and CHSE-214 cells
IHNV	30	not detected	EPC and CHSE-214 cells
VHS	30	not detected	EPC and CHSE-214 cells
SVCV	-	not tested	EPC and FHM cells
AS	30	not detected	BHIA medium
YR	30	not detected	BHIA medium
ESC	30	not detected	BHIA medium
BCD	30	not detected	TYES medium
CD	30	not detected	TYES medium
RS	-	not tested	ELISA
WD	-	not tested	Pepsin/Trypsin Digest

Comments	Virus (whole bodies) pooled in 3 fish pools. 19/30 fish (heart tissue) with growth on BHIA medium plates. Gram negative, motile bacteria. The bacteria were keyed out to be *Vibrio vulnificus* (by API).

[1] **IPNV** Infectious Pancreatic Necrosis Virus, **IHNV** Infectious Hematopoietic Necrosis Virus, **VHS** Viral HemorrhagicSepticemia Virus, **SVCV** Spring Viremia of Carp Virus, **AS** Furunculosis (*Aeromonas salmonicida)*, **YR** Enteric Redmouth (*Yersinia ruckeri)*, **ESC** Emphysematous Putrefactive Disease *(Edwardsiella ictaluri)*, **BCD** Coldwater Disease (*Flavobacterium psychrophilum)*, **CD** Columnaris (*Flavobacterium columnare)*, **RS** BKD (*Renibacterium salmoninarum*), **WD** Whirling Disease (*Myxobolus cerebralis*), **CS** Salmonid Ceratomyxosis (*Ceratomyxa shasta).*

Table 2. Results of fish health examination for Pacific lamprey ammocoetes collected from the Clackamas River, 22 September 2009 by the Lower Columbia River Fish Health Center (Ken Lujan, USFWS).

FISH HEALTH REPORT 2009

FISH SOURCE	FISH EXAMINED
Location: Clackamas River (Milo McIver State Park) **County**: Clackamas **Contact Person:** Jeff Jolley **Affiliation:** USFWS **Phone:** (360) 604-2500	**Species:** Pacific lamprey **Age:** Ammocoetes **CHN:** W09-117 **Number of fish:** 30 **Date Sampled:** 9/22/2009

DISEASE AGENT [1]	SAMPLE SIZE	RESULTS	COMMENTS
IPNV	30	not detected	EPC and CHSE-214 cells
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YR	30	not detected	BHIA medium
ESC	30	not detected	BHIA medium
BCD	30	not detected	TYES medium
CD	30	not detected	TYES medium
RS	-	not tested	ELISA
WD	-	not tested	Pepsin/Trypsin Digest

Comments	Virus (whole bodies) pooled in 3 fish pools. 15/30 fish (heart tissue) with growth on BHIA medium plates. Gram negative, motile bacteria. The bacteria were keyed out to be *Vibrio vulnificus* (by API).

[1] **IPNV** Infectious Pancreatic Necrosis Virus, **IHNV** Infectious Hematopoietic Necrosis Virus, **VHS** Viral HemorrhagicSepticemia Virus, **SVCV** Spring Viremia of Carp Virus, **AS** Furunculosis (*Aeromonas salmonicida),* **YR** Enteric Redmouth (*Yersinia ruckeri),* **ESC** Emphysematous Putrefactive Disease *(Edwardsiella ictaluri),* **BCD** Coldwater Disease (*Flavobacterium psychrophilum),* **CD** Columnaris (*Flavobacterium columnare),* **RS** BKD (*Renibacterium salmoninarum*), **WD** Whirling Disease (*Myxobolus cerebralis*), **CS** Salmonid Ceratomyxosis (*Ceratomyxa shasta).*

Eagle Creek (i.e., reaches above the water intake for ECNFH) was sampled again on 26 January 2010 and 17 August 2010. No lampreys were detected during either sampling event but high water may have precluded adequate sampling in the winter.

Captive housing configuration

Larval Pacific lampreys (n=104) were collected from the North Fork of Eagle Creek using an AbP-2 backpack electrofisher (ETS Electrofishing, Verona, WA) on 17 November 2009. Larvae were transported to Eagle Creek National Fish Hatchery and housed in plastic tubs (61.5 x 41.2 x 22.4 cm), containing 5-7 cm of sand substrate at an approximate density of 10 per tub. The substrate source was a spoil pile that was periodically cleaned from the presettling pond below the ECNFH intake and contained natural Eagle Creek sediments. The average organic content was 5.3% (n = 8 samples, loss-on-ignition methods [Heiri et al. 2001]). The plastic tubs were placed in rectangular fiberglass troughs (43.2 cm wide x 40.6 cm deep x 4.9 m long), in a raceway and supplied with Eagle Creek water in a flow-through system (Figure 2).

Figure 2. Larval Pacific lamprey recirculating holding configuration at ECNFH.

The captive holding configuration progressed adaptively as aspects of the configuration were found to be inadequate. In addition, because *Vibrio* spp. was isolated in the sample of lamprey screened for pathogens, those brought to ECNFH were isolated in the hatchery areas so that their effluent did not contact other areas of the hatchery. This was deemed a precautionary

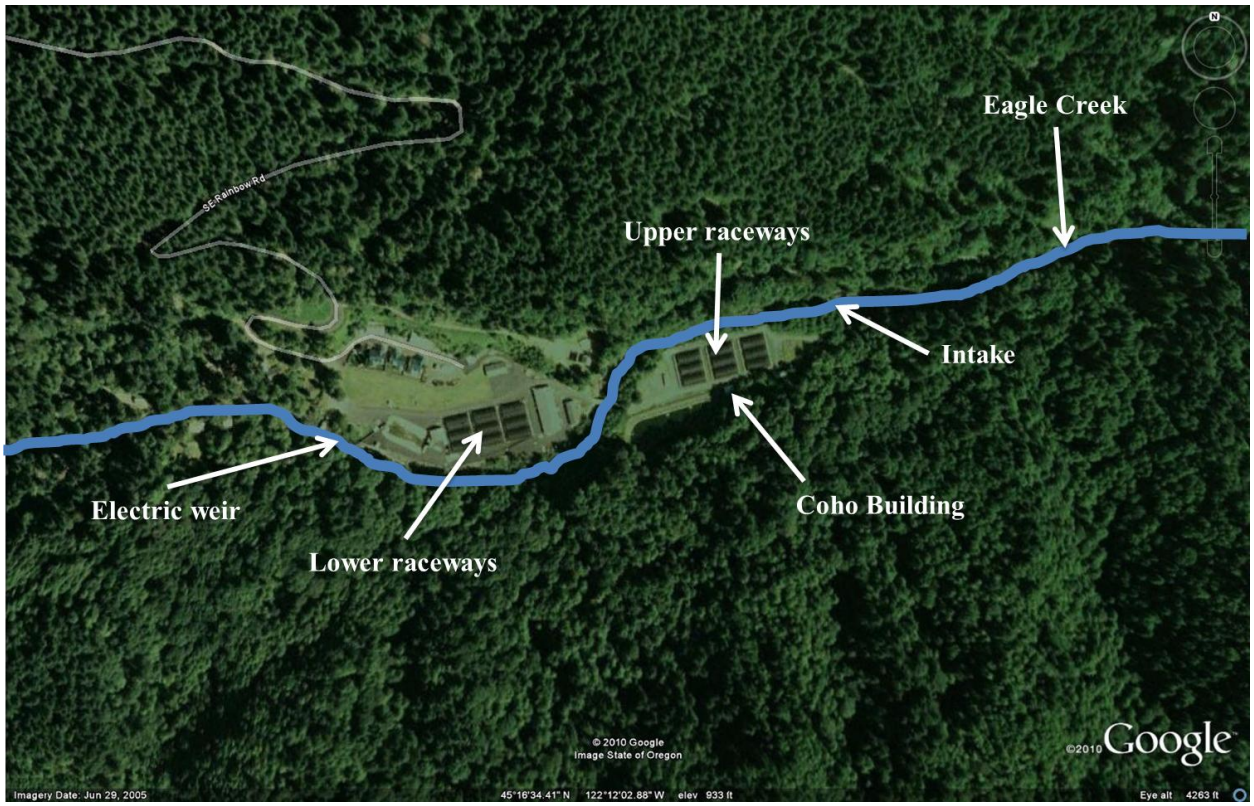

Figure 3. Schematic of Eagle Creek National Fish Hatchery.

and conservative approach. The lampreys were confined to the upper raceways section of the hatchery (Figure 3).

In mid-November of 2009 an extended period of ambient air temperature below 0° C led to the potential of water in the holding tubs freezing. At this time a temporary holding configuration was assembled in the Coho Building at ECNFH. The trough and holding tubs were moved and a recirculating setup was assembled. Each holding tub was supplied with an aerator and portable heaters were supplied to prevent the water from freezing (Figure 2). The lampreys were held in this configuration through the winter. On 26 January 2010 we anesthetized the lamprey using tricaine methanosulfate (MS-222, 50 mg/L), and each was tagged with unique visible implant elastomer (VIE) tag (Silver et al. 2009), measured (TL in mm), and weighed (wet weight in g). A total of 104 (mean TL = 91.4±1.7 mm SE) were returned to their holding configuration.

In the spring of 2010, two troughs were plumbed into the flow-through system in the middle section of the upper raceways (i.e., original location of captive lamprey; Figure 2). Finally, the troughs were moved to the next lower set of raceways (within the upper raceway section) in summer 2010 (Figure 4). Shade screens were used in summer to moderate temperatures. On 6 August 2010 this group of lamprey was again inventoried as described above and then incorporated into a feeding study which is detailed below. At this time there were 85 remaining ammocoetes indicating that 19 mortalities and/or escapes occurred in this time.

Figure 4. Pacific lamprey holding configuration in upper raceways of ECNFH.

Salinity tolerance experiments

Experiment 1. Abernathy Fish Technology Center salinity tolerance experiments

Pacific lamprey ammocoetes were collected annually from Cedar Creek, a tributary of the Lewis River (Clark County, Washington) from 2006 to 2009. Lampreys were collected using an AbP-2 backpack electrofisher (ETS Electrofishing, Verona, WA). The fish were reared at Abernathy Fish Technology Center located on Abernathy Creek (Cowlitz County, Washington) as part of a lamprey metamorphosis study. For the duration of the metamorphosis study, lampreys were held in plastic tubs (61.5 x 41.2 x 22.4 cm), containing 5-7 cm of sand substrate and supplied with Abernathy Creek water in a flow-through system. Holding and

rearing conditions were generally consistent with those described in McGree et al. (2008). Larvae were fed weekly at a rate of 0.27 g baker's yeast and 0.03 g BioKyowa larval fish food per lamprey per week. During the fall of 2009, eleven of the remaining ammocoetes went through metamorphosis to macrophthalmia, and nine of those were used in salinity tolerance experiments.

In March 2009, prior to initiation of the salinity experiment, ammocoetes were removed from their rearing tubs and divided into eight experimental groups. Individual lamprey were anesthetized with tricaine methanosulfate (MS-222, 50 mg/L), identified from previous unique visible implant elastomer (VIE) tags (Silver et al. 2009), measured (TL in mm), and weighed (wet weight in g). Lamprey were placed in plastic tubs (dimensions as described above), supplied with constant flow of Abernathy Creek water and allowed to recover. The holding tubs did not contain sediment, but each had several large rocks to provide cover and lids were placed on the tubs to shade lamprey. Lampreys were held in these tubs for 72 h before initiation of salinity experiments.

Eight experimental tubs were prepared to receive groups of ammocoetes. All tubs were supplied with seven gallons of fresh Abernathy Creek water. Two tubs functioned as a control and were kept at their naturally occurring salinity (i.e., freshwater, 0 ‰). Desired levels of salinity were produced in the other six tubs by dissolving a predetermined amount of synthetic sea salt (Red Sea Fish pHarm, Houston, Texas) in each tub. Two tubs were salinated to a concentration of 10 ‰, two tubs were salinated to a concentration of 21 ‰ and two tubs were salinated to a concentration of 35 ‰. The salinity of each tub was measured using a portable, hand-held refractometer. Once desired concentrations had been achieved, sand substrate was added to each tub to a depth of approximately 2-3 cm. The tubs were then placed in troughs

acting as water baths which were supplied with a constant flow of Abernathy Creek water to maintain creek water temperature in the experimental tubs. Each tub was aerated with an electric bubbler. The tubs were maintained in this orientation for 72 h before experimental animals were introduced.

Lamprey groups were randomly assigned to one of the four treatments: 0‰ (freshwater), 10‰, 21‰, and 35‰ (seawater). There were two replicates of per treatment, each containing up to eight ammocoetes and two macrophthalmia (Table 3). One replicate (10 ‰) received only three ammocoetes because three others had escaped from their holding containers prior to experimentation. Groups of ammocoetes and macrophthalmia were directly transferred from the holding tubs to their respective treatment tubs. Water temperature (mean 6.2^{o}C, range 5.1-7.3^{o}C) and salinity were monitored daily and animals were not fed during the experiment. Animals were monitored every 24 h by visually inspecting the tubs for ammocoetes on the surface of the substrate. Lampreys that did not move in response to being touched were considered mortalities and were removed from the tub (Table 4). Mortalities were identified by their unique VIE tag. All lampreys not visible on the surface of the sediment were assumed to be alive.

After 24 h, a subsample of four ammocoetes per treatment was randomly selected to be sacrificed and have their blood drawn for subsequent analyses of blood plasma Na^{+} and Cl^{-} concentrations and blood plasma osmolality (Table 5). Selected individuals were euthanized by overdosing with MS-222 (750 mg/L), the tails were cut off, and blood samples from the caudal vein were collected into heparinized capillary tubes. Samples were centrifuged at 5000 g for 5 min, hematocrit was recorded, and the plasma was stored at -80ºC. The experiment was terminated at 96 h and all surviving individuals were euthanized and blood plasma samples were taken for future analyses.

Table 3. Number of each stage of lamprey, mean TL (SE in parentheses) in each salinity tolerance treatment at Abernathy FTC and Eagle Creek NFH in 2010.

Experiment	Treatment	Replicate	Number of ammocoetes	Mean TL (mm)	Number of macrophthalmia	Mean TL (mm)
Abernathy	0‰	1	8	108 (5)	1	121 (-)
	0‰	2	7	106 (5)	1	128 (-)
	10‰	1	6	105 (5)	1	130 (-)
	10‰	2	3	106 (7)	1	124 (-)
	21‰	1	7	105 (8)	2	126 (2)
	21‰	2	7	114 (3)	1	125 (-)
	35‰	1	8	110 (3)	1	124 (-)
	35‰	2	8	109 (5)	1	119 (-)
Eagle Creek	0‰	1	10	117 (4)	-	-
	0‰	2	10	115 (4)	-	-
	10‰	1	10	114 (4)	-	-
	10‰	2	10	111 (4)	-	-
	21‰	1	10	111 (4)	-	-
	21‰	2	10	115 (4)	-	-
	35‰	1	10	110 (4)	-	-
	35‰	2	10	113 (4)	-	-

Mortality of ammocoetes was 100% and 67% after 24-h in the 35‰ and 21‰ treatments, respectively (Table 4). Mortality was 100% after 96-h in the 21‰ treatment indicating limited to no ability to tolerate salinity at these concentrations. No mortality was observed in the 10‰ or freshwater treatments in 2009. This indicates the ability to tolerate lower salinity concentration by Pacific lamprey ammocoetes, at least for the duration that was monitored. Long term survival at this concentration is unknown. In addition, 1 macrophthalmia died in the 35‰ treatment and was observed after 72-h exposure. All other macrophthalmia survived the duration of the exposure.

Table 4. Mortality of lamprey ammocoetes in salinity tolerance trials at Abernathy FTC and Eagle Creek NFH in 2010.

Experiment	Treatment	Replicate	24 h percent mortality	96 h percent mortality
Abernathy	0‰	1	0.0	0.0
	0‰	2	0.0	0.0
	10‰	1	0.0	0.0
	10‰	2	0.0	0.0
	21‰	1	66.7	100.0
	21‰	2	100.0	-
	35‰	1	100.0	-
	35‰	2	100.0	-
Eagle Creek	0‰	1	0.0	0.0
	0‰	2	0.0	0.0
	10‰	1	0.0	25.0
	10‰	2	0.0	12.5
	21‰	1	100.0	-
	21‰	2	100.0	-
	35‰	1	100.0	-
	35‰	2	100.0	-

Experiment 2. Eagle Creek Salinity Tolerance Experiment

Pacific lamprey ammocoetes were also collected from the North Fork Eagle Creek, of the Willamette River Basin (Clackamas County, Oregon) on 26 May 2010. Eighty Pacific lampreys were collected using an AbP-2 backpack electrofisher (ETS Electrofishing, Verona, WA) and were transported Eagle Creek National Fish Hatchery located on Eagle Creek (Clackamas County, Oregon). Lampreys were placed in holding tubs (described above) and held for 10 d prior to initiation of the experiment. Lamprey were again randomly assigned to eight experimental groups (n=10 per tub) as described above, were placed in plastic tubs, supplied

with constant flow of Eagle Creek water and allowed to acclimated for 72 h before initiation of the experiment. Mean water temperature during the experiment (7-11 June 2010) was 8.6°C (range 7.4-10.2°C). No macrophthalmia were used in this experiment. The remainder of the experiment was conducted identically to that described above and blood plasma was again examined.

Table 5. Mean blood plasma and osmolality of lamprey in salinity tolerance trials at Abernathy FTC and Eagle Creek NFH in 2010.

Experiment	Stage	Exposure (hr)	Treatment (ppt)	Mean percent plasma	N	Mean osmolality (mOs/Kg)	N
Abernathy	Ammocoete	24	0	65 (4)	4	178 (14)	4
		24	10	79 (3)	4	207 (28)	3
		96	0	81 (3)	11	200 (12)	10
		96	10	70 (3)	10	232 (13)	10
	Macrophthalmia	96	0	78 (4)	2	245 (11)	2
		96	10	84 (6)	2	186 (2)	2
		96	21	86 (4)	3	219 (18)	3
		96	35	82 (-)	1	171 (-)	1
Eagle Creek	Ammocoete	24	0	69 (1)	4	168 (5)	4
		24	10	64 (3)	4	247 (7)	4
		96	0	69 (2)	16	195 (2)	16
		96	10	68 (3)	13	282 (5)	11

Mortality of ammocoetes was 100% 24-h in the 21‰ and 35‰ treatments (Table 4) indicating no ability to tolerate salinity at these concentrations. After 96-h, mortality was 0% in the freshwater treatment and ranged from 12.5% to 25% in the 21‰ treatment indicating some ability to tolerate lower salinity concentration by Pacific lamprey ammocoetes, at least for the duration that was monitored. Long term survival at this concentration is unknown.

Feeding experiments

Pacific lampreys (n=104) were collected from the North Fork Eagle Creek, of the Willamette River Basin (Clackamas County, Oregon) on 17 November 2009. Lampreys were

collected using a backpack electrofisher (described above). This group of lampreys was the first group of lampreys brought into the hatchery for use in developing a captive rearing configuration and protocol (outlined above).

On 6 August 2010, prior to initiation of a feeding experiment, the lamprey were inventoried for baseline length and weight information. Individual lamprey (n = 85 survivors, outlined above) were anesthetized with tricaine methanosulfate (MS-222; 50 mg/L), identified from previous unique visible implant elastomer (VIE) tags (Silver et al. 2009) and randomly assigned to feeding treatment groups (Table 6). Lampreys were also measured (TL in mm) and weighed (wet weight in g). In addition, a hydrostatic weight in water (g) was taken for calculation of body density. Body density is given as:

wet weight/([wet weight – weight in water]/density of water)

Figure 5. Hydrostatic weighing apparatus for larval Pacific lamprey.

Gentle pressure and/or the use of a syringe filled with water were used to expel as much air as possible from each lamprey's buccal cavity. Lampreys were weighed using the "weigh below" option on an Ohaus digital scale. Lampreys were attached to a hook and clip apparatus and submerged in a container of water (Figure 5).

Lampreys were randomly assigned to one of four potential feeding treatments: 1) no food, 2) combination of baker's yeast and larval fish food, 3) cottonwood leaves, and 4) algae.

Each feeding treatment contained two replicates for a total of eight experimental tubs (Table 6). Commercially available algae wafers (Kyorin Food Industries, Ltd, Himeji, Japan) were ground and fed at a rate of 0.3 g per lamprey. Black cottonwood (*Populus* spp.) leaves collected from the floodplain of the Columbia River were chosen to generically represent willow species that commonly grow in the riparian zone where lampreys occur. This type of feeding regime was previously used by Shirakawa et al. (2009). Leaves were dried in an oven at 100°C for 4 hours and then ground into a fine powder. The ground leaves were fed at a rate of 0.3 g per lamprey. A combination of commercially available baker's yeast and larval fish food (BioKyowa, Inc., Chesterfield, MO) were fed at a rate of 0.27 g yeast + 0.03 g larval fish food per lamprey (Polkinghorne et al. 2001; McGree et al. 2008). A solution of water and leaves or water and algae was created prior to feeding by adding the food to 500 mL water and allowing soaking for approximately 24 h. Soaking presumably increases the chance that the food will sink and therefore be available to filter feeding larval lamprey and decreases the chance that the food floats and passes out of the container. Lampreys were fed once per week.

Table 6. Number and mean TL (mm) of Pacific lamprey ammocoetes in each feeding trial at Eagle Creek National Fish Hatchery 2010.

Tote	Description	Number	Mean TL (mm)	Mean weight (g)	Mean body density (g/mL)
6	Algae	10	82.4 (6.6)	1.0 (0.2)	1.08 (0.01)
7	Algae	10	83.3 (4.4)	0.9 (0.1)	1.13 (0.02)
2	Leaf	12	86.8 (4.6)	1.1 (0.2)	1.20 (0.09)
8	Leaf	10	81.4 (5.3)	0.8 (0.2)	1.14 (0.03)
3	No food	12	88.3 (5.8)	1.1 (0.2)	1.34 (0.16)
4	No food	9	85.8 (5.1)	1.1 (0.2)	1.17 (0.07)
1	yeast+larval food	12	83.3 (4.5)	0.9 (0.2)	1.24 (0.09)
5	yeast+larval food	10	85.1 (5.6)	1.0 (0.2)	1.13 (0.02)

Lampreys were monitored weekly for mortalities on the sediment surface (previous experience indicated that most mortalities were observed on the surface). All mortalities were identified and frozen for (for potential health screenings). Excessive detritus and fungal growth were periodically skimmed from the sediment surface as deemed necessary.

Lampreys will be examined for potential growth in early 2011. Lampreys in each tote will be agitated from the sediment, anesthetized, identified, measured (TL) and weighed (including underwater) as described above. Potential differences in growth rate (i.e., initial weight-final weight) will be examined by feeding treatment.

Findings and Recommendations

Health and disease of lampreys is poorly understood and our initial screenings are a starting point in understand the pathology of Pacific lamprey ammocoetes. Although it was encouraging to find larval lampreys free of pathogens that are common concerns to salmonids, the finding of the *Vibrio* bacterium is noteworthy. *V. vulnificus* is commonly found in shellfish, eel *Anguilla* sp. culture. Furthermore, it can transmit laterally through water and has human health concerns (Amaro et al. 1995). This bacterium has also been isolated from ammocoetes collected at John Day Dam on the mainstem Columbia River (Ken Lujan, USFWS, personal communication). It is unknown if *Vibrio* is pervasive in the environment.

Screenings of lamprey collected from above the ECNFH water intake would be valuable. If lamprey occurring in this area are presumably disease free then greater flexibility of how lamprey are housed within ECNFH would be allowed and a greater diversity of contingency plans in cases of inclement weather or other unforeseen events would exist. At this time we have been unable to detect larval lamprey in this area it is unknown if they are actually absent or at

such low densities to preclude detection. Eagle Creek has an electric weir to divert returning hatchery origin Salmonids into ECNFH. Although this weir is operated for the majority of the year (Larry Telles, USFWS, personal communication) it is unknown if it may also prevent adult Pacific lamprey from moving above ECNFH which may explain our inability to detect ammocoetes in this area.

Finally, a basic understanding of the pathology of lampreys is lacking. *Aeromonas salmonicida* (the causative agent of furunculosis) and *A hydrophila* is known to infect adult Pacific lamprey (Cummings et al. 2008; Clemens et al. 2009; CRBLTWG 2011) and *Renibacterium salmoninarum* (the causative agent of bacterial kidney disease) has been shown to reside in sea lamprey *Petromyzon marinus* (Faisal et al. 2006) but no infection was found in directly challenged Pacific lamprey adults (Bell and Traxler 1986). Virtually no information is available on the pathology of larval and juvenile Pacific lamprey. Future research directed at direct disease challenges of Pacific lamprey with pathogens of concern (e.g., IHNV or BKD) may provide information related to the ability to larval lamprey to serve as vectors of transmission.

The initiation of Pacific lamprey captive rearing at ECNFH has the potential to provide many insights into the basic biology and ecology of this important species. Facilities that prevent lamprey escape, provide protection from extreme climatic events (i.e., excessive summer heating, prolonged sub-zero temperatures), and allow experimental manipulation of environmental parameters would be beneficial. For example, the ability to vary thermal regimes may provide insight into how this animal may be affected by global climate change, thereby increasing our understanding of ecosystem effects. Understanding the feeding, nutrition, and

growth of larval lamprey may assist in providing rearing conditions which creates robust animals.

Novel approaches to rearing Pacific lamprey ammocoetes are valuable. We commonly observe lamprey "escapes" from their holding containers. The exact route of escape is unknown and anecdotal observations may link them to relatively higher flow events. Numerous attempts to improve the holding containers has decreased, but not eliminated, the incidence of lamprey escapes. Improved holding containers or new approaches that eliminate the possibility of escape are necessary. In addition, lamprey mortalities that remain in the sediment may decompose and may not be detected or documented.

Acknowledgements

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