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Evaluation of Larval Pacific Lamprey Occupancy in Portland Harbor Superfund Area Restoration Sites

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On the cover: *An aerial view of the Alder Point restoration site at the tip of Sauvie Island. Newly-constructed slough habitat through the site connects the Willamette River and Multnomah Channel (Photo by G. Silver).*

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Abstract – Within and around the Portland Harbor Superfund site on the Willamette River, habitat restoration actions focused on juvenile salmonids including Chinook salmon *Oncorhynchus tshawytscha* are being implemented which may also have effects on co-occurring Pacific lamprey *Entosphenus tridentatus*. Use of restored habitats by lampreys, particularly the larval life stage has not been extensively studied. As such, there is interest in monitoring the effectiveness of the restoration, in part, relative to larval Pacific lamprey as well as learning more about larval lamprey habitat preferences and use of different habitats. Determining the effects of restoration actions on Pacific lamprey requires evaluation of lamprey occurrence before and after project implementations. Here we report on evaluations of occupancy, detection, and habitat use of larval Pacific lamprey and *Lampetra* spp. at shoreline, confluence, and slough habitats at the Alder Point and Rinearson Natural Area restoration sites. We likewise evaluated lamprey occupancy at six reference sites in the lower Willamette River and Multnomah Channel. A generalized random tessellation-stratified (GRTS) approach was used to delineate sample quadrats (30 m x 30 m square) across the lower Willamette River and Multnomah Channel in a random, spatially-balanced manner. Using a unique deepwater electrofisher, a total of 50 quadrats were sampled in and around the Alder Point restoration site: 10 quadrats within newly-constructed Alder Slough, 10 quadrats at each of three confluence areas where Alder Slough intersects the Willamette River or Multnomah Channel, and 10 quadrats adjacent to restored shoreline habitat in the Willamette River and Multnomah Channel. Larval lamprey (n = 2) were detected at two quadrats, one in confluence habitat and one in shoreline habitat. In general, quadrat-specific detection probability at Alder Point post-restoration (d = 0.04) was similar to that pre-restoration in 2014 (d = 0.07). At the Rinearson Natural Area restoration site, no sampling was conducted as habitat restoration actions were not complete in 2016. At reference sites, 10 quadrats were sampled in confluence habitat at Oswego Creek, Cemetery Creek, Columbia Slough, and McCarthy Creek. Ten quadrats were also sampled in shoreline habitat at Cemetery Creek, Ross Island, McCarthy Creek, and Multnomah Channel. At reference sites, larval lamprey (n = 15) were detected in 13 of 80 (d = 0.16) quadrats sampled and detection probabilities at Ross Island were similar in 2014 and 2016. Five of the six reference sites were occupied by larval lamprey. This information will be useful for evaluating the effects of habitat restoration on occupancy and distribution of larval lamprey in the lower Willamette River, and monitoring changes in occupancy over time.

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Introduction

Pacific lamprey *Entosphenus tridentatus* in many areas, such as the Columbia River Basin (CRB), have experienced a great decline in abundance (Close et al. 2002) and have been given protected status within Oregon (Kostow 2002). Lamprey are culturally important to Native American tribes, are ecologically important within the food web, and are an indicator species whose decline provides further insight into the impact of human actions on ecological function (Close et al. 2002). Much information is lacking on the basic biology, ecology, and population dynamics that is required for effective conservation and management.

Pacific lampreys have a complex life history that includes a multiple year larval (ammocoete), migratory juvenile (macrophthalmia), and adult marine phase (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 distribution and habitat preference of larvae comes from CRB tributary systems (Moser and Close 2003; Torgersen and Close 2004; Stone and Barndt 2005; Stone 2006) and coastal basins (Farlinger and Beamish 1984; Russell et al. 1987; Gunckel et al. 2009).

Larval lamprey are known to occur in sediments of low-gradient streams (<5th order [1:100,000 scale]; Torgersen and Close 2004) but their use of larger river habitats in relatively deeper areas is less known. Downstream movement of larvae, whether passive or active, occurs year-round (Nursall and Buchwald 1972; Gadomski and Barfoot 1998; White and Harvey 2003). Sea lamprey *Petromyzon marinus* ammocoetes have been documented in deepwater habitats in tributaries of the Great Lakes, within the 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), and in large water bodies associated with the St. Marys River (Young et al. 1996). However, references to other species occurring in deepwater or lacustrine habitats are scarce (American brook lamprey *L. appendix*; Hansen and Hayne 1962). In the Pacific Northwest, observations of larval lamprey occurrence in large rivers have been made, for example during smolt monitoring operations at Columbia River hydropower facilities, impinged on screens associated with juvenile bypass systems (Moursund et al. 2003; CRITFC 2008), or through observation during dewatering events. Specific collections of ammocoetes have been made in large river habitats in British Columbia which are thought to be representative of ammocoetes dispersing downstream (Beamish and Youson 1987; Beamish and Levings 1991). More recently, evaluations of larval Pacific lamprey occupancy and distribution in mainstem river habitats have suggested widespread occurrence in certain areas of the Columbia River and Willamette River mainstem (Jolley et al. 2012; Jolley et al. 2013, Jolley et al. 2014)

A portion of the mainstem of the lower Willamette River that is known to be occupied by larval Pacific and western brook lamprey (Jolley et al. 2012) was declared a Superfund Site in 2000 by the U.S. Environmental Protection Agency. The Superfund study area extends from river kilometer 3.2 to river kilometer 18.9 and has a broader focus area extending from the Columbia River to Willamette Falls (Figure 1). To mitigate for past environmental damage being identified through the Natural Resource Damage Assessment (NRDA) process, this area is subject to various restoration activities as well as assessments of the effectiveness of any restoration. Presently, aquatic restoration projects are focused on restoring juvenile Chinook salmon *Oncorhynchus tshawytscha* habitat. It is unclear whether any of the restoration activities will provide additional benefits to other co-occurring species including larval and juvenile Pacific lamprey that may likewise occur in these areas. However, these activities provide an opportunity to understand the potential effects of habitat restoration on larval and juvenile lampreys. As such, there is interest in monitoring the effectiveness of the restoration, in part, relative to larval Pacific lamprey.

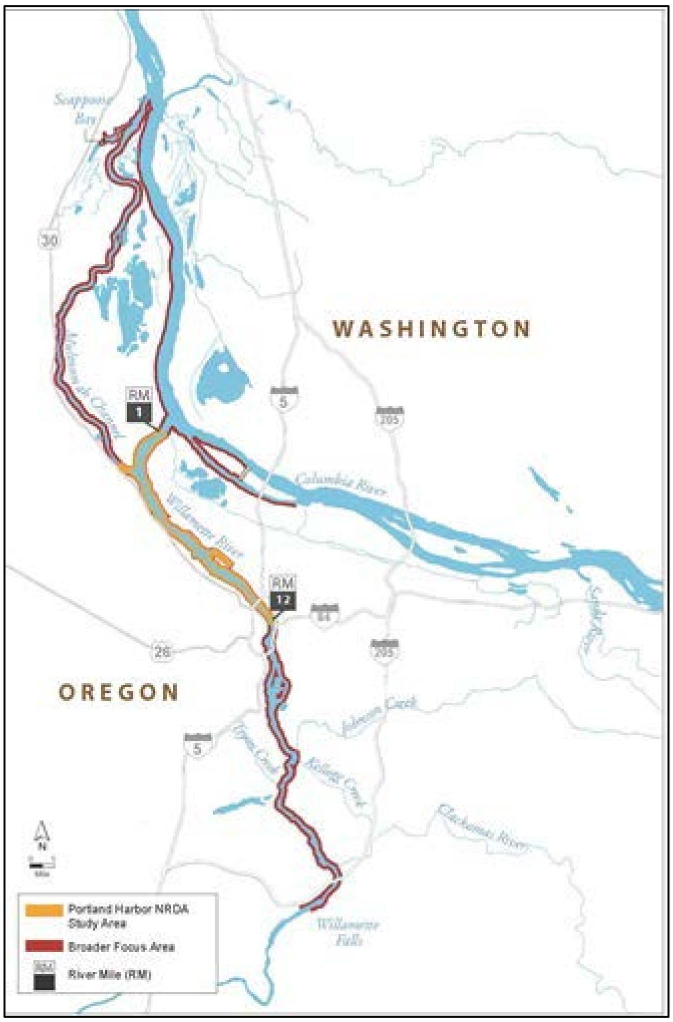

Figure 1. Portland Harbor Superfund study area (orange outline) and the broader focus area (red outline) on the lower Willamette River.

A lamprey monitoring plan (LMP) for restoration projects in the Portland Harbor Superfund area was developed based on a set of monitoring goals and objectives that were identified by the Trustee Council and lamprey biologists over two workshops held in the fall of 2011. The LMP priorities included (i.) monitoring the impact of restoration actions on larval and juvenile lamprey populations and health in Portland Harbor, and (ii.) gathering information about larval and juvenile lamprey life history, biology, and habitat requirements that could be used by the Trustee Council to inform future design and evaluation of lamprey restoration projects. Since lamprey biology and life history are different from other aquatic biota, the overlap between the LMP and the general restoration monitoring and stewardship plan is not extensive. The LMP differs from the general restoration monitoring and stewardship plan, in part, because the lamprey monitoring is proposed to continue for a period of 20 years. In most cases, the metrics proposed for collection as part of the lamprey monitoring effort need to be co-located with lamprey sampling. To maximize efficiencies, the Trustee Council will, to the extent possible, use data collected as part of the LMP for general restoration monitoring and stewardship. Biologists recommended monitoring lamprey for 20 years, with the goal of capturing data for 1 to 2 complete generations. Pre-implementation monitoring will be conducted to the extent practical at each restoration site. Lampreys are expected to colonize habitats rapidly. Therefore, monitoring will be conducted on a yearly basis for the first five years, and every five years thereafter. In general, the proposed work is guided by the LMP. However, due to site specific conditions and constraints, the specific metrics and timing of monitoring proposed for any given site may differ slightly from those outlined in the LMP.

In 2016, we proposed to begin post-habitat restoration monitoring of larval lamprey occupancy, distribution, and habitat use in or near Alder Point and Rinearson Natural Area restoration sites in the first year after habitat restoration was complete. Understanding larval lamprey usage of habitats in and adjacent to restoration sites is critical to gauging the effectiveness of restoration activities. At present, little specific information is available on whether lampreys colonize restored habitats, which life stages may use these habitats, or how quickly and for how long they use these habitats. A before-after control-impact (BACI) approach will be used to evaluate the effectiveness of restoration activities, as that allows us to make inferences about whether changes in lamprey occupancy observed at the restoration site are the result of the restoration actions. Thus, we propose to determine whether larval Pacific lamprey occupy restoration sites and reference sites both prior to and after restoration actions. Our specific objectives for this phase of NRDA restoration monitoring were as follows:

1. Determine whether lamprey occupy restoration sites in the lower Willamette River and Multnomah Channel.
2. Determine whether lamprey occupy reference sites in the lower Willamette River and Multnomah Channel.
3. Determine the types of habitat available at each site and in which habitat types lamprey are detected.
4. Characterize lamprey species and life history stage that occupy each site.
5. Evaluate the health of lamprey detected at each site.

Study Sites

Restoration Sites

Alder Point

The Alder Point restoration site is located at the southern tip of Sauvie Island (Multnomah County, OR), and thus is bordered on the east side by the Willamette River (at approximately river km 6), and on the west side by Multnomah Channel (Figure 2). Slough habitat (henceforth Alder Slough) was constructed through the restoration site, connecting the Willamette River and Multnomah Channel. Alder Slough intersects the Willamette River at two distinct confluence habitats, and Multnomah Channel at one confluence (Figure 3). Restoration of shoreline habitat at the site (i.e., levee removal) occurred along both the Willamette River and Multnomah Channel. Larval lamprey are known to occur in the mainstem of the Willamette River in this region (Jolley et al. 2012), and have the potential to occur in restored areas within confluence and shoreline habitats in the mainstem Willamette River and Multnomah Channel as well as within Alder Slough. Pre-restoration sampling was conducted at shoreline habitat in Multnomah Channel and the Willamette River mainstem in fall 2014 (Jolley et al. 2015). Post-restoration monitoring would consist of sampling for larval lamprey in shoreline habitats in the mainstem Willamette River and Multnomah Channel, as well as newly created confluence habitats in Multnomah Channel and the Willamette River and newly created slough habitat (Alder Slough) within the restoration site (Figure 3).

Rinearson Natural Area

Rinearson Creek flows through the Rinearson Natural Area restoration site (Clackamas County, OR) and enters the Willamette River from the east, just downstream of the mouth of the Clackamas River (river km 39; Figure 2). Currently the site has tributary or slough habitat that drains into the Willamette River, as well as associated confluence habitat in the mainstem Willamette River (Figure 4). Larval lamprey are known to occur in the mainstem of the Willamette River in this region (Jolley et al. 2012), and have access to and the potential to occur in proposed restoration areas in Rinearson Creek and confluence habitats in the mainstem Willamette River. Pre-restoration sampling was conducted at confluence habitat in the Willamette River mainstem as well as wade-able depth tributary habitat in Rinearson Creek in spring 2015 (Silver et al. 2016). Post-restoration monitoring would consist of sampling for larval lamprey in tributary reaches in Rinearson Creek as well as confluence habitats in the mainstem Willamette River.

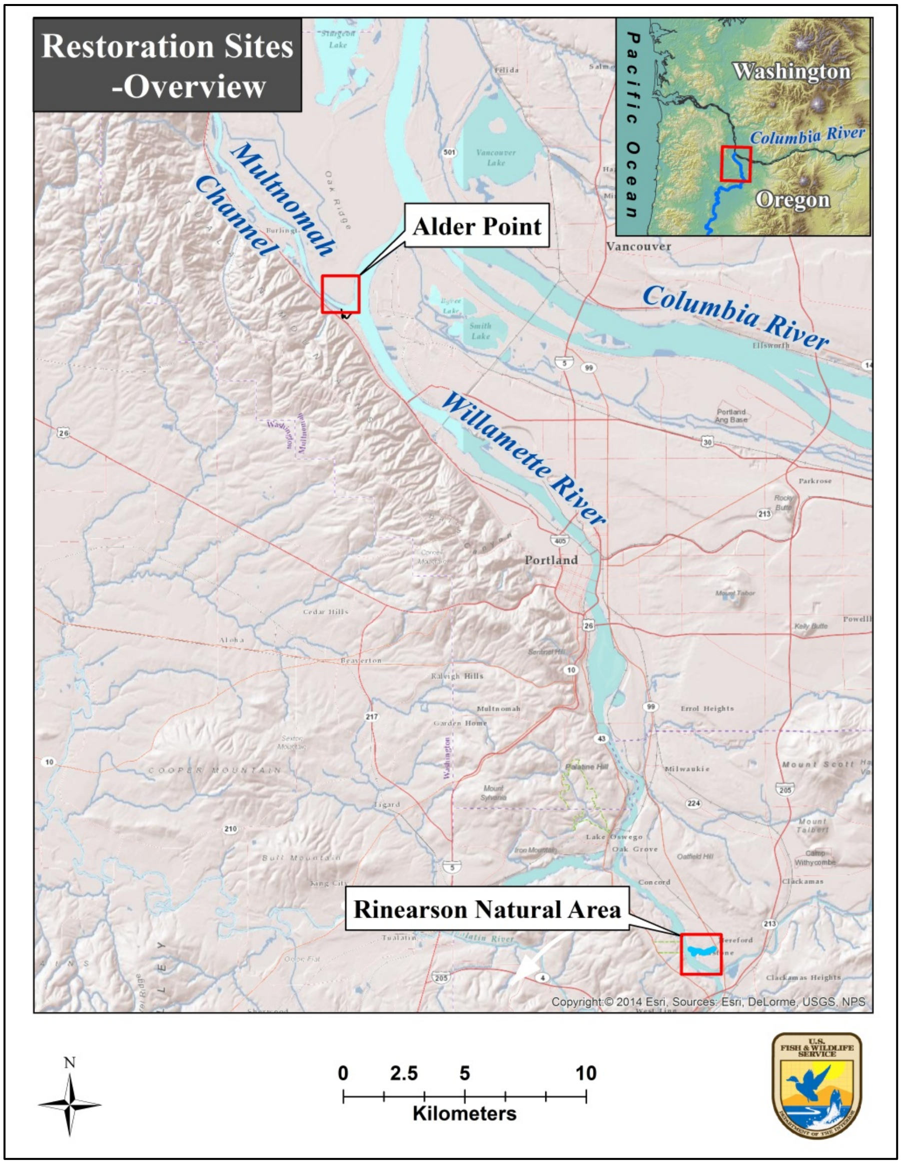

Figure 2. Locations of the Alder Point and Rinearson Creek Natural Area restoration sites in the lower Willamette River. The Alder Point restoration site is at the southern tip of Sauvie Island (near river km 5) and has shoreline on both the Willamette River and Multnomah Channel. Rinearson Creek (near river km 39) enters the Willamette River just downstream of the Willamette-Clackamas river confluence.

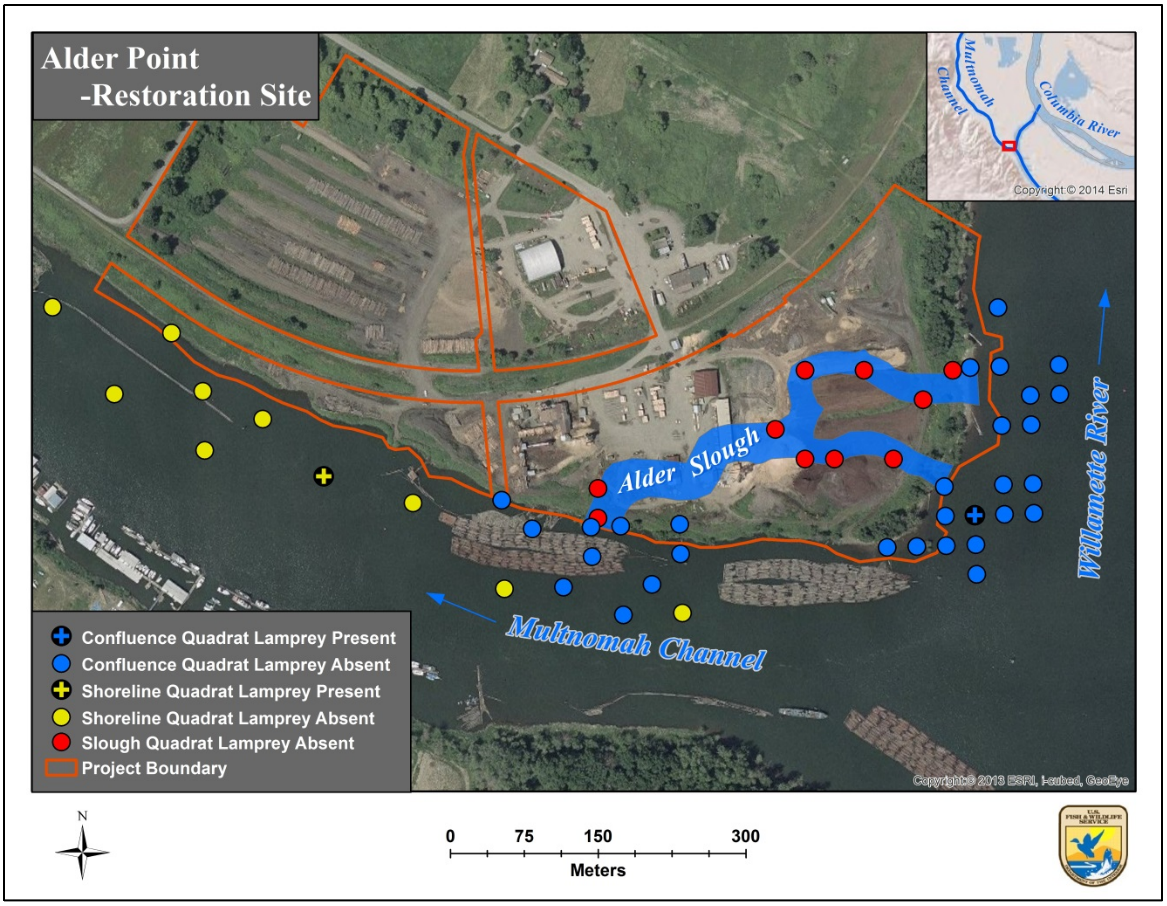

Figure 3. Confluence quadrats (blue points; each point represent a quadrat center point), shoreline quadrats (yellow points), and slough quadrats (red points) sampled at the Alder Point restoration site in 2016.

Figure 4. Confluence quadrats (blue points) and tributary sample reaches (red points) at the Rinearson Natural Area restoration site.

Reference Sites

Six reference sites were identified throughout the lower Willamette River and Multnomah Channel (Figure 5). Reference sites were selected in locations that contained confluence, shoreline, or slough habitats and in areas not proposed for habitat restoration in the immediate future. The confluence, shoreline, or slough habitats at the reference sites are similar to those at restoration sites following habitat restoration. Larval lamprey are known to occur in the mainstem of the Willamette River and Multnomah Channel in the vicinity of the reference sites (Jolley et al. 2012), and have access to and the potential to occur in confluence and shoreline habitats at the reference sites.

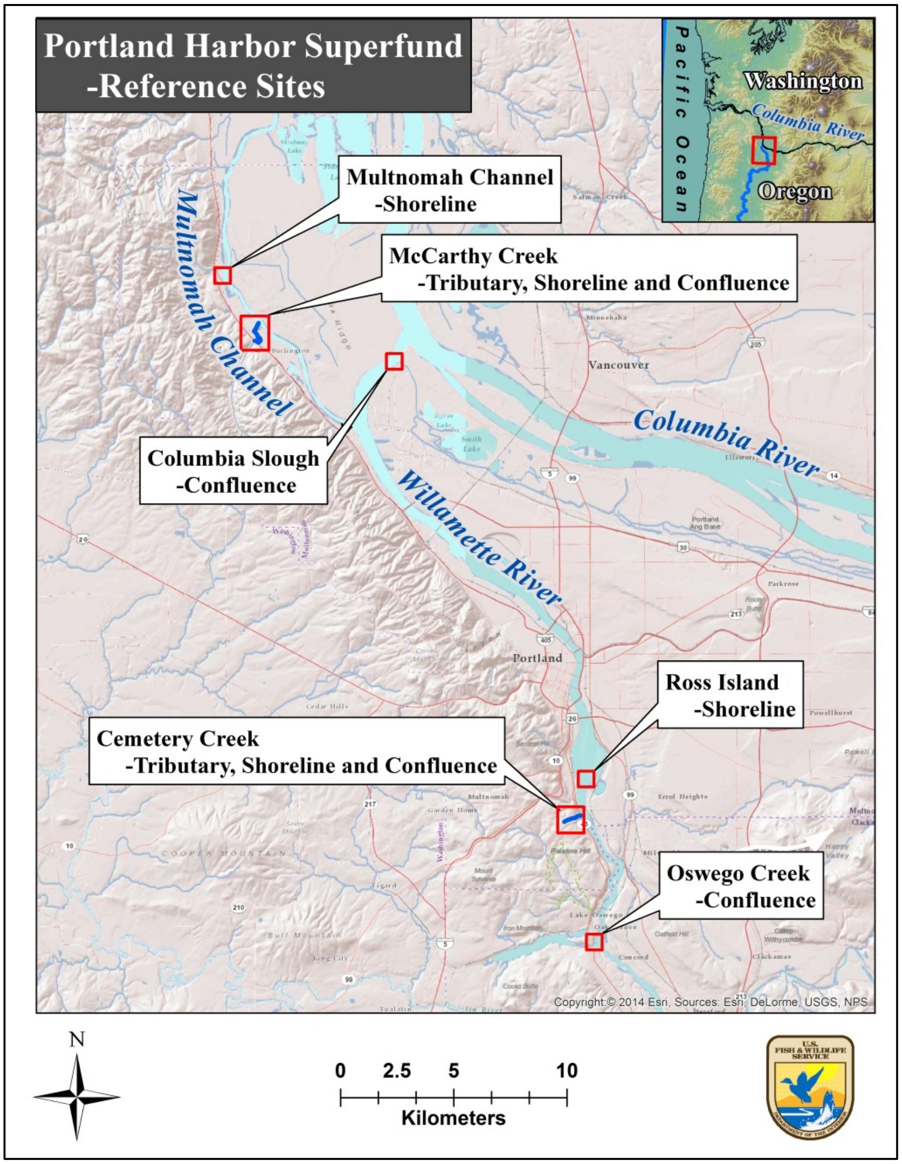

Figure 5. Locations of the six reference sites in the lower Willamette River and Multnomah Channel.

Ross Island Shoreline

The Ross Island reference site, located just upstream of the Ross Island Bridge near downtown Portland (near river km 24; Figure 6), contains shoreline habitat similar to that of restored shorelines at restoration sites. The Ross Island reference site was also sampled prior to restoration at Alder Point and was sampled during the same season (summer 2014) as pre-restoration sampling at Alder Point.

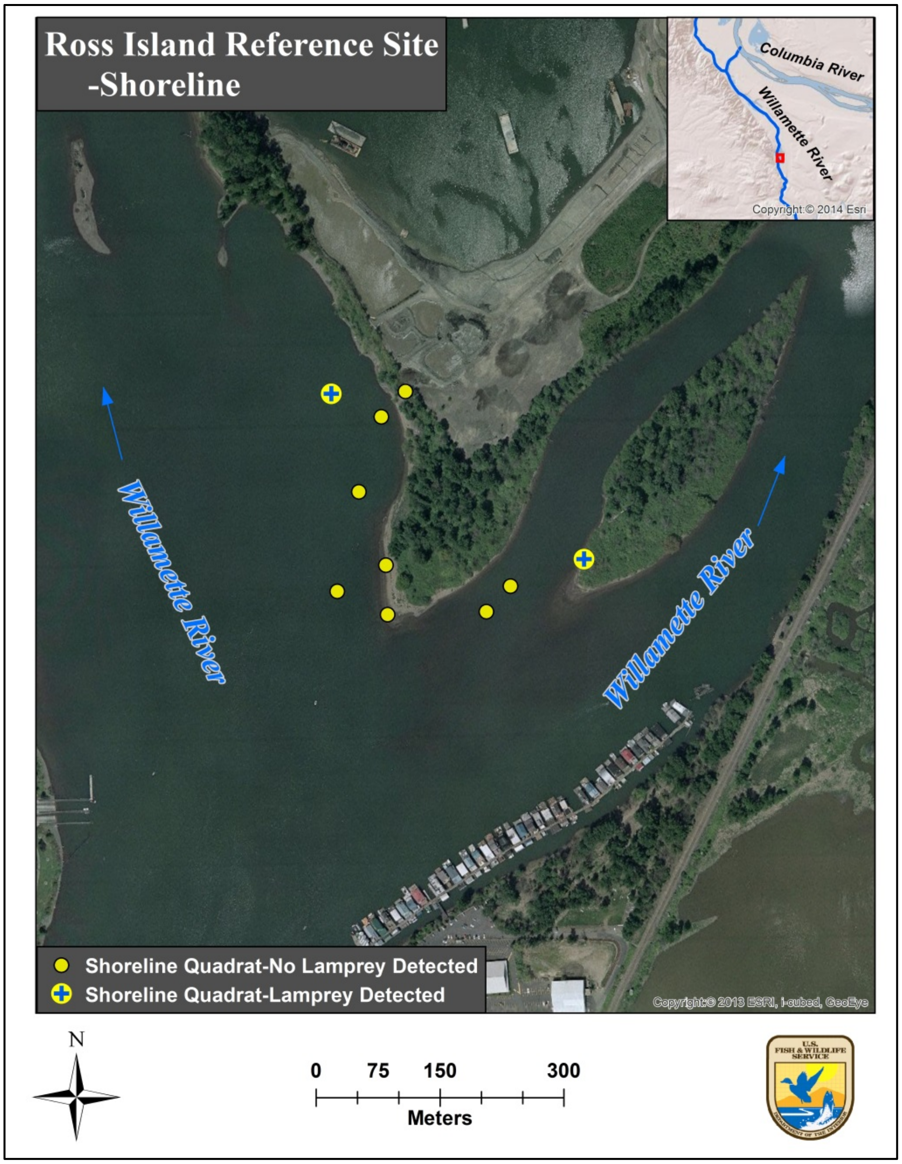

Figure 6. At the Ross Island reference site larval lampreys were detected at 2 of 10 shoreline quadrats sampled within the mainstem Willamette River in 2016.

Multnomah Channel Shoreline

The Multnomah Channel reference site is located just downstream of the McCarthy Creek reference site (near river km 24; Figure 7). The Multnomah Channel reference site contains shoreline habitat similar to that of restored shorelines at restoration sites. Larval lamprey have access to and the potential to occur in Multnomah Channel.

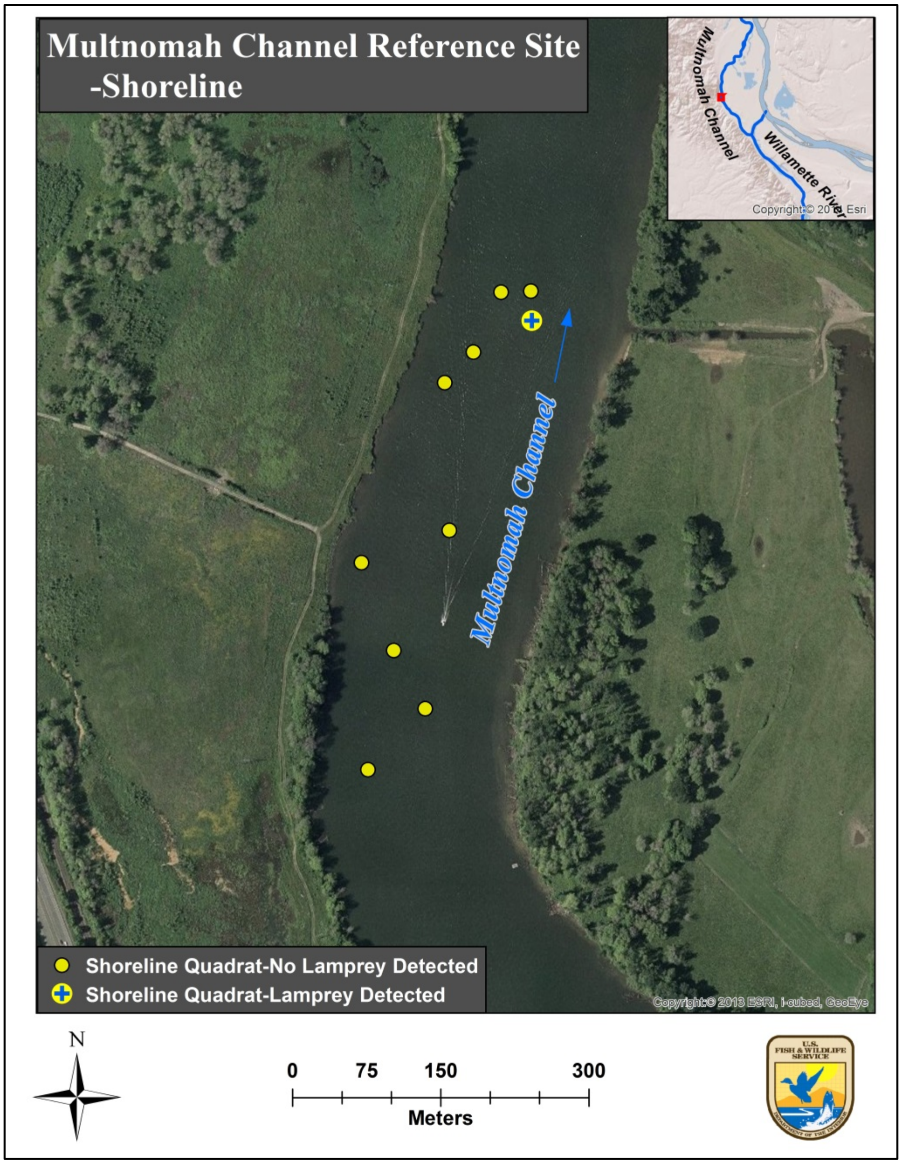

Figure 7. At the Multnomah Channel reference site larval lampreys were detected at 1 of 10 shoreline quadrats sampled within the mainstem Multnomah Channel in 2016.

Oswego Creek Confluence

Oswego Creek enters the Willamette River from the west near the town of Lake Oswego (near river km 34; Figure 8). Confluence habitat occurs in the mainstem Willamette River associated with the mouth of Oswego Creek and is similar to confluence habitat at restoration sites. Larval lamprey are known to occur in the mainstem of the Willamette River in this region (Jolley et al. 2012), and have access to and the potential to occur in confluence habitats at this site.

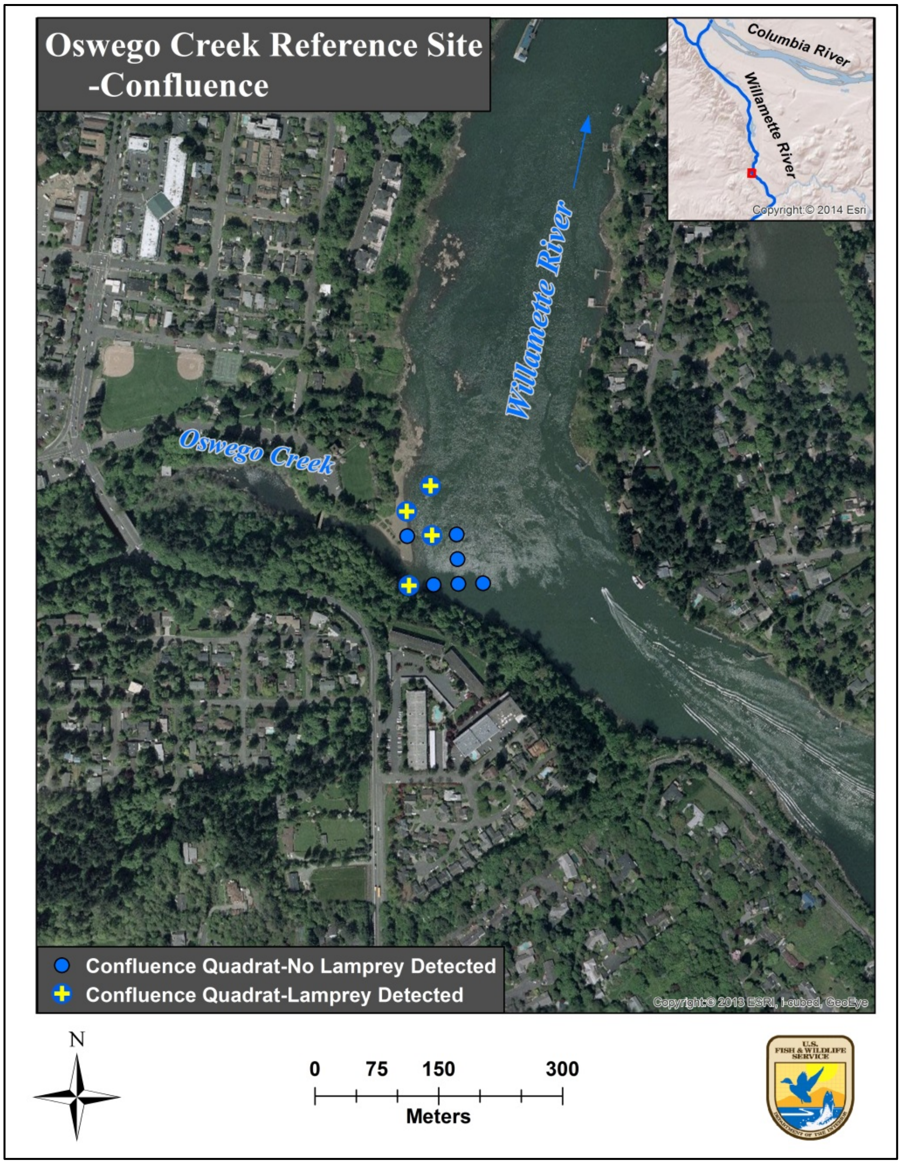

Figure 8. At the Oswego Creek reference site larval lampreys were detected at 4 of 10 shoreline quadrats sampled within the mainstem Willamette River in 2016.

Columbia Slough Confluence

Columbia Slough enters the Willamette River from the east near the confluence of the Willamette and Columbia Rivers (near river km 2; Figure 9). Confluence habitat occurs in the mainstem Willamette River associated with the mouth of Columbia Slough and is similar to confluence habitat at restoration sites. Larval lamprey are known to occur in the mainstem of the Willamette River in this region (Jolley et al. 2012), and have access to and the potential to occur in confluence habitats at this site.

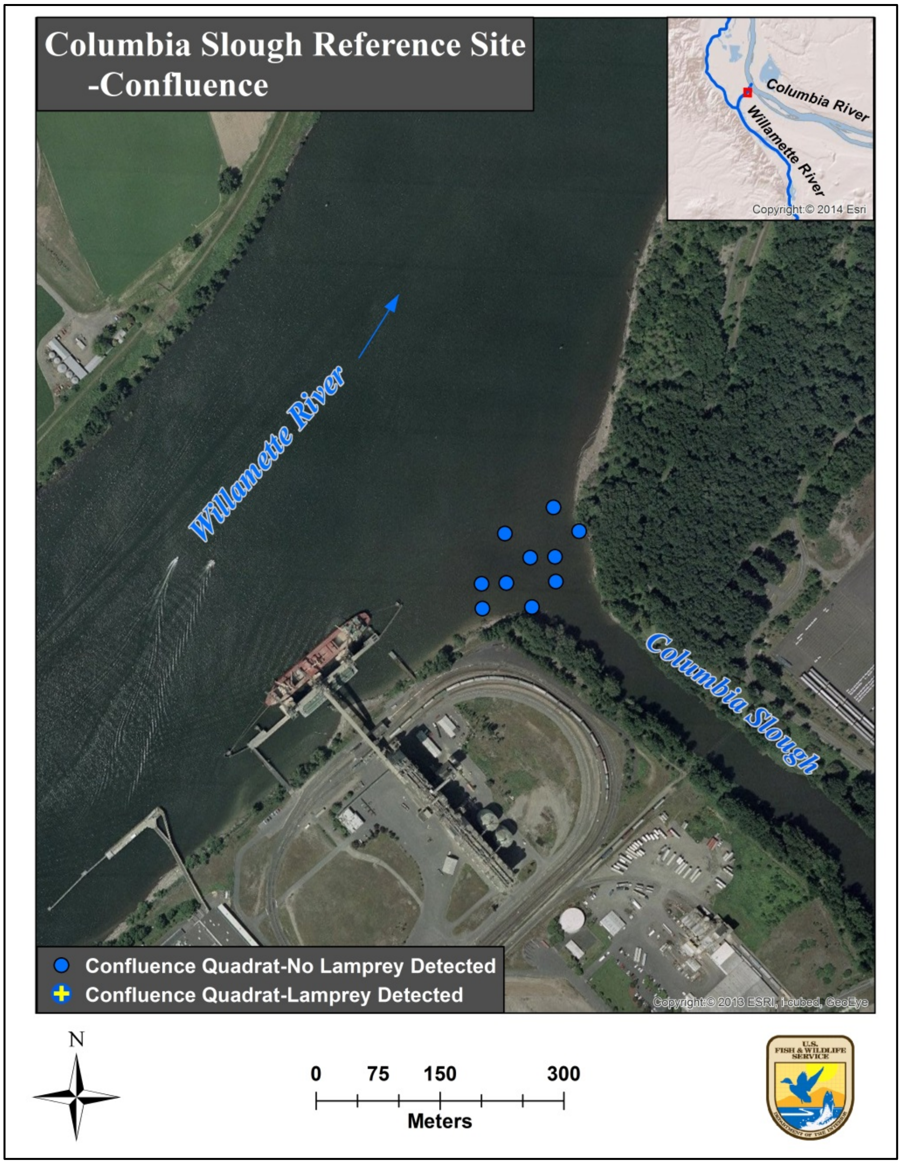

Figure 9. At the Columbia Slough reference site larval lampreys were detected at 0 of 10 confluence quadrats sampled within the mainstem Willamette River in 2016.

Cemetery Creek Tributary, Confluence, and Shoreline

Cemetery Creek enters the Willamette River from the west, upstream of Ross Island (near river km 27; Figure 10). The Cemetery Creek reference site has tributary or slough habitat that drains into the Willamette River, as well as confluence and shoreline habitats in the mainstem Willamette River. Larval lamprey are known to occur in the mainstem of the Willamette River in this region (Jolley et al. 2012), and have access to and the potential to occur in Cemetery Creek, as well as confluence and shoreline habitats in the mainstem Willamette River. During pre-restoration sampling, Cemetery Creek served as a reference site to the Rinearson Natural Area, and was selected in part because it is similar in size and located in proximity to the Rinearson Natural Area restoration site.

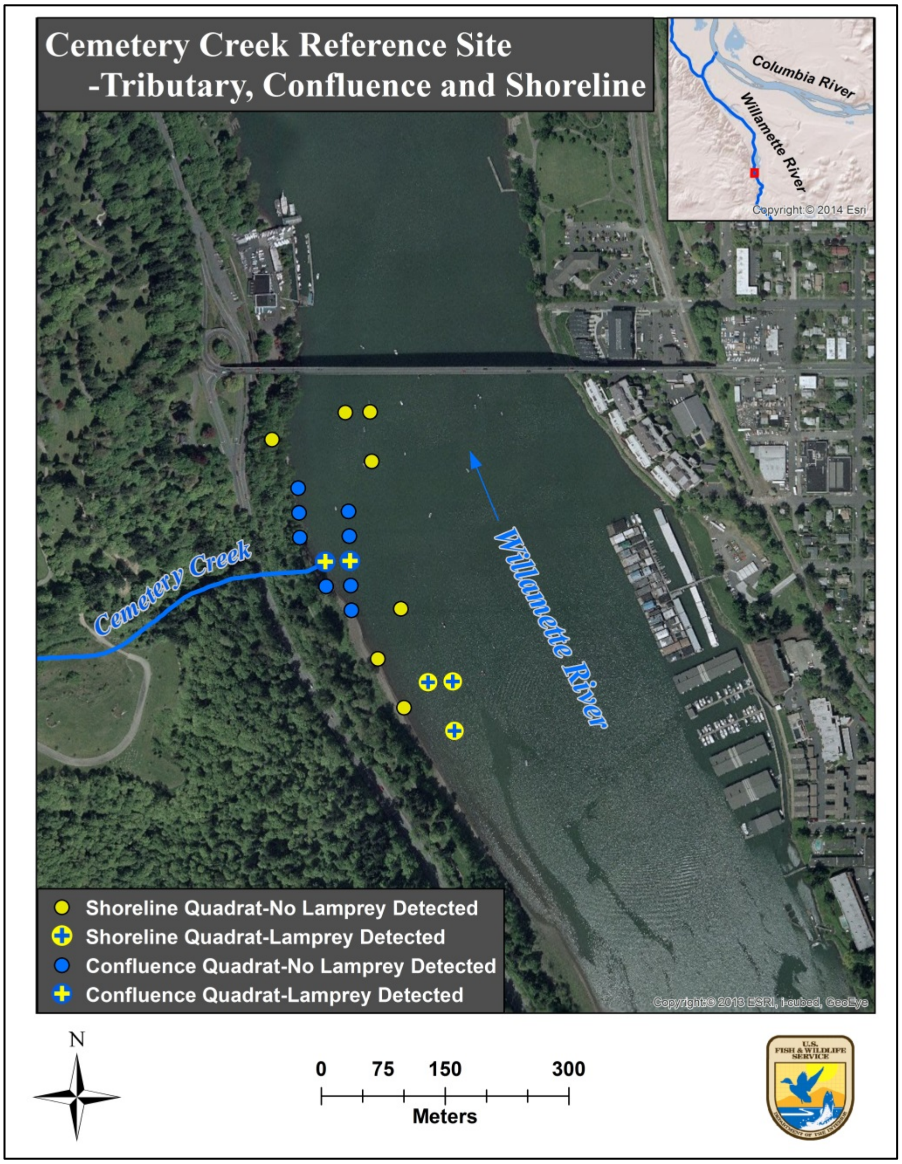

Figure 10. At the Cemetery Creek reference site larval lampreys were detected at 2 of 10 confluence quadrats sampled and 3 of 10 shoreline quadrats sampled within the mainstem Willamette River in 2016. No tributary sampling was conducted in Cemetery Creek in 2016 due to a lack of viable habitat.

McCarthy Creek Tributary, Confluence, and Shoreline

McCarthy Creek enters the Multnomah Channel from the southwest, downstream of the Sauvie Island Bridge (near river km 29; Figure 11). The McCarthy Creek reference site has tributary or slough habitat that drains into the Multnomah Channel, as well as confluence and shoreline habitats in Multnomah Channel. Larval lamprey have access to and the potential to occur in McCarthy Creek, as well as confluence and shoreline habitats in Multnomah Channel.

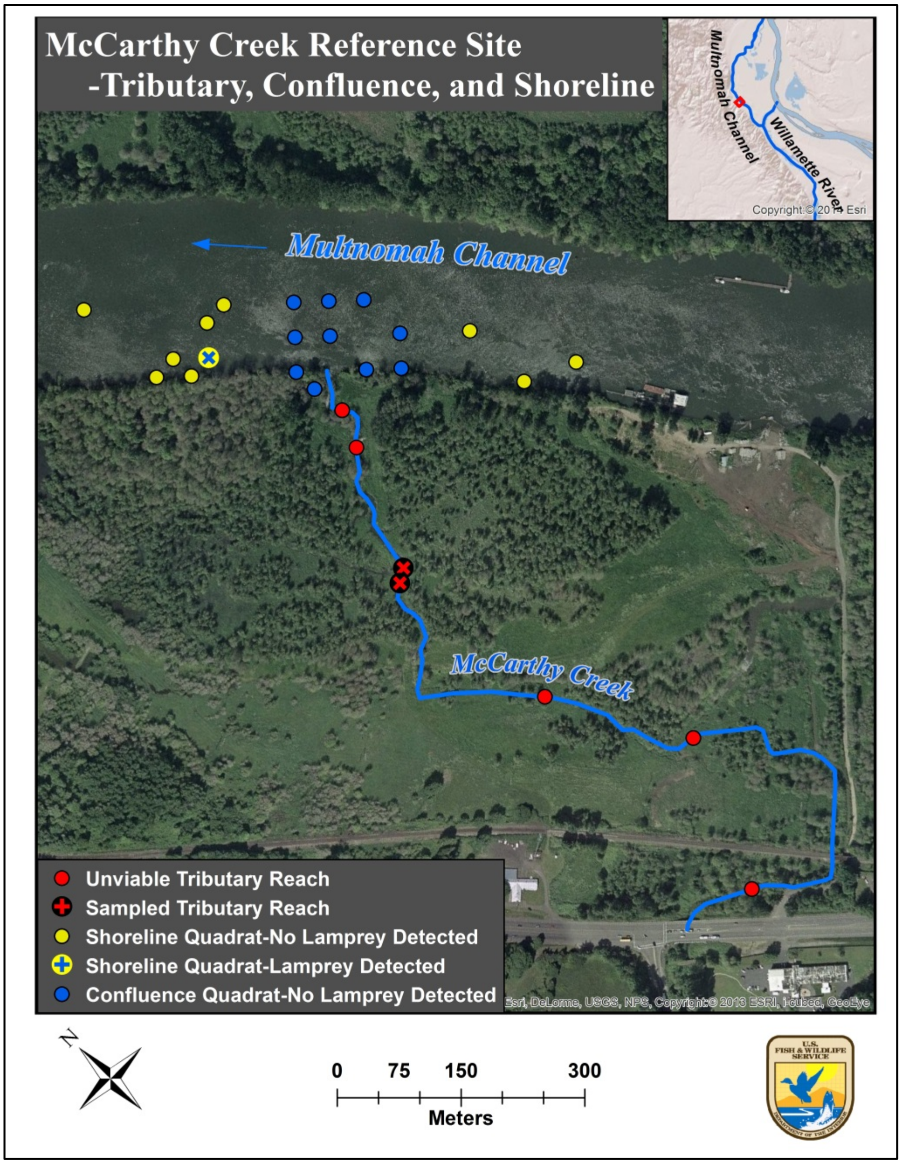

Figure 11. At the McCarthy Creek reference site larval lampreys were detected at 0 of 10 confluence quadrats sampled and 1 of 10 shoreline quadrats sampled within the mainstem Multnomah Channel in 2016. No larval lamprey were detected in two tributary reaches sampled in McCarthy Creek in 2016. The remaining tributary reaches were not sampled as they were not viable habitat.

Methods

Sample Framework

We evaluated occupancy of larval lamprey in the restoration and reference sites by adapting an approach that has been applied previously to studies of larval lamprey occupancy in the Columbia River basin in both mainstem and tributary habitats (Silver et al. 2010; Jolley et al. 2012; Jolley et al. 2013; Jolley et al. 2014; USFWS unpublished data). The approach has several requirements: 1) a unit- and gear-specific detection probability (assumed or estimated); 2) the probability of presence (given no detection) at a predetermined acceptably low level; and 3) random identification of spatially balanced sample units that allow estimation of presence and refinement of detection probabilities. A unit-specific probability of detection, d_{unit}, was calculated as the proportion of sample quadrats or reaches in which larvae were captured. The posterior probability of area occupancy, given a larval lamprey was not detected, was estimated as:

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

where P(F) is the prior probability of larval lamprey presence. Although in this case we knew the lower Willamette River was occupied with larval lamprey, a 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($\sim F$), 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). Random identification of spatially-balanced sample units was achieved by using a generalized random -tessellation stratified (GRTS) approach to delineate sample units in an ordered, unbiased manner (Stevens and Olsen 2004). Patterns of occupancy by area were compared using the Fisher's Exact test for differences in detection probabilities. Significance levels were set at α = 0.05.

Confluence and Shoreline Area Sample Framework

Sample quadrats at confluence and shoreline areas area a subset of quadrats previously delineated and overlaid on the entire lower Willamette River from Willamette Falls to the Columbia River including Multnomah Channel, in association with previous lamprey research in this region (Jolley et al. 2012). Quadrats were delineated using the generalized random-tessellation stratified (GRTS) approach scripted in Program R (Stevens and Olsen 2004; Jolley et al. 2012; R Core Team, 2013). The GRTS method assigns a hierarchical order to quadrats which can be used as an unbiased method of ranking the priority of quadrats for sampling. Delineation of quadrats that are unbiased, randomly selected, and spatially-balanced within a sample universe allows for calculation of unit-specific detection probabilities. In turn, unit-specific estimates of detection probability can be applied to determine sample effort necessary for achieving a desired level of certainty that an area is not occupied by lamprey when they are not detected. Here we proposed to use a sampling effort (number of sample quadrats) that we estimate would allow for at least 80% certainty that larval lampreys do not occupy at least 20% of a confluence or shoreline area when they are not detected (see Bayley and Peterson 2001; Peterson and Dunham 2003). The amount of effort was based, in part, on estimates of quadrat-specific detection probabilities generated from previous work (Jolley et al. 2012). Sample effort was also dependent, in part, on total area. This sample effort corresponded to sampling of 10 quadrats at each confluence and/or shoreline area at both restoration and reference sites.

Wade-able Tributary Sample Framework

Evaluation of larval lamprey occupancy of wade-able depth tributary habitats will be conducted at restoration sites pre- and post-restoration. For each tributary area longer than 400 m, we will develop a layer of 50 m-long sample reaches for subsampling. The GRTS approach will again be used to delineate sample reaches in a random, spatially-balanced order (Stevens and Olsen 2004). The GRTS method assigns a hierarchical order to the reaches within the creek which is used as an unbiased method of ranking the priority of reaches for sampling. Delineation of sample reaches that are unbiased, randomly selected, and spatially-balanced within a sample universe allows for calculation of unit-specific detection probabilities. In turn, unit-specific estimates of detection probability can be applied to determine sample effort necessary for achieving a desired level of certainty that a tributary is not occupied by lamprey when they are not detected. As they are selected in the GRTS approach, the lower numbered reaches are given highest priority for sampling. Here we proposed to use a subsampling effort (number of sample reaches) that would allow for at least 80% certainty that larval lampreys do not occupy at least 20% of a tributary area when they are not detected (see Bayley and Peterson 2001; Peterson and Dunham 2003). The amount of effort was based, in part, on estimates of reach-specific detection probabilities generated from previous work (Silver et al. 2010; USFWS unpublished data). Sample effort was also dependent, in part, on total area. For wade-able depth tributaries, if the area of interest is less than 400 m in length, we propose to sample all reaches (contiguous 50 m reaches). If the area of interest is 400 m or longer, we propose to sample seven reaches.

Alder Point Restoration Site

Confluence Quadrat Selection

Confluence quadrats at the Alder Point site comprised a subset of quadrats filtered from the lower Willamette River and Multnomah Channel layers (described above). Quadrats were filtered from the larger layers according to the placement of a semicircular buffer of 100 m radius centered on the confluence of each tributary/slough and the Willamette River or Multnomah Channel (Figure 3). The three branches of Alder Slough each form a distinct confluence area at Alder Point, two occur on the Willamette River and one occurs on Multnomah Channel. In this case, the confluence quadrat selection process was duplicated at each of the three confluence areas (Figure 3), resulting in 60 total sample quadrats at the three Alder Slough confluence areas. At each of the three confluence locations, the 10 lowest numbered quadrats as ordered by the GRTS method were assigned the highest priority for sampling.

Shoreline Quadrat Selection

Shoreline quadrats at the Alder Point site also comprised a subset of quadrats filtered from the lower Willamette River and Multnomah Channel layers (described above). Quadrats were filtered from the larger layers according to the placement of a 100m-wide polygon, from the waterline perpendicular 100m into the Willamette River or Multnomah Channel. The length of the shoreline polygon was determined by the project area boundaries (Figure 3). The shoreline quadrat selection process resulted in 117 total sample quadrats adjacent to restored shorelines at Alder Point. The 10 lowest numbered shoreline quadrats as ordered by the GRTS method were assigned the highest priority for sampling.

Slough Quadrat Selection

To evaluate larval lamprey occupancy of Alder Slough, a layer of 30 m x 30 m quadrats was developed and overlaid on the newly constructed channel at Alder Point. Using the GRTS approach, quadrats in Alder Slough were delineated in a random spatially-balanced manner. The lowest 10 numbered quadrats were assigned the highest priority for sampling.

Rinearson Natural Area Restoration Site

Confluence Quadrat Selection

At the Rinearson Natural Area, Rinearson Creek forks into two distributary channels near the Willamette River creating two distinct confluence areas in the restoration site. In this case, the confluence quadrat selection process was carried out as described above at Alder Point, and duplicated at each of the two distinct confluence areas (Figure 4). The selection process resulted in 34 total sample quadrats at the two confluence areas. At each of the two confluence locations, the lowest numbered quadrats as ordered by the GRTS method were assigned the highest priority for sampling.

Wade-able Tributary Sample Reach Selection

Evaluation of larval lamprey occupancy in Rinearson Creek post-restoration is proposed to occur over an approximately 1200 m long segment of creek, spanning from the confluence with the Willamette River upstream to the crossing of River Road (Milwaukie, OR; Figure 4). Because the area of interest in Rinearson Creek was longer than 400 m, we proposed subsampling seven 50 m-long GRTS reaches in the creek. Sample reaches were delineated at a rate of one 50 m reach for every 50 m of stream. Thus, within the approximately 1200 m long study area in Rinearson Creek, 24 sample reaches were delineated, of which the lowest numbered reaches, as ordered by the GRTS method, were assigned the highest priority for sampling (Figure 4).

Reference Sites

Ross Island Shoreline

The Ross Island reference site contains shoreline habitat. The quadrat selection process was carried out as described above for shorelines at Alder Point. The length of the shoreline was modeled after that of restoration sites. The 10 lowest numbered shoreline quadrats as ordered by the GRTS method were again assigned the highest priority for sampling (Figure 6).

Multnomah Channel Shoreline

The Multnomah Channel reference site contains shoreline habitat. The quadrat selection process was carried out as described above for shorelines at Alder Point. The length of the shoreline was modeled after that of restoration sites. The 10 lowest numbered shoreline quadrats as ordered by the GRTS method were again assigned the highest priority for sampling (Figure 7).

Oswego Creek Confluence

The Oswego Creek reference site contains confluence habitat within the mainstem Willamette River. The confluence quadrat selection was carried out as described above for confluences at Alder Point. The 10 lowest numbered confluence quadrats as ordered by the GRTS method were again assigned the highest priority for sampling (Figure 8).

Columbia Slough Confluence

The Columbia Slough reference site contains confluence habitat within the mainstem Willamette River. The confluence quadrat selection was carried out as described above for confluences at Alder Point. The 10 lowest numbered confluence quadrats as ordered by the GRTS method were again assigned the highest priority for sampling (Figure 9).

Cemetery Creek Tributary, Confluence, and Shoreline

The Cemetery Creek reference site has tributary, confluence and shoreline habitats. In Cemetery Creek, the tributary area of interest was less than 400 m in length, spanning from the confluence with the Willamette River upstream approximately 300 m to a reach of very high gradient. Because the viable sample area of interest was less than 400 m in length, we proposed to sample all viable reaches (contiguous 50 m reaches) in Cemetery Creek up to a total of 350 m. In confluence habitat within the mainstem Willamette River, quadrat selection was carried out as described above for confluences at Alder Point. The 10 lowest numbered confluence quadrats as ordered by the GRTS method were again assigned the highest priority for sampling. In shoreline habitat within the mainstem Willamette River, quadrat selection was carried out as described above for shoreline habitat at Alder Point. The 10 lowest numbered shoreline quadrats as ordered by the GRTS method were again assigned the highest priority for sampling (Figure 10).

McCarthy Creek Tributary, Confluence, and Shoreline

The McCarthy Creek reference site has tributary, confluence and shoreline habitats. Evaluation of larval lamprey occupancy in McCarthy Creek is proposed to occur over an approximately 1350 m long segment of creek, spanning from the confluence with the Multnomah Channel upstream to the crossing of Highway 30 (near Burlington, OR). Because the area of interest in McCarthy Creek was longer than 400 m, we proposed subsampling seven 50 m-long GRTS reaches in the creek. Sample reaches were delineated at a rate of one 50 m reach for every 50 m of stream. Thus, within the approximately 1350 m long study area in, 27 sample reaches were delineated, of which the lowest numbered seven reaches as ordered by the GRTS method were assigned the highest priority for sampling (Figure 11).

In McCarthy Creek confluence habitat within the Multnomah Channel, quadrat selection was carried out as described above for confluences at Alder Point. The 10 lowest numbered confluence quadrats as ordered by the GRTS method were again assigned the highest priority for sampling. In shoreline habitat within the mainstem Multnomah Channel, quadrat selection was carried out as described above for shoreline habitat at Alder Point. The 10 lowest numbered shoreline quadrats as ordered by the GRTS method were again assigned the highest priority for sampling (Figure 11).

Quadrat Sampling

Each sampling event consisted of a single drop with deepwater electrofishing equipment within the 30 x 30 m quadrat (Bergstedt and Genovese 1994; Jolley et al. 2012). Quadrats were accessed and sampled by boat, using quadrat center point Universal Transverse Mercator (UTM) coordinates for navigation. When quadrats could not be sampled due, for example, to dewatered conditions, depth less than 0.3 m, excessive velocity, or excessive depth (>21 m) they were eliminated and subsequent quadrats were increased in priority (Table 1). The deepwater electrofisher was comprised of a modified AbP-2 electrofisher (ETS Engineering, Madison, WI) which delivered electrical stimulus to river bottom substrates at electrodes mounted to a fiberglass bell (or hood; 0.61 m^2 in area). 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. The electrofisher bell was coupled by a 76 mm vinyl suction hose to a gasoline-fueled hydraulic pump. The hydraulic pump was started approximately 5 seconds prior to shocking to purge air from the suction hose. Suction was produced by directing flow from the pump through a hydraulic eductor, which allows larvae to be collected in a mesh basket (27 x 62 x 25 cm; 2 mm wire mesh) while preventing them from passing through the pump. A 60 second pulse delivery was followed by an additional 60 seconds of pumping to further allow displaced larvae to cycle through the hose and into the collection basket. 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) and the Willamette River (Jolley et al. 2012).

Wade-able Tributary Sampling

For wade-able depth tributary areas, each sampling event consisted of electrofishing 50 m reaches for larval lamprey (Silver et al. 2010). Sample reaches were accessed on foot using GPS units loaded with sample reach UTMs for navigation. When a reach could not be sampled due, for example, to dewatered conditions, excessive depth (e.g. > 2 m), or lack of access due to private property, they were eliminated and subsequent reaches were increased in priority. Once a sample reach was accessed, a 50 m segment was measured and flagged. Water temperature and conductivity were recorded in each reach. The reach was electrofished using an AbP-2 backpack electrofisher. Power output settings for the AbP-2 were adapted from Weisser and Klar (1990). Initially, the electrofisher delivered three DC pulses per second at 25% duty cycle, 125 V, with a 3:1 burst pulse train (i.e., three pulses on, one pulse off). This current is designed to stimulate burrowed ammocoetes to enter the water column. Once a larva was observed in the water column, 30 pulses/second were applied to temporarily immobilize the larva for capture in a net. We spent relatively more time within each reach electrofishing areas of preferred larval lamprey rearing habitat where depositional silt and sand substrates were dominant (henceforth Type I habitat, Slade et al. 2003). Relatively less time was spent electrofishing areas with hard bedrock and boulder substrates. All larval lamprey observed were captured and placed in buckets containing stream water.

Biological Data Collection

Collected lamprey were anesthetized in a solution of buffered tricaine methanesulfonate (MS-222), measured for total length (TL in mm; total weight was not measured), classified according to developmental stage (i.e., larvae, juvenile, or adult), and when possible (i.e., larvae > 60 mm TL; Goodman et al. 2009) identified to genus (i.e., *Entosphenus* [Pacific lamprey] or *Lampetra* [western brook or river lamprey]) according to visual evaluations of caudal fin pigmentation patterns. Caudal fin tissue samples were also collected for potential future assignment of genus genetically (Spice et al. 2011; Docker et al. *in review*). Tissue samples are archived at the Columbia River Fish& Wildlife Conservation Office (CRFWCO) pending funding availability for genetic identification. Upon resuming active swimming behavior, larvae were released near the area of capture. Physical anomalies (lesions, suspected bird strikes, tumors, etc.) were recorded for all larvae. If abnormalities were observed on a larva, the individual would be euthanized and preserved for potential evaluation at a later date. In addition, observations of juveniles, adults, or suspected Pacific lamprey nests were also recorded.

Habitat Data Collection

Confluence and Shoreline Areas

Concurrent to each sampling event a sediment sample was taken (when possible) from each quadrat with a Ponar bottom sampler (16.5 cm x 16.5 cm). Each sample was mixed thoroughly and approximately two, 250-500 ml subsamples were transferred to containers provided by a contracted laboratory. Samples were labeled with the site number, replicate number and date, placed on ice, returned to the USFWS office, and subsequently handled per the instructions provided from the contracted laboratory. Water temperature (°C), conductivity (μS/cm) and water depth were also measured at each quadrat and are presented as mean (± SE) unless otherwise noted.

Wade-able Tributary Areas

Sediment samples were collected from each 50 m sample reach. Samples were mixed thoroughly and approximately two, 250-500 ml subsamples were transferred to containers provided by a contracted laboratory. Each sample was labeled with the reach number, replicate number and date, placed on ice, returned to the USFWS office, and subsequently handled per the instructions provided from the contracted laboratory.

Within each sample reach, water temperature (°C) and conductivity (μS/cm) were measured, and visibility was qualitatively ranked as good, fair, or poor. The proportion (%) of Type 1 burrowing substrate within each reach was estimated. In general, larval lamprey habitats are classified as Type I, II, or III, and it is widely accepted that larvae appear to prefer Type I habitat the most and Type III the least (see Slade et al. 2003). Non-sediment habitat variables are presented as mean (± SE) unless otherwise noted.

Results

Restoration Sites

All lamprey collected at restoration sites were of the larval life stage, no detections of juveniles or evidence of adults (i.e., spawning nests) occurred. All larvae collected appeared healthy based on visual observation of external features, no abnormalities or indications of disease or poor health were observed.

Alder Point

We sampled 30 of 30 confluence quadrats visited, 10 of 10 shoreline quadrats visited, and 10 of 10 slough quadrats visited at Alder Point (Table 1). The feasibility of being able to sample a quadrat in each location was 100%, as no quadrats were found unfeasible (i.e., dewatered conditions). Larval lampreys (n = 2) were detected in 1 of 30 confluence quadrats (d = 0.03;

Figure 3), and 1 of 10 shoreline quadrats (*d* = 0.1; Figure 3; Table 1). No lampreys were detected in 10 quadrats sampled in the newly constructed Alder Slough. The total number of larvae occupying any individual quadrat was one.

Of the two larvae collected at Alder Point, one was identified morphologically as a western brook lamprey (TL = 79 mm), while one was too small to accurately identify visually (TL = 40 mm; Table 1; Figure 12). Larvae less than 40 mm TL are likely age-0 or age 1 while larger larvae are likely older (although definitive estimates of age based on size are difficult) (Meeuwig and Bayer 2005).

Sample depths ranged from 0.3 m to10.5 m, and larvae were detected at depths from 0.6 m to 3.0 m. Water temperature ranged from 17.8°C to 18.8°C and conductivity ranged from 107.5 μS/cm 127.7 μS/cm. Sediment samples collected at each confluence quadrat were transferred to ALS Environmental Laboratory (Kelso, WA) in October 2016 for quantification of parameters such as grain size, grain type, and organic content. See Appendix 1 for information on sediment analyses.

Table 1. Total number of quadrats visited, sampled, occupied by larval lamprey, and corresponding larval lamprey detection probability (*d*). Identification of larvae was done morphologically. Small (i.e., less than 60 mm TL) larvae cannot be accurately identified and are classified as unidentified (i.e., UNID).

		Quadrats							
	Site	**Visited**	**Sampled**	**Occupied**	***d***	**Pacific Lamprey**	***Lampetra* spp.**	**UNID**	**Total**
Restoration	Alder Slough	10	10	0	0	0	0	0	0
	Alder Confluence	30	30	1	0.03	0	0	1	1
	Alder Shoreline	10	10	1	0.1	0	1	0	1
Reference	Ross Island Shoreline	10	10	2	0.2	2	0	0	2
	Multnomah Channel Shoreline	10	10	1	0.1	0	0	1	1
	Oswego Creek Confluence	10	10	4	0.4	2	1	3	6
	Columbia Slough Confluence	10	10	0	0	0	0	0	0
	Cemetery Creek Confluence	13	10	2	0.2	0	0	2	2
	Cemetery Creek Shoreline	10	10	3	0.3	1	0	2	3
	McCarthy Creek Confluence	10	10	0	0	0	0	0	0
	McCarthy Creek Shoreline	10	10	1	0.1	0	0	1	1
	Totals	133	130	15	NA	5	2	10	17

Rinearson Natural Area

No sampling occurred at the Rinearson Natural Area restoration site in 2016, as restoration actions were not complete. Sampling is scheduled to occur in 2017 pending completion of restoration actions.

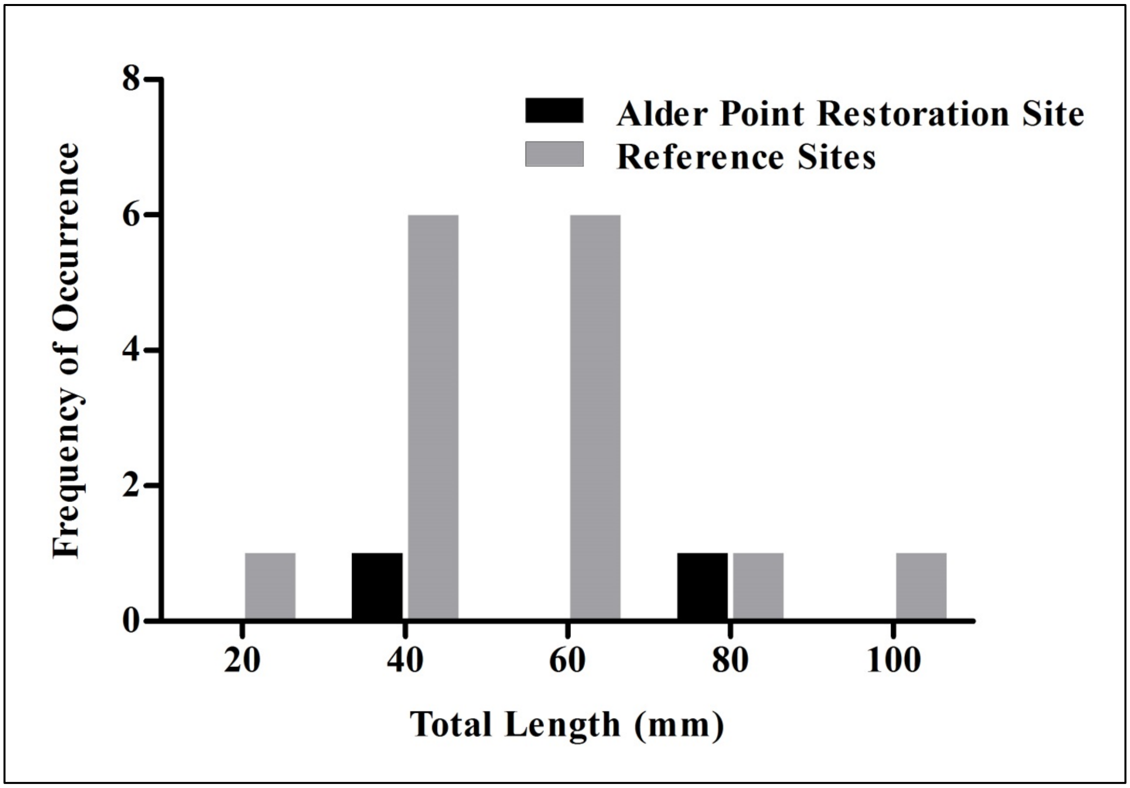

Figure 12. Length-frequency (total length in 20 mm bins centered on values on X-axis) of larval lampreys detected at the Alder Point Restoration site and the six reference sites in 2016.

Reference Sites

All lamprey collected at reference sites were of the larval life stage, no detections of juveniles or evidence of adults (i.e., spawning nests) occurred. All larvae collected appeared healthy based on visual observation of external features, no abnormalities or indications of disease or poor health were observed.

Ross Island Shoreline

We sampled 10 of 10 shoreline quadrats visited at Ross Island (Figure 6). Larval lamprey (n = 2) were detected at 2 of 10 quadrats sampled (d = 0.2; Table 1). Both larval lamprey collected at Ross Island shoreline were identified as Pacific lamprey (TL = 60 mm and 95 mm; Figure 12). The total number of larvae occupying any individual quadrat was one; no other life stages were detected. All collected larvae were in good condition and no visible external abnormalities were observed. Sample depths ranged from 0.8 m to10.4 m, and larvae were detected at depths from 1.2 m to 10.4 m. Water temperature was 21.8°C and conductivity was 81.8 μS/cm.

Table 2. Occupancy results from pre- and post-restoration sampling at Alder Point and Ross Island. Total number of quadrats visited, sampled, occupied by larval lamprey, and corresponding larval lamprey detection probability (*d*). Identification of larvae was done morphologically. Small (i.e., less than 60 mm TL) larvae cannot be accurately identified and are classified as unidentified (i.e., UNID).

			Quadrats							
	Sample Year	**Site**	**Visited**	**Sampled**	**Occupied**	***d***	**Pacific Lamprey**	***Lampetra* spp.**	**UNID**	**Total**
Pre-Restoration	2014	Alder Point Restoration	30	29	2	0.07	0	3	0	3
	2014	Ross Island Reference	28	26	5	0.19	0	6	0	6
Post-Restoration	2016	Alder Point Restoration	50	50	2	0.04	0	1	1	2
	2016	Ross Island Reference	10	10	2	0.2	2	0	0	2

Multnomah Channel Shoreline

We sampled 10 of 10 shoreline quadrats visited in Multnomah Channel (Figure 7). Larval lamprey (n = 1) were detected at 1 of 10 quadrats sampled (*d* = 0.1; Table 1). The larval lamprey collected at Multnomah Channel shoreline was too small to identify visually (TL = 41 mm; Figure 12). The total number of larvae occupying any individual quadrat was one; no other life stages were detected. All collected larvae were in good condition and no visible external abnormalities were observed. Sample depths ranged from 3.3 m to10.5 m, and larvae were detected at a depth of 7.4 m. Water temperature was 19.7°C and conductivity was 117.7 μS/cm.

Oswego Creek Confluence

We sampled 10 of 10 confluence quadrats visited at Oswego Creek confluence (Figure 8). Larval lamprey (n = 6) were detected at 4 of 10 quadrats sampled (*d* = 0.4; Table 1). Of the six larval lampreys collected at Oswego Creek confluence, two were identified morphologically as a Pacific lamprey (both TL = 51 mm), one was identified as a western brook lamprey (TL = 55) and three were too small to identify visually (TL = 32 mm, 35 mm, and 37 mm; Figure 12). The total number of larvae occupying any individual quadrat ranged from one to two; no other life stages were detected. All collected larvae were in good condition and no visible external abnormalities were observed. Sample depths ranged from 0.7 m to 8.1 m, and larvae were detected at depths from 1.1 m to 4.9 m. Water temperature was 15.1°C and conductivity was 80.5 μS/cm.

Columbia Slough Confluence

We sampled 10 of 10 quadrats visited at Columbia Slough confluence (Figure 9). Larval lamprey (n = 6) were detected at 0 of 10 quadrats sampled (*d* = 0; Table 1). Sample depths ranged from 1.0 m to 2.3 m. Water temperature was 16.1°C and conductivity was 103.9μS/cm.

Cemetery Creek Tributary, Confluence and Shoreline

No sampling was conducted in Cemetery Creek tributary habitat in 2016 due to lack of viable habitat (< 50% was Type I habitat). We sampled 10 of 13 quadrats visited at Cemetery Creek confluence (Figure 10). Larval lamprey (n = 2) were detected at 2 of 10 confluence quadrats sampled (*d* = 0.2; Table 1). Both larval lampreys collected at the Cemetery Creek confluence were too small to identify visually (TL = 51 mm; TL = 52 mm; Figure 12). We sampled 10 of 10 shoreline quadrats visited at Cemetery Creek shoreline (Figure 9). Larval lamprey (n = 3) were detected at 3 of 10 shoreline quadrats sampled (*d* = 0.3; Table 1). Of the three larval lampreys collected, one was identified morphologically as a Pacific lamprey (TL = 73 mm), while two were too small to identify visually (both TL = 48 mm; Figure 12). The total number of larvae occupying any individual quadrat was one; no other life stages were detected. All collected larvae were in good condition and no visible external abnormalities were observed. Sample depths ranged from 0.4 m to 9.2 m, and larvae were detected at depths from 0.9 m to 5.1 m. Water temperature ranged from 15.6°C to 22.1°C and conductivity ranged from 80.9μS/cm to 82.6 μS/cm.

McCarthy Creek Tributary, Confluence and Shoreline

We sampled two of seven, 50 m tributary reaches visited in McCarthy Creek (Figure 11). The remaining five reaches could not be sampled due to either dewatered conditions or water and mud in excess of wade-able depth. In the two reaches sampled, 99% of the habitat was estimated to be Type I and no larval lamprey were detected. We sampled 10 of 10 quadrats visited at McCarthy Creek confluence (Figure 11). Larval lamprey were detected at 0 of 10 confluence quadrats sampled (*d* = 0; Table 1). We sampled 10 of 10 shoreline quadrats visited at McCarthy Creek (Figure 11). Larval lamprey were detected at 1 of 10 (*d* = 0.1; Table 1) shoreline quadrats sampled. The larval lamprey collected at McCarthy Creek shoreline (TL = 21 mm; Figure 12) was too small to identify visually. The total number of larvae occupying any individual quadrat was one; no other life stages were detected. All collected larvae were in good condition and no visible external abnormalities were observed. Sample depths ranged from 0.8 m to 11.0 m, and larvae were detected at a depth of 1.3 m. Water temperature ranged from 16.6°C to 19.8°C and conductivity ranged from 94.3μS/cm to 116.8 μS/cm.

Conclusions

At the Alder Point restoration site, comparisons of pre-and post-restoration sampling show similarities in patterns of larval lamprey occupancy and rates of detection. In 2014 (prior to habitat restoration), we sampled 29 shoreline quadrats at Alder Point in the mainstem Willamette River and Multnomah Channel. A total of three larval lamprey were detected in 2 of the 29 quadrats sampled (*d* = 0.07). In 2016 (year one following restoration), we sampled 50 shoreline and confluence quadrats at Alder Point in the mainstem Willamette River and Multnomah Channel. A total of two larval lampreys were detected in 2 of the 50 shoreline and confluence quadrats sampled (*d* = 0.04). Rates of larval detection in these mainstem habitats were similar pre- and post-restoration. All larvae detected both before and after restoration were identified as *Lampetra* spp. (with the exception of one larva in 2016 too small to identify visually, i.e., < 60 mm TL); no known Pacific lamprey larvae were observed. In 2016 we also sampled 10 quadrats in Alder Slough, a newly constructed channel that was dredged through previously terrestrial habitat. Alder Slough bisects the restoration site and has two confluences with the Willamette River and one with Multnomah Channel. No larval lamprey were detected in the 10 quadrats sampled (*d* = 0.00) in Alder Slough in year one following restoration. Prior to habitat restoration at the site this waterway did not exist. Sampling Alder Slough prior to restoration was not necessary to know that larval lamprey did not occupy the area. In any event, to date, the restoration does not appear to have resulted in a change in lamprey occupancy and distribution. It is not known whether, and after how long larval lamprey colonization of this newly-created habitat may occur. Continued monitoring of larval lamprey occupancy of Alder Slough is warranted and will provide a better understanding of larval lamprey colonization rates of newly available habitats.

At the Ross Island reference site, comparisons of pre- and post-restoration sampling also show similarities in patterns of larval lamprey occupancy and rates of detection. In 2014 (prior to restoration actions at Alder Point) we sampled 26 Ross Island shoreline quadrats in the mainstem Willamette River. A total of six *Lampetra* spp. larvae were detected at five quadrats (d = 0.19). In 2016 a total of two larval lamprey were detected at 2 of 10 quadrats sampled (d = 0.2). Rates of larval detection at Ross Island shoreline quadrats were similar pre- and post-restoration. The two larvae detected in 2016 were visually identified as Pacific lamprey, whereas the six larvae detected in 2014 were visually identified as *Lampetra* spp. In this regard, it is possible there was a change in the species occupying the Ross Island area. Alternatively, the species proportions were not significantly different between the sampling events. Thus, these differences may reflect (for example) the sample effort or a difference in species composition related to seasonal differences in patterns of occupancy. Additional sampling across seasons, flow conditions, and sample depths would further elucidate differences in patterns of larval occupancy in the lower Willamette River that may be driven by such parameters.

Reference site monitoring is an important component of the lamprey monitoring program associated with the Portland Harbor Superfund restoration. Patterns of larval lamprey occupancy at reference sites will provide a baseline for evaluating changes in larval lamprey occupancy at restoration sites over time, and assessing the utility of restoration actions for larval lamprey. We propose to conduct annual monitoring at the six reference sites (including Ross Island) sampled in 2016 and discussed in this report. The initial selection of reference sites was done to include habitats that were, to the greatest extent possible, similar to those of proposed restoration sites. Small, wade-able sized tributaries (1st and 2nd order) of the lower Willamette River have been identified for restoration (or construction) at some mitigation sites. Consequently, we included as reference sites two tributary streams in the lower Willamette River and Multnomah Channel, Cemetery Creek and McCarthy Creek. Confluence habitats in the mainstem Willamette River and Multnomah Channel at each tributary were also selected. It was presumed that the two tributaries were potentially suitable for Pacific lamprey occurrence. However, after attempted sampling events at these tributaries in 2014 and 2016, they were found to lack viable lamprey habitat. Cemetery Creek has a barrier culvert at a railroad crossing less than 100 m from its confluence with the Willamette River. McCarthy Creek below Highway 30 was found to be mostly dewatered, as the stream appears to be diverted from its natural channel. In an effort to maximize the utility of future reference site sampling, we propose to eliminate the wade-able portions of Cemetery Creek and McCarthy Creek from the group of reference sites. As such, the 10 confluence quadrats in the mainstem Willamette River and Multnomah Channel associated with each respective tributary would also be eliminated, reducing the total number of mainstem sample quadrats at the six reference sites from 80 to 60. An effort to identify alternate reference tributaries in the lower Willamette River is ongoing. However, finding suitable alternative streams has proven to be a challenge. If a suitable tributary is not identified, the wade-able depth reference tributary sampling may be eliminated from future sampling efforts. This change is not expected to significantly impact the ability to make comparisons and conclusions about larval lamprey occupancy in the lower Willamette River and Portland Harbor Superfund area going forward.

Similar to the results of previous years' sampling (Jolley et al. 2015; Silver et al. 2016) we observed a combination of larval Pacific Lamprey and *Lampetra* spp. in the lower Willamette River. Five of the six reference sites were occupied by larval lamprey of one or both species, with lamprey of all species being absent at the Columbia Slough mouth. Pacific Lamprey were detected at three of the six reference sites sampled (Ross Island shoreline, Oswego Creek confluence, and Cemetery Creek confluence). *Lampetra* spp. were detected at one reference site (Oswego Creek), while larvae too small to identify visually were detected at two reference sites (Multnomah Channel and McCarthy Creek shorelines). Assigning genus identification to these larvae would require genetic methods to be used. Currently, funding for genetic identification of larvae is not available. Tissue samples collected from all larvae are archived at the CRFWCO (in the event funding becomes available at a future date).

Mainstem habitats associated with the Alder Point restoration continue to appear suitable to and available for colonization by larvae moving downstream in the mainstem Willamette River and Multnomah channel. This was evidenced by the presence of larvae in shoreline and confluence habitats. The newly created sloughs did not appear to have been colonized by larval lamprey. It remains unclear whether they will provide useful habitat for lamprey. Thus, to date, lamprey appear to be using the post-restoration area of Alder Point in a manner similar to pre-restoration. The larvae detected at the Alder Point restoration site as well as at reference sites are likely to have originated from tributaries that enter the Willamette River upstream of the study areas (for example, the Clackamas River basin) and gradually dispersed downstream to their location of capture. No known spawning areas have been identified in the mainstem Willamette River or Multnomah Channel, although mainstem spawning may be plausible in areas where suitable substrates and flow regimes occur. Evidence suggesting dispersal of larval lamprey out of tributaries and into mainstem habitats has been observed previously in the mainstem Columbia River and Willamette River basins (Jolley et al. 2012; Jolley et al. 2013; Jolley et al. 2014) and may occur over extensive distances (Scribner and Jones 2002; Derosier et al. 2007). Future sampling of shoreline, confluence, and slough habitats at Alder Point are planned and will be useful for monitoring spatial and temporal changes in occupancy including possible colonization within newly created habitats in Alder Slough.

This report details findings at the Alder Point restoration site in year one following habitat restoration. According to the initial lamprey monitoring plan, post-restoration monitoring will occur annually at restoration sites through the initial five years post-restoration. Thus, we anticipate continued monitoring of Alder Point in calendar years 2017 through 2020. Post-restoration monitoring at Rinearson Natural Area is anticipated to begin in calendar year 2017 (assuming restoration is finalized) and likewise occur annually over the initial five years post-restoration. Annual sampling of reference sites is also expected to continue in conjunction with restoration site monitoring. The results of 2017 restoration and reference site sampling, along with potential pre-restoration monitoring at newly proposed restoration sites will be summarized in a report in spring of 2018.

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Appendix 1.

Results from sediment sampling have been provided to and can be obtained from:

Industrial Economics, Inc.
Jennifer Kassakian
2067 Massachusetts Ave.
Cambridge, MA 02140

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U.S. Fish and Wildlife Service
Columbia River Fish and Wildlife Conservation Office
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