Technical White Paper:

Guidelines for Trap & Haul of Adult Pacific Lamprey

Living Document, Version 1.0

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By the Lamprey Technical Workgroup

For the Pacific Lamprey Conservation Initiative

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TABLE OF CONTENTS

Guidelines for Trap & Haul of Adult Pacific Lamprey

Executive Summary

Anadromous lampreys are of conservation concern worldwide (Clemens et al. 2021). One of the primary sources of lost production is due to the inability of adult lampreys to pass human-made obstacles (both physical dams and thermal/chemical barriers; Moser et al. 2021a). The adult life stage includes lampreys that are no longer feeding and are actively migrating upstream, in fresh water, towards spawning grounds (Clemens 2019). Hence, passage barriers can limit access to adult spawning habitat and rearing habitat for larvae (Clemens et al. 2021). The use of methods to trap and haul adult anadromous lampreys past these obstacles or to remove them from construction areas, is increasingly being used to reduce losses and increase access to available habitat. However, it is critical to evaluate whether trap and haul operations are a better recourse than efforts to increase volitional passage for adult Pacific Lamprey (*Entosphenus tridentatus*).

Trapping of adult Pacific Lamprey should only occur under the guidance of local federal, state, and tribal biologists, using the appropriate state- or tribally-issued permits. In some situations, trap and haul may not be advisable, due to lack of high-quality upstream habitat or other considerations. Where appropriate, trap and haul of adult Pacific Lamprey is generally conducted at dams or other artificial barriers where they accumulate during upstream migration. Traps can be set outside of dam fishways, integrated into fishway designs, or positioned at the terminus of lamprey-specific fishways. Upon collection, handling should be minimized to reduce stress on both the lampreys and their human friends. Even soft dip nets and cotton gloves can remove the mucus layer of individual lamprey, abrade their skin, and expose them to infection. After initial capture, net buckets (i.e., bottomless buckets with a net attached at the bottom rims) can be used to quickly and efficiently move lamprey to the transport vehicle and preclude subsequent netting. While in the net buckets, lampreys can attach to the bucket walls and are more likely to become quiescent.

Holding in clean, cold (< 15 °C (59 °F), well-oxygenated water after the initial capture can reduce stress, particularly for long hauling operations. Prophylactic treatment with intra-peritoneal injection of antibiotics can reduce the incidence of bacterial infection (Jackson et al. 2019). Hauling operations should monitor temperature and oxygen levels during transit and preferably provide lamprey with cold (< 15 °C [59 °F]) well-oxygenated (80 – 150% saturation) water. A rule of thumb is to avoid densities of more than 1 adult lamprey per 4 L (1.1 gallon). Upon arrival at the receiving waters, adults can be dip-netted from the transport tank into the receiving stream. Perforated PVC lining of the lower 1/3 of the transport tank can allow ease of lamprey removal following tank dewatering and release of adult lamprey can also be facilitated by a flume that allows them to slide directly into the water without additional handling.

Genetic sampling has provided invaluable information on the successful reproduction of transported adults in the Columbia River (Hess et al. 2021, 2022). Program evaluation in Columbia River tributaries has also used radio-tracking to document survival and distribution of transported lamprey that are fitted with transmitters (e.g., PGE 2011; Jackson and Moser 2012). While the guidelines presented here are based primarily on more than 25 years of trap and haul operations for native Pacific Lamprey in the Columbia River drainage, an even longer history of trap and haul has been employed by managers in the Laurentian Great Lakes to control landlocked, invasive Sea Lamprey (*Petromyzon marinus*; Siefkes 2017). Case studies in Appendix A highlight these programs and others conducted with lampreys worldwide.

Introduction

Anadromous lampreys are of conservation concern worldwide (Clemens et al. 2021). As lamprey populations become increasingly imperiled, transportation of lampreys for restoration and recovery ("trap and haul [T&H]" or "translocation") is an emerging management tool (see Table 2 in Clemens et al. 2021). Both T&H and translocation move lamprey above barrier(s); however, translocation refers to operations that move the lamprey many miles above the barrier(s) where they were collected; T&H refers to moving lamprey just upstream of a single barrier. One of the primary threats to anadromous lampreys is lost production due to the inability of adult lamprey to access historical habitats for spawning and subsequent larval rearing above human-made barriers (both physical and environmental; Moser et al. 2021a). Some barriers include fish ladders, but these ladders are often designed for other fish species and do not necessarily allow for the volitional passage of lamprey and thus can be complete or partial barriers (e.g., LTWG 2022a). Volitional passage is preferred whenever possible, as discussed later in this document. However, circumstances may call for the use of T&H or translocation of anadromous lampreys past these obstacles to enhance or restore native production above them (e.g., Hess 2021, 2022; PGE 2011; Gephard 2019; Arakawa 2021), as well as to move them away from unsafe areas (i.e., construction areas, poor water quality, predator concentration areas).

There are examples of T&H operations for a variety of lamprey species worldwide. Sea Lamprey in their native range along the Eastern United States and in Europe are of conservation concern (Gephard 2019). Transportation of this species has been conducted in coastal rivers of Connecticut, the Mondego and Vouga rivers in Portugal to increase distribution. In the Dordogne River of France, native Sea Lamprey adults are transported to protect them from predation by Wels Catfish (*Siluris glanis*; L. Carry, Migrateurs Garonne Dordogne Charente Seudre France, Pers. Comm.). Efforts to restore European River Lamprey (*Lampetra fluviatilis*) have relied on transport of adults to hatchery facilities and large-scale transport and release of artificially-propagated progeny (Aronsuu et al. 2019). In Japan, artificial propagation programs to recover severely depleted populations of Arctic Lamprey (*Lethenteron camtschaticum*) were implemented starting in the late 1970s and again in the early 2000s (Arakawa 2021). Southern Hemisphere lampreys have also been trapped and hauled to aid passage over barriers in New Zealand and Tasmania. Pacific Lamprey, the primary focus of this document, have declined throughout the Pacific Northwest and are extirpated from many historical habitats in the Columbia River Basin and elsewhere (PLCI 2024). Much of the following information is based on T&H and translocation operations for adult Pacific Lamprey at large dams in the Columbia River Basin.

We reviewed methods developed over more than 25 years of T&H for Pacific Lamprey in the Columbia River Basin (Close et al. 2009; Ward et al. 2012; Hess et al. 2022, 2023). This program, originally conceived of and conducted by Native American tribal biologists, was developed to collect adults from mainstem Columbia River hydropower dams and move them upstream from these barriers. For more information on tribal lamprey translocation programs, the Pacific Lamprey Tribal Restoration Plan (CRITFC 2025) and Pacific Lamprey Supplementation Framework (CRITFC et al. 2014) provide history and specifics of tribal efforts to restore native lamprey.

The adult life stage includes lamprey that are no longer feeding and are actively migrating upstream, in fresh water, towards spawning grounds (Clemens 2019). The original tribal operations moved adult Pacific Lamprey many miles upstream past multiple barriers (sometimes referred as "translocation", CRITFC et al. 2014). Later, T&H was used in Columbia River tributaries to move adults upstream of a single, artificial barrier (e.g., PGE 2011).

As is the case for Pacific salmonids (*Oncorhynchus* species; Kock et al. 2020), T&H of Pacific Lamprey (Figure 1) has been employed to accomplish a variety of objectives:

- reintroduce adult, pre-spawn lamprey into habitats above barriers to increase distribution,
- augment populations above partial barriers, until long-term volitional passage can be improved,
- increase larval production (by transporting adults or larvae) to provide larval pheromone cues and thus increase adult attraction,
- remove or protect lamprey from unfavorable or potentially lethal environmental conditions or emergency situations (e.g., fishways failures or spill events, as part of a salvage or rescue effort (see LTWG 2020 for more information on salvage), and
- for research.

Figure 1. Adult Pacific Lamprey held in a transport container (Photo by M. Moser, Moserworks, LLC).

Adult Pacific Lamprey returning to the Columbia River are often larger in general than adults returning to other river systems along the West Coast (see Figure 2 in Clemens et al. 2019). Smaller Pacific Lamprey adults or adults of other lamprey species may have different swimming abilities, migration timing, maturation rates, or other factors that should be considered when applying recommendations from this document. While there are specific examples of T&H on the landscape (highlighted by case studies in Appendix A of this document), there is limited synthesis of information on lamprey-specific T&H.

The primary goal of this paper is to consolidate available information and resources on T&H operations to help fisheries managers and biologists that are considering lamprey T&H and need information about the appropriate use of T&H for Pacific Lamprey. To this end, we summarize the logistics of T&H programs, including the relevant biology of Pacific Lamprey, trap design and siting, holding and hauling considerations, release methods, and evaluation of program success. Case studies that describe specific, on-the-ground projects are also included (Appendix A). This paper focuses on the T&H of adult Pacific Lamprey (pre-spawning adults in freshwater). While our focus is T&H for adult Pacific Lamprey, we include discussion and case studies on other lamprey species and life stages to provide a broad range of understanding, make resources available, and promote widespread sharing of ideas that can benefit lamprey management.

This T&H document is one of several guideline documents developed by the Lamprey Technical Workgroup for Pacific Lamprey. For greater detail on related aspects of Pacific Lamprey management, review of these other documents is highly recommended (all available on the PLCI Lamprey Technical Workgroup website: https://www.pacificlamprey.org/ltwg).

> For biology, habitats, and life history information:
> Comparison of Pacific Lamprey and Pacific Salmon Life Histories, Habitat and Ecology (LTWG 2023).
>
> For biology and fish salvage methods for lampreys, including e-fishing:
> Best management guidelines for native lampreys during in-water work (LTWG 2020).
>
> For behavior, considerations, information and examples on adult passage:
> Practical guidelines for incorporating adult Pacific Lamprey passage at fishways, Version 2.0 (LTWG 2022a).
>
> Barriers to Adult Pacific Lamprey at Road Crossings: Guidelines for Evaluating and Providing Passage (LTWG 2020).
>
> For information on downstream passage of early life stages:
> Review of factors affecting larval and juvenile lamprey entrainment and impingement at fish screen facilities (LTWG 2022b).

Comparison of Volitional Passage vs. Trap & Haul

Allowing volitional passage of adult lamprey can be more cost effective, less invasive, and more likely to approximate natural dispersal patterns than T&H. For example, retrofits to make a barrier or fishway permeable to lamprey require initial investments, but long-term operation and maintenance costs are minimal compared to prolonged T&H operations. Lamprey that pass volitionally do not experience stressors associated with capture, handling and transport. Stress of handling and concentration of adults for holding and transport could increase susceptibility to disease pathogens and thereby increase risk of disease dispersal (Jolley and Lujan 2019).

Volitional passage allows for natural migration timing and habitat/mate selection, unless dam passage is only possible for some members of the migrating population (e.g., the largest; Keefer et al. 2009) or during some times of the year (e.g., during high water; Jackson and Moser 2012). T&H may compress passage into shorter windows of time, bias habitat use and constrain mate availability. T&H programs should use data on lamprey behavior, migration timing, habitat selection, and sex ratios from the location of interest or from nearby locations to ensure the successful survival and reproduction of transported lamprey.

As in salmonids, transported lamprey could experience higher rates of pre-spawn mortality due to stress or predation (Kock et al. 2020). However, adult Pacific Lamprey that are volitional migrants can also be exposed to elevated predation at dam spillways or in narrow fishways where predators can congregate (CRITFC 2025). Sublethal effects of T&H could include delayed or aborted spawning, fallback, and failure to complete migration, depending on how T&H is implemented (Clabough et al. 2015).

Concerns have been raised that T&H could inadvertently create genetic bottlenecks, which may occur if strong trapping bias selects for certain traits. The same can be true for volitional passage (e.g., if a barrier is only permeable to a segment of the migrating population). Pacific Lamprey do not appear to home to their natal stream, but genetic analysis has revealed that traits such as life history type, run-timing and adult body form exhibit adaptive variation that is genetically controlled (Hess et al. 2014; Parker et al. 2019). Moreover, T&H programs that selectively remove fish from the donor population could have effects on the fitness of both the donor and transported populations (Ward et al. 2012).

Unidirectional passage occurs when only adult lamprey are safely passed upstream, but larvae and juveniles have no safe downstream passage route. In these situations, both volitional migrants and T&H populations would experience poor outmigrant success because larvae and juveniles experience high mortality during downstream passage. Hence production is lost to the adult lamprey that successfully spawn upstream from barriers to outmigrant passage. Risks to outmigrants include, but are not limited to, screen impingement, turbine mortality, irrigation entrainment, and/or high avian predation at tailrace boils (Moser et al. 2015a).

In some cases, T&H may be the only long-term passage alternative or an acceptable short-term solution. At some high-head barriers, there is insufficient space for construction of lamprey-friendly fishways. Lack of funding often limits the ability to retrofit fishways for lamprey or provide lamprey-friendly new construction. Even if funding and space are available, lack of larvae upstream of the barrier to attract the adults and/or inadequate attraction flows may limit lamprey use of an existing fishway. In such cases, fisheries managers may decide that T&H is a necessary tool to increase the upstream larval lamprey population size while barriers are being fixed or removed (Hess et al. 2021, 2022, 2023).

While there are methods to obtain counts of volitional migrants, T&H provides a unique opportunity to monitor program success. By completely controlling upstream passage, it is possible to count every individual lamprey entering the previously inaccessible area and collect genetic samples. Later genetic analysis for parentage of offspring and larval related-ness can provide estimates of successful spawner numbers and the conditions that led to recruitment of offspring, as in Hess et al. (2021, 2022, 2023). These data can provide insights into all aspects of successes and failures and inform adaptive management.

T&H also provides the ability to quickly respond to emergency situations such as fishway failures, water quality degradation or natural disasters. In-water construction (e.g., channel restoration) may also require relocating lamprey out of the construction area, especially if it is to be dewatered (LTWG 2020). Other dangerous environmental conditions for lamprey can occur when low discharge, extremely warm water temperatures, and/or dewatering operations threaten pre-spawning adults or larvae. Often these conditions occur in artificially managed systems where water withdrawal occurs simultaneously with low flow and high temperature in summer and in impounded reaches (Liedtke et al. 2023). The risks of leaving lamprey in such hazardous environments may outweigh those of T&H (Figure 2). Additional information and techniques for salvaging lampreys are provided in the document "Best Management Guidelines for Native Lampreys During In-water Work" (LTWG 2020).

Figure 2. Stressed lamprey captured during an extremely turbid water quality event in the Umatilla River of Oregon (Photos by A. Jackson, Confederated Tribes of the Umatilla Indian Reservation).

Finally, T&H is often needed for research and can also be used to jump start a population of lamprey. Radiotelemetry of transported adults can provide insights into dispersal and spawning site selection in areas where lamprey currently do not have access (e.g., David 2025). Following dam removals, T&H of lamprey into upstream areas can expedite attraction of pre-spawning adults, which are attracted by both larval migratory pheromones and adult male sex pheromones (Moser et al. 2015b; Hess et al. 2021). While lamprey can naturally colonize streams where they have been extirpated (e.g., Jolley et al. 2018; Moser and Paradis 2017; Reid and Goodman 2020; Hess et al. 2021), T&H of lamprey can speed recovery after human-caused or natural disasters (e.g., 2025 PetroCard petroleum spill in the Elwha drainage, Tanker Truck Spill into Indian Creek - Washington State Department of Ecology). T&H of adult lamprey into upstream areas can expedite recovery and provide insights into the ability for them to use damaged or previously inaccessible habitats following restoration actions (Hess et al. 2021).

Evaluating the Need for Trap & Haul

Evaluating the need for T&H at a particular barrier or series of barriers is a significant undertaking. Practitioners are encouraged to think carefully through the biological, scientific, logistical, and fiscal ramifications of T&H. They are also encouraged to communicate clearly and make decisions with fisheries managers from other organizations to ensure procurement of necessary scientific take permits, maximization of critical thinking and, ultimately, program success. Consulting local biologists familiar with lamprey migrations and behavior is valuable and highly recommended.

The following lists information needed to determine if T&H is appropriate:

- Species life history and migration timing (seasonal and daily),
- Current and historical distribution,
- Quality and quantity of upstream habitats,
- Donor population status,
- Upstream barrier type (e.g., complete barrier or partial barrier; seasonal or other constraint, such as only the largest fish can pass),
- Available downstream migration routes to complete life cycle,
- Barrier ownership and accessibility,
- Permit requirements and potential challenges to obtaining permits,
- Other species considerations (e.g., predators),
- Timeframe – how long are T&H operations needed, and
- Potential costs and funding opportunities.

The following paragraphs ***illustrate these needs*** and provide some example scenarios:

A clearly stated program objective and timeframe is necessary.

Hypothetical scenario: There is a water quality crisis and the immediate need to move fish away from a potentially lethal high temperature or pollutant exposure. Conclusion: T&H, as part of a salvage operation (see LTWG 2020), is an obvious solution in this case, as there is no time or space to implement volitional passage around the environmental hazard.

An understanding of lamprey migration motivation and barrier permeability is needed.

Hypothetical scenario: A barrier or series of barriers provide insufficient passage to achieve management goals. Upstream presence of adults and larvae provides strong migration motivation. While not immediately available, funding to retrofit the barrier(s) is possible. Conclusion: T&H could be used as a stop gap measure to ensure that production continues in upper areas while passage improvements are implemented. However, the goal to eventually improve volitional passage should not be inadvertently replaced/co-opted by focus on T&H operations.

The availability and quality of upstream spawning habitat must be assessed.

Hypothetical scenario: A high-head barrier with no possibility of lamprey passage is situated at the lower end of a watershed with many miles of prime lamprey spawning habitat. The barrier can be operated in a way to minimize downstream passage mortality of larval and juvenile lamprey. A long-term commitment to T&H funding is available and there is the ability to assess efficacy of the T&H effort in terms of increased production. Conclusion: A T&H program with an adaptive management approach could be adopted to assess the benefits of T&H and potential alternatives.

The size of the donor population should be quantified to allow cost/benefit analysis.

Hypothetical scenario: A series of dams winnows the number of adult lamprey accessing the upper portion of a drainage. The uppermost dam is impassable and provides no safe passage alternatives for emigrating juveniles. While there is limited spawning habitat above the uppermost dam, there is also some suitable habitat below the dam. Conclusion: A T&H operation may not be warranted at this location due to the small size of the donor population below the uppermost dam and the likely losses of both adults (due to transport stressors) and their outmigrating progeny.

Relevant Pacific Lamprey Biology

Knowledge of lamprey biology is needed for successful T&H. Pacific Lamprey are the largest species of anadromous lamprey native to the Pacific Northwest. Detailed descriptions of their life history are provided elsewhere (see Close et al. 2002; Clemens et al. 2010; Dawson et al. 2015), but some aspects of their life history (Figure 3) are particularly relevant to T&H implementation. Pre-spawning adults migrate from the ocean to spawning grounds in freshwater rivers, lose weight, and can hold in freshwater for 1-3 years prior to spawning (Moser et al. 2015b). Pre-spawning adults are attracted to spawning grounds by both larval migratory pheromones and adult male sex pheromones (Moser et al. 2015b). Holding habitat varies, but adults are often found in deep, swift water seeking refuge within coarse substrate, bedrock crevices, rock revetments, or by large wood (Lampman 2011; Clemens and Schreck 2021).

Spawning generally occurs in the spring and early summer, but timing depends on water temperature, latitude and the local hydrograph (Stone 2006; Gunckel et al. 2009; Clemens et al. 2010). Relatively low flows and warm water temperatures are associated with earlier spawning (Clemens et al. 2009, 2016); relatively high river flows and cool water temperatures can be associated with slowed migration and later spawning periods (Brumo et al. 2009; Clemens and Wagner 2024); timing varies geographically.

A major concern in some T&H operations is the reproductive readiness of transported fish and the gender ratio. Pacific Lamprey females can spawn with multiple males, and males can spawn with multiple females (Johnson et al. 2014). Therefore, unequal numbers of each sex is not always a major problem. Identification of lamprey gender prior to development of secondary sexual characteristics is challenging. Use of blood chemistry and real-time ultra-sound technology is currently being investigated and holds some promise for helping researchers to ensure adequate sex ratios that will allow for successful spawning after release (J. Nagler, University of Idaho, Pers. Comm.).

The life cycle of Pacific Lamprey requires migration corridors in rivers for both upstream migrating adults (Clemens and Wagner 2024) and downstream migrating larvae and juveniles (Moser et al. 2015; Figure 3). Information about providing passage for downstream migration is outside the scope of this paper, but adequate downstream passage is an important consideration prior to initiating T&H above a barrier.

Adult Pacific Lamprey are primarily nocturnal and tend to move low in the water column along the river bottom. To rest, lamprey will often attach to rocks or other smooth surfaces (including metal, concrete, or glass) using their oral disc mouth. They can free-swim in the water column but also use burst-and-attach locomotion to move forward, allowing them to pass through some areas that have faster flows than lamprey sustained swimming speeds (Reinhardt et al. 2008). Adult Pacific Lamprey can also ascend wetted surfaces that are vertical or at steep angles using this burst-and-attach locomotion (Reinhardt et al. 2008; Kemp et al. 2009; Frick et al. 2017). In recent years, lamprey passage systems and wetted walls have been designed, fabricated, and installed in areas where congregations of lamprey were observed. These structures either terminate in a trap for collection and transport or provide an exit ramp for volitional passage (e.g., Moser et al. 2011; Zobott et al. 2015; Moser et al. 2019a; LTWG 2022a). Additional discussion on lamprey swimming and climbing abilities and behaviors in fishways that can assist in the collection of adult Pacific Lamprey is presented in LTWG (2022a).

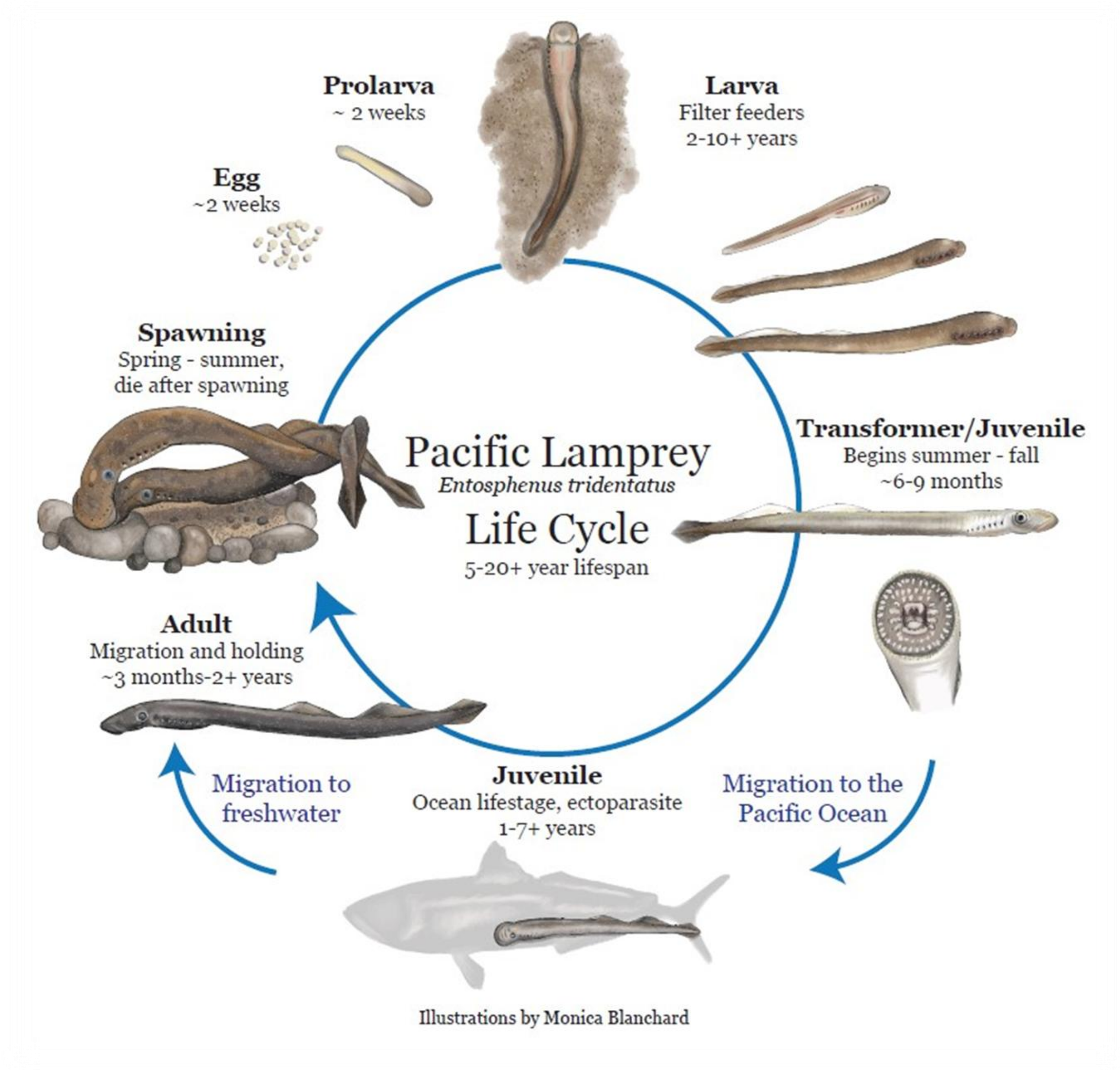

Figure 3. Pacific Lamprey life history cycle. Illustrations by M. Blanchard, Washington Department of Fish and Wildlife.

Trap and Haul Methods

Trapping

Adult Pacific Lamprey has been captured by hand since time immemorial for tribal consumption in the Pacific Northwest (Close et al. 2002). In more recent times, lamprey species have also been captured for commercial fisheries in the U.S and world-wide (Almeida et al. 2021) and for research to control invasive Sea Lamprey in the Great Lakes (Schuldt and Heinrich 1982; Radtke and Kuczynski 2020; Miehls et al. 2021; Holub et al. 2022). Some of these Sea Lamprey trap designs have been modified for use with Pacific Lamprey.

Generally, free-swimming Pacific Lamprey are trapped in rivers or streams at congregation areas or trapped within existing fishways. In fishways, traps are designed to not hinder passage of other species while taking advantage of fishway features to improve lamprey collection. Traditionally, lamprey traps (sometimes called eel pots) were of a baffled design (Figure 4) similar to a large minnow-trap style construction (e.g., Portuguese and Swedish commercial fishing gear, Almeida et al. 2021). These traps are sometimes deployed at the base of a barrier to increase lamprey encounters with the trap and improve collection success.

Figure 4. Traditional lamprey pot or "tube trap" (left photo by R. Lampman (Yakama Nation Fisheries); right photo by G. Silver (Columbia River Inter-Tribal Fish Commission). Traps can be either double funneled (especially if lamprey are likely to approach from both directions) or funneled on one side with a removable lid on the other.

For many T&H operations, trapping is conducted immediately below the dam that is preventing volitional upstream passage by adult lamprey. Consequently, adult lamprey are concentrated at the dam base, near fishway entrances (if present), and sometimes within fishways (e.g., where difficult passage conditions may prevent lamprey from successfully navigating the entire fishway). Effective sites for deploying traps can often be determined by observing adult lamprey congregations at night, when they are most active. Adult Pacific Lamprey will climb walls and be visible at the surface when they are blocked and are seeking a route upstream. These are good places to site a trap.

Collection operations have also successfully used traps that are integrated into fishways at dams and take advantage of fishway infrastructure (Figure 5). For example, in pool and weir style fishways, a trap can be positioned at the crest of a weir so that lamprey moving

Figure 5. Lamprey traps deployed either at the base of a barrier (left, photo by U.S. Fish and Wildlife Service) or integrated into a fishway (right, photo by Portland General Electric).

along the wall and over the weir will encounter the trap entrance (Moser et al. 2007; LTWG 2022a). Blocking the lower orifice openings at the base of the weir can force more lamprey to move upward and into the trap at night when other migratory fish species are not active. These trap designs are often positioned near a power supply to allow operation of a mechanical hoist, which facilitates trap retrieval. For manual haul back, a davit can be positioned from a fishway railing to allow use of a chain hoist or other mechanical advantage.

Other trap operations at dams make use of structures specifically designed to attract lamprey and exclude other species (e.g., Moser et al. 2011). Such lamprey-specific structures can be located where lamprey congregate: inside a fishway (e.g., Moser et al. 2019a), in attraction water or auxiliary water supply channels (e.g., Moser et al. 2011), or adjacent to a fishway entrance (A. Jackson, Confederated Tribes of the Umatilla Indian Reservation; unpublished data). These may feature a series of wetted ramps and rest boxes (also known as Lamprey Passage Structure or LPS; Zobott 2013), tube-like designs (Goodman and Reid 2017) or a wetted wall (Frick et al. 2017) that terminates in an easily accessed trap (Figure 6).

Fishways in the Pacific Northwest have largely been designed to pass anadromous salmon (e.g. Clay 1995; Keefer et al. 2010; Kirk et al. 2016; Silva et al. 2018; Keefer et al. 2021). Unlike salmonids, Pacific Lamprey are not adapted for passing some of the high-velocity, highly turbulent features common to these fishways (e.g., Moser and Mesa 2009; Reid and Goodman 2016a; LTWG 2022a). Due to the difference in swimming behaviors between Pacific Lamprey and salmonids, the aforementioned attributes of fishways and lack of smooth, continuous surfaces for lamprey attachment can create complete or partial barriers to upstream migration of adult Pacific Lamprey (Keefer et al. 2010; Goodman and Reid 2017).

Pacific Lamprey may not be able to enter a fishway due to high velocities and lack of attachment surfaces. In such instances, trapping within the fishway will not be productive. Efforts to fix the entrance and other problematic passage areas downstream from the trap location is necessary, otherwise the trap (or trap entrance) must be located outside of the fishway. If adult Pacific Lamprey are congregating just below fishway entrances, placing the trap (or entrance to the trap) adjacent but outside of the fishway entrance is recommended.

Alternatively, lamprey may be able to enter a fishway but are blocked by an area of high velocity, turbulence or lack of attachment sites in the fishway. Lamprey may congregate at these blockages within the fishway, and once known, traps or trap entrances can be sited at these areas to collect upstream migrating lampreys. For example, lamprey were found to have difficulty passing through the serpentine weir section at Bonneville Dam, which was immediately above a counting station where the ladder width was narrowed by picket leads. Many lamprey fell back below this section and moved into the auxiliary water supply area behind (upstream of) the picket leads, where other fish could not enter. Installation of a ramp (LPS) in this area provided an attractive route where lamprey could be collected and volitionally passed over the dam (Moser et al. 2011).

When integrating a trap into an existing fishway, there are several measures that can be used to potentially improve trap entrance conditions and trapping efficiency (LTWG 2022a):

- Ensure smooth continuous surfaces are available for lamprey attachment and use of burst and attach locomotion, particularly in high velocity areas.
- Reduce turbulence and provide unidirectional flow.
- Ensure "false attraction" areas are addressed by ensuring that gaps between pickets are appropriately spaced to prevent lamprey from entering danger areas or those with no passage (e.g., Moser et al. 2008). In some cases, where adult Pacific Lamprey are smaller (e.g., along the coast), the gaps may need to be as little as 1.3 cm (0.5 inch; LTWG 2022a).
- Consider modifying fishway operations at night when lamprey are active and other migratory species are not, such as reducing fishway entrance velocities and lighting at night (e.g., Johnson et al. 2012).
- Consider adding bollards, large rock placements or other features which provide a favorable hydraulic path to guide lamprey to the trap entrance (e.g., Moser et al. 2019a).
- Consider the addition of rest boxes within the fishway to provide shelter during daylight hours from predation (e.g., otters, sturgeon), particularly if the fishway is long and lamprey are not likely to access the trap entrance within one night (e.g., Moser et al. 2021b).

The above concepts are discussed in greater detail in Practical Guidelines for Incorporating Adult Pacific Lamprey Passage at Fishways (LTWG 2022a). If you are considering using a trap within a traditional salmonid fishway, please refer to this document. Once in a trap box, lamprey are "escape artists". Therefore, use fykes, baffles, brushes, trap doors, or other "one-way valves" that prevent lamprey from leaving the trap (Figure 6). Trap exits can also be fitted with perforated plates or mesh tubing to prevent lamprey attachment on exit slides.

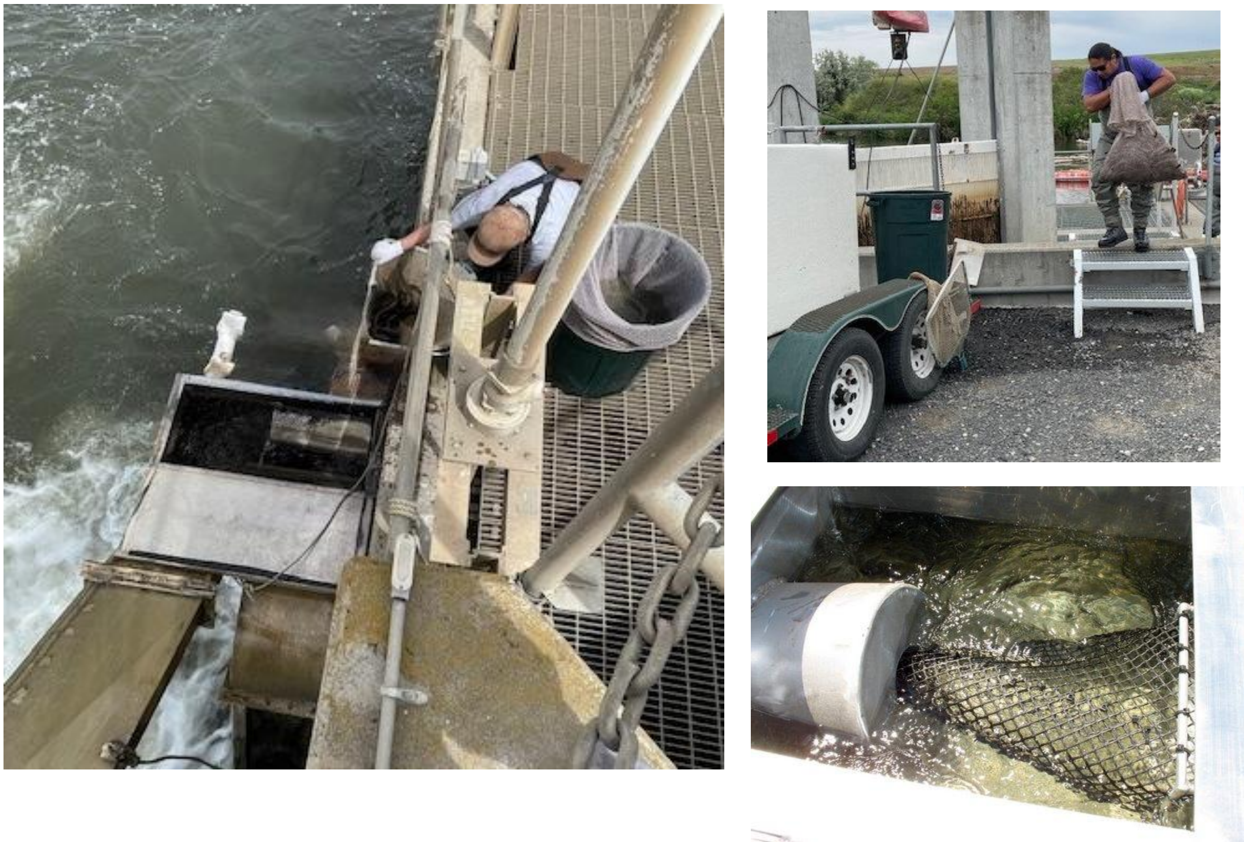

Figure 6. Trapping adult Pacific Lamprey from a Lamprey Passage Structure at Three-Mile Falls Dam, Umatilla River, Oregon (Photos by A. Jackson, Confederated Tribes of the Umatilla Indian Reservation, left and upper right). The lower right photo shows a “one-way valve” (the mesh cone) within the 3-Mile Falls Dam LPS that prevents lamprey from returning downstream (Photo by M. Moser, Moserworks, LLC).

Holding

For holding and hauling of lampreys, the following recommendations are updated from LTWG (2020; pp. 15-16):

- Maintain the holding and transport container water temperature within ±2 °C (3 °F) of the release location water temperature to prevent temperature shock to the lamprey. Slow acclimation is recommended (<±3 °C [5 °F] per hour) to minimize stress and maximize survival.
- Keep water temperatures cool (< 18 °C [64 °F]). Use ice made from source river water or frozen sealed containers of ice, if possible. Natural pure salt (3 – 5 ppt) may also be used to reduce stress for longer transports (> 1 hour).
- Monitor water temperature and dissolved oxygen regularly and make changes as needed to ensure water quality parameters are adequate. Dissolved oxygen levels can be maintained using air stones with battery-powered aerators or from oxygen tanks and a regulator.

- Hold lampreys in flow-through water as much as possible.
- Lampreys prefer dark environments — cover to darken containers.
- Densities of adult lamprey for transport should generally not exceed 1 fish for each 4 L (~1.1 gallon) of water. In general, holding densities should not exceed 60 kg/1,000 L (132 lb/ 264 gallons) or ~150 individuals/1,000 L (~264 gallons) in cold, flow through conditions (Moser et al. 2019b); however, as water quality deteriorates, lowering the density of lamprey per volume is recommended..
- Equip holding and transport containers with aerators to ensure dissolved oxygen levels are near or above saturation.
- Provide smooth surfaces for lamprey attachment with their sucker mouths. Avoid using containers with only mesh (such as laundry bags) or perforated metal screen surfaces that do not allow lamprey to attach and rest.
- Pacific Lamprey can easily climb up the container walls. To prevent escapes, seal container tops with continuous mesh or solid, clamped-down lids. Allow room for adults to attach out of the water (10-13 cm [4-5 inches]) near the top of the container, which will keep lamprey calm if water quality conditions start to deteriorate.

Prior to hauling, adult Pacific Lamprey benefit from a period of holding in quiet, flow-through tanks with cool temperatures and high water quality (T. Sween, Nez Perce Tribe, Pers. Comm.). For Pacific Lamprey transported upstream by tribal biologists in the Columbia and Snake rivers, a marked decrease in mortality occurred when adults were allowed to recover in hatchery tanks supplied with cold, well-oxygenated water for several days after trapping at Bonneville Dam (Columbia RKM 235; Close et al. 2009; Ward et al. 2012). In early years of this program, lamprey were either immediately transported upstream after trapping or were held in suboptimal conditions (i.e., turbid, warm > 20 °C [68 °F] river water) until crews were able to pick them up. Now, holding tanks inside the Captive Brood Building at the ODFW Bonneville Hatchery are supplied with cold, clean well water (<10 °C [50 °F]; Figure 7). Use of this holding facility has reduced the mortality rate to near zero.

Tribal biologists have extensive experience with long-term holding of adult Pacific Lamprey used for T&H, translocation (e.g., Close et al. 2009), overwintering and release, or use in artificial propagation (Moser et al. 2019b; Lampman et al. 2021). When daily average water temperatures approach 22 °C (71.6 °F), caution should be used to ensure safe handling and successful T&H. When maximum temperatures are 24 °C (75.2 °F), conditions are approaching known mortality thresholds for lamprey (Clemens 2022; CRITFC 2025).

Holding densities should not exceed 60 kg/1,000 L (132 lb/ 264 gallons) or ~150 individuals/1,000 L (~264 gallons) in cold, flow through conditions (Moser et al. 2019b). Densities should be reduced when water temperature is warm, and fish are stressed. Stress is often signaled by pale color (especially in the ventral region), lethargy, and increased rate of gill pore pumping (Moser et al. 2023; M. Moser, Moserworks LLC, Pers. Comm.; e.g., Figure 2). Stressed lamprey adults will also climb out of the water by attaching to the container sides above the water surface.

Figure 7. Pacific Lamprey holding tank at the Oregon Department of Fish and Wildlife's Bonneville Hatchery Captive Broodstock Building facility used for the CRITFC-Tribal translocation program (Photo by G. Silver, Columbia River Inter-Tribal Fish Commission). Note screened inlet and outlet pipes to prevent lamprey escape.

Figure 8. A perforated holding box used to acclimate Pacific Lamprey in Portland General Electric's North Fork Clackamas fish ladder prior to nighttime release (from David 2023).

High flow rates of well-oxygenated water (with complete water turnover in 25–30 min) or natural spring water (19 L/min [~5 gallons/min]) can aid recovery after trapping (Lampman et al. 2021). It is always a good idea to aerate the holding water with a set of air pumps that are independent of the water delivery system, so that holding water does not become anoxic in the event of a pump failure. In general, back-ups and redundancy of equipment is recommended to prevent delays, injuries and mortalities.

Holding adult lamprey after trapping can also occur in the river, stream or fishway where the adults are trapped (Figure 8). Floating net pens with secure lids are firmly anchored and accessed with dipnets for lamprey retrieval. It is important to ensure that there are suitable surfaces for lamprey to attach to inside the net pen (e.g., avoid the exclusive use of net material). This method has been employed by Portland General Electric (PGE) staff in Oregon for extended holding/recovery of Pacific Lamprey (David 2023).

Hauling

Many of the guidelines for holding apply to hauling (LTWG 2020). Various aspects of holding can be stressful to fish (Portz et al. 2006). Methods to reduce fish stress during transport are reviewed by Harmon (2009) and emphasize the need to minimize stress by controlling density, reducing handling, keeping water temperatures low, and providing dissolved oxygen. As is the case for holding, limiting density to 1 lamprey in 4 L (1.1 gallons) is generally recommended; however, as water quality deteriorates, lowering the density of lamprey per volume is recommended. Experienced haulers in the Columbia River limit density to 150 fish per 1,000 L (264 gallons), which is one fish per 6.7 L (1.8 gallons).

Most of the recommendations for hauling finfish (e.g., Harmon 2009) apply to adult lamprey transport with a few exceptions. Adult lamprey do not feed during pre-spawning migration, so concerns regarding ammonia and food waste build up in transport tanks do not apply. Unlike most other fishes, lamprey require some surface to attach with their oral disc to reduce stress and allow them to reach a quiescent state in the transport tank. The problem is that when they attach, it is difficult to get them to release without creating further stress. One solution has been to line the lower third of the tank and its bottom with perforated PVC, perforated metal plate, or Vexar case liner to prevent attachment when the water level is lowered, prior to release (M. Synbal, U.S. Fish and Wildlife Service, Pers. Comm).

As is the case with other fishes, moving lamprey from the holding area to the transport tank can be more stressful than the stress caused by transport (Harmon 2009). Consequently, minimizing the duration and intensity of handling stress is paramount. For lamprey, collection into a "net bucket" suspended in the transport tank minimizes the time out of water and contact with the net (Figure 9). This transport system allows the lamprey to attach to the rim of the bucket when the bucket is dewatered (through the dipnet attached to the bottomless bucket). Sorting and holding fish in net buckets also reduces the number of times free-swimming lamprey must be transferred by dipnet from one container to another, a process that can take a long time and stress lamprey in the receiving tank. When re-suspended in the transport tank, net bucket usage allows lamprey to attach during transport, provides good water exchange, and reduces stress at release by eliminating the need for additional net capture. This method also provides the opportunity to sort fish into separate buckets for release in multiple locations, if desired.

Hauling is typically conducted using insulated tanks on dedicated transport trucks or trailers (Figure 10). Oxygen bottles with regulators are used to super-saturate the water in tanks (80-

Figure 9. Use of net buckets for short-term holding (while collecting from a trap, left) and short transport to and from transport tank (Photos by G. Silver, Columbia River Inter-Tribal Fish Commission). Buckets with lids can be suspended in transport tank water to eliminate the need to net at each transfer. The net bucket innovation (right) was designed by Raymond Ellenwood (Nez Perce Tribe).

Figure 10. Insulated tanks on dedicated trucks or trailers used for hauling Pacific Lamprey adults (photos by R. Lampman, Yakama Nation).

150% dissolved oxygen saturation), to relieve lamprey stress during transport. In addition, water from the receiving water body can be frozen to allow for cooling in transit and simultaneously allow the lamprey to acclimate to the water chemistry of the water body where they will be released (Figure 11). Frozen tap water can be used if there are no options for using frozen river water (although it is important to beware of chlorine contamination). The use of rock salt (up to 5 ppt) or a sea salt substitute can also reduce osmoregulatory stress and help with control of fungus and other potential pathogens while lamprey are in transit. Stresscoat® (e.g., API® Fish Care; 0.5 ml/~4 L [1/8 tsp/gallon]) and/or a low dosage of anesthetics (~20% of the concentration used for sedation) can be applied to the tank water to help reduce the impact of handling, transport stress, and hyperactivity (especially if other means of reducing stress are not available or successful).

Figure 11. Receiving water frozen in 20-L (5-gallon) buckets (left) can be used to cool lamprey during transit to reduce stress. Ladder (right) is critical for accessing tanks in transit (Photos by R. Lampman, Yakama Nation).

Releasing

Minimizing handling after transport is paramount to the success of T&H and translocation and the subsequent ability of the lamprey to successfully spawn after release. If possible, a chute or flume to directly release fish at the release site without additional handling is easier on both lamprey and biologists (Figure 12). Additionally, the bottom of the transport tank can be lined with perforated PVC and sloped to allow fish to slither out when a gate at the tank exit is lifted. Holding fish between transport and release can also reduce stress, help lamprey acclimate to new water quality conditions, reduce fallbacks, and protect adults from predation when they are disoriented following their release (T. Sween, Nez Perce Tribe, Pers. Comm.; Figures 7 and 8).

Adult Pacific Lamprey are nocturnal and most capable of avoiding predation and resuming migration when released at night. Unfortunately, this is often logistically difficult to achieve for the human crews involved. Holding lamprey in a darkened trap box at the release location that has a small escape hatch can allow adults to volitionally escape when they are most active and least likely to be disoriented. Releasing lamprey into an area with moderate flow can help adults to orient more quickly and find their way into the river thalweg (Figure 12).

Figure 12. Release flume used by Confederated Tribes of the Umatilla Indian Reservation staff (left) and dipnet release of adult Pacific Lamprey. Note gold color of stressed fish (right) in this emergency transit scenario (Photos by A. Jackson- Confederated Tribes of the Umatilla Indian Reservation).

Monitoring and Evaluation

A key component of any T&H program is the appropriate evaluation of survival and reproduction of transported lamprey. For adult Pacific Lamprey T&H and translocation in the Columbia River Basin, a Supplementation Research Framework was developed to guide these efforts (CRITFC 2014). The framework explicitly requires genetic analyses to track genetic diversity and the fitness consequences of T&H and translocation. Although Pacific Lamprey are capable of high levels of gene flow across most of their range, it is important to maintain any local diversity to preserve adaptive genetic variants that respond to localized conditions (Hess et al. 2013). Hence, collection protocols should be cognizant of the need to maintain the diversity of donor stock (Ward et al. 2012). This need is also explicitly stated in Table 6.3 of the Oregon Department of Fish and Wildlife's Coastal, Columbia, and Snake Conservation Plan for Lampreys in Oregon (ODFW 2020):

- "*Address limiting factors in the basins receiving adults*
- *Provide and improve downstream passage and screening to maximize downstream escapement of larval and juvenile Pacific Lamprey*

- *Monitor genetic population structure and adaptively alter translocation practices to minimize negative genetic effects*
- *Prevent excessive harvest of donor population(s) of Pacific Lamprey for translocation*
- *Continue pathogen screening and disease inoculation to prevent translocation of pathogen bearers*
- *Monitor the success of reproduction of translocated lamprey and adaptively manage translocations to maximize the production of early life stages*".

Genetic analysis also allows the measurement of reproductive success via parentage-based tagging (i.e., collection of genetic samples from all transported adults). Subsequent genetic analysis of offspring allows identification of parentage for each individual and the ability to test the success of specific T&H operations (e.g., was production better at specific release sites, were some release methods better than others, does holding overwinter convey an advantage, etc.). Genetic analysis also allows precise information on larval age (so long as the spawning year is established), thereby allowing assessment of growth and the relative contribution of production from T&H parents (Hess et al. 2022).

Radiotelemetry is also used regularly to confirm that adult Pacific Lamprey will resume spawning migration and distribute to spawning ground sites. Radiotelemetry investigations at Bonneville Dam (Columbia RKM 235) confirmed that adults collected at the dam, surgically implanted with a transmitter, and released several kilometers downstream would re-approach and attempt to pass over the dam (Keefer et al. 2013). Behavior of Pacific Lamprey transported upstream from River Mill Dam on the Clackamas River was tracked using radio transmitters (David 2025). These fish were released in the North Fork reservoir and dispersed widely without exhibiting negative consequences of T&H (David 2025). Pacific Lamprey transported from Willamette Falls were also radio-tagged and released above the Fall Creek Dam as part of a reintroduction to historical habitats; these fish also dispersed into stream reaches above the reservoir and successfully spawned (B. Weems, Confederated Tribes of the Grand Ronde, Pers. Comm.).

At a minimum, sampling to confirm successful spawning of transported adults should be conducted. Electrofishing of larvae in optimal habitat (Reid and Goodman 2016b; see also Clemens et al. 2022) or use of screw traps to collect outmigrant larvae and juveniles have been used to confirm upstream reproduction by transported adults (e.g., Hess et al. 2021; M. Blanchard, Washington Department of Fish and Wildlife, Pers. Comm.; B. Weems, Confederated Tribes of the Grand Ronde, Pers. Comm.). Environmental DNA is another potential tool, but because eDNA detection cannot identify specific life stages, attention is required in setting up the sampling design with careful consideration for release, migration, and spawning timing. Information on environmental DNA can be found in LTWG's Overview of eDNA and applications for lamprey research and monitoring (2021).

Trap and Haul- Tips and Tricks

General

- Evaluate the biological, logistical and financial considerations prior to implementing T&H.
- Use volitional passage incorporated into other fish passageways if practicable and effective.
- Use T&H on an interim basis while working to establish volitional passage, when possible.
- Communicate and gather information from local biologists.
- Define the overall objective and timeframe for T&H, and if needed, identify specific goals and timelines.
- Use caution when water temperatures exceed 18 °C [64 °F].
- Ensure all necessary permits and permissions are obtained early.

Trapping Adult Pacific Lamprey

- Survey at night for lampreys during upstream migratory periods to locate areas where passage is completely or partially blocked and lamprey are forced to congregate. Pacific Lamprey can often be seen at the surface when they encounter such physical or hydraulic barriers (e.g., existing fishway entrances, within fishways, and below barriers). These areas of congregation identify good areas to place traps or trap entrances.
- Note that adult Pacific Lamprey are attracted to pheromones of larval and spawning Pacific Lamprey. Traps for Pacific Lamprey below areas where these life stages are not yet present may have reduced attraction.
- A variety of traps can be used (individual pots, ramps, wetted walls), singly or in combination, depending on the area where trapping needs to occur.
- Collection boxes should have continuous inflow for both attraction and maintenance of good water quality.
- Collection boxes should have a mechanism to prevent lamprey from escaping after entering (broom bristles, finger flaps, funnels/fykes made with zip ties or mesh, etc.).

Holding and Hauling of Pacific Lamprey

- Reduce duration and intensity of handling as much as possible to reduce stress and increase survival. Minimize frequency that dip netting is used to remove and transfer free-swimming lamprey from one location to another.
- Holding in a quiet, flow-through system (e.g., holding tank, or enclosure/float pen securely anchored within the river) with good water quality for several days after initial collection can increase survival of lamprey to be transported, particularly for long transport distances.
- Prevent escape of lamprey by ensuring all inlet and outlet pipes are screened and containers have secure lids or mesh with an overabundance of clamps. Eliminate even small gaps between tank dividers and the tank side or bottom.
- For Pacific Lamprey, the following parameters are recommended:

- Water temperatures:
  - Target temperatures below 15 °C (59 °F) for holding and transport.
  - Use caution when water exceeds 18 °C (64 °F); ideally temperatures would be in the range of 11-15 °C (~52-59 °F).
  - Freeze river water in buckets to help cool transport water.
  - Use commercial ice with caution, ice should remain bagged to prevent dropping temperatures too quickly.
  - NOTE: Water temperatures of 24 °C (~75 °F) and greater are lethal for Pacific Lamprey adults (CRITFC 2025).
- Oxygen saturation:
  - Use tanks of oxygen with regulators, or use other forms of aeration.
  - Increase oxygen saturation up to 150% during high temperature conditions to reduce stress.
  - Oxygen saturation of 80-150% during transport appears to decrease transport mortalities.
- Flow rate during holding should be at least 19 L/min (5 gal/min).
- Density during holding should not exceed one adult lamprey for each 4 L (~1.1 gallon) of water.
- Density during hauling:
  - Densities of adult lamprey for transport should generally not exceed 1 fish for each 4 L (~1.1 gallon) of water. As water quality deteriorates, lowering the density of lamprey per volume is recommended.
  - For a 600-L (150-gallon) insulated tote, density can be up to 200 adults (1 fish per 3 L [0.8 gallon]) if oxygen saturation is increased to 150 % and temperatures are lower than 15 °C (59 °F).
  - For very short hauls (< 1 hour) or with much fewer fish, lamprey can be transported with aeration and cooling in 20-L (5-gallon) buckets or larger coolers.
- For hauling water, additional options to reduce stress and decrease infections include:
  - Use Stresscoat® or similar products (e.g., API® Fish Care at 0.5 ml/4 L [1/8 tsp/1.1 gallon])
  - Add a low dosage of anesthetics (~20% of the concentration used for sedation)
  - Add rock salt or Instant Ocean® or similar product to elevate the salinity to approximately 3-5 ppt and thereby help to preserve the mucous layer and reduce stress, particularly in warm conditions.
  - A prophylactic injection of oxytetracycline (0 .05 cc Liquimycin [LA-200] / 500 g wet weight) can help to control bacterial infection induced by stress.
- Provide darkness.
- Provide smooth, solid attachment surfaces.
- Secure lids on buckets and totes to prevent lamprey from escaping. Tightly secure bucket lids; use zip ties to secure lids on totes.

  - Allow room for adults to attach out of the water (10-13 cm [4-5 inches]) near the top of the container will keep lamprey calm if water quality conditions start to deteriorate.
- For hauling and transport:
  - Ensure all equipment is in good working order, and duplicates are on hand.
  - Keep a well-stocked tool kit with duct tape, electrical tape and plenty of tubing for oxygen supply lines. Airstones, nets, hoses, etc., can get damaged with weather exposure during the off season.
  - The oxygen regulator is a particularly weak link. If possible, have a backup in the event of failure.
  - Test everything thoroughly before transport season and test again immediately before transport.
  - Monitor water quality parameters during transport and adjust as needed to reduce stress. Use of a WiFi monitoring system allows for more regular checks and less need to stop for monitoring.

Release

- Net buckets with unique marks can be floated within a transport tank to minimize sorting and netting at the release site.
- Select release sites with good water quality, moderate flow (to help fish orient), and limited predation. To avoid fall back, do not release into high flows upstream from barriers.
- Release at night or place lamprey in a release box in the river that allows them to hold and volitionally leave when they are ready.
- Adjust transport temperatures to match release water temperatures within 2 °C (~4 °F) if possible.

Lamprey-Friendly Equipment

- Use lamprey-friendly gear:
  - Use soft mesh nets and wear cotton gloves over latex gloves for direct handling.
  - Use Net Buckets or plastic totes for transporting to eliminate additional sorting and netting.
    - Net buckets can hold 15 adults.
    - Totes (75 L [20 gallon] capacity) can hold up to 30 lamprey.
  - Use insulated tanks for transport to maintain water quality, especially for long hauls or transport during hot temperatures.
  - Line the lower one-third of release tanks with mesh or perforated material to prevent lamprey from attaching during release.
  - Use perforated flumes to release directly from the transport tank to the receiving waters, thereby avoiding needs to net/carry lamprey to release sites.

Net Bucket Construction: Remove the bottom of a 20-L (5-gallon) plastic bucket. To the bottom rim, attach a circular dip net of soft flexible mesh (or a net of 6 mm knotless seine webbing) so that it is continuous along the rim. The net can be attached by sewing through holes drilled in the rim, or with zip ties (Figures 9 and 13). If using zip ties to attach netting to the bucket rim, ensure that the head end of the zip tie (square portion with sharp corners) is oriented away from the inside of the bucket to prevent abrasion on lamprey inside the buckets.

Black plastic totes (75-L [20-gallon] plastic boxes) with locking lids and holes drilled along the sides for water flow can also be used to hold and transport lamprey, just as net buckets. These totes can hold up to ~30 adult Pacific Lamprey (Figure 13). During transport, zip ties are placed on each handle to prevent lamprey from escaping the totes.


Figure 13. Net-bucket (left) and typical transport tote (right) used to transport adult Pacific Lamprey short distances. Note, these containers can be nested in the same type of unmodified container with water until ready to be dewatered and carried in air to the truck tank (Photo of net bucket by G. Silver, Columbia River Inter-Tribal Fish Commission; photo of tote provided by M. Mayfield, Douglas County Public Utility District).

Literature Cited

Ackerman, N.K., David, M.M., and Pyper, B., 2016. Evaluation of Adult Pacific Lamprey Upstream Passage Effectiveness through the Clackamas River Hydroelectric Project. 2015/2016 Progress Report. Clackamas River Project (FERC 2195). Prepared for Portland General Electric, Portland, Oregon.

Ackerman, N.K., Pyper, B.J., David, M.M., Wyatt, G.J., Cramer, D.P. and Shibahara, T.M., 2019. Passage effectiveness at a pool-and-weir fishway designed to accommodate Pacific Lampreys. *North American Journal of Fisheries Management*, *39*(3), pp.426-440. https://doi.org/10.1002/nafm.10281

Almeida, P.R., Arakawa, H., Aronsuu, K., Baker, C., Blair, S.R., Beaulaton, L., Belo, A.F., Kitson, J., Kucheryavyy, A., Kynard, B. and Lucas, M.C., Moser, M.L., Potaka, B., Romakkaniemi, A., Staphonkus, R., Tamarapa, S., Yanai, S., Yang, G., Zhang, T., and Zhuang, P., 2021. Lamprey fisheries: History, trends and management. *Journal of Great Lakes Research*, *47*, pp.S159-S185. https://doi.org/10.1016/j.jglr.2021.06.006

Arakawa, H. 2021. Conservation of Arctic lamprey and its fishery culture in Japan. PhD dissertation, Ishikawa Prefectural University. 196 pp.

Aronsuu, K., Vikström, R., Marjomäki, T.J., Wennman, K., Pakkala, J., Mäenpää, E., Tuohino, J., Sarell, J. and Ojutkangas, E., 2019. Rehabilitation of two northern river lamprey (*Lampetra fluviatilis*) populations impacted by various anthropogenic pressures: lessons learnt in the past three decades. *Jyväskylän yliopiston bio-ja ympäristötieteiden laitoksen tiedonantoja*, (2/2019). https://urn.fi/URN:ISBN:978-951-39-7801-3

Bergstedt, R.A., McDonald, R.B., Twohey, M.B., Mullett, K.M., Young, R.J. and Heinrich, J.W., 2003. Reduction in sea lamprey hatching success due to release of sterilized males. *Journal of Great Lakes Research*, *29*, pp.435-444. https://doi.org/10.1016/S0380-1330(03)70506-1

Bergstedt, R.A. and Twohey, M.B., 2007. Research to support sterile-male-release and genetic alteration techniques for sea lamprey control. *Journal of Great Lakes Research*, *33*, pp.48-69. https://doi.org/10.3394/0380-1330(2007)33[48:RTSSAG]2.0.CO;2

Brumo, A.F., Grandmontagne, L., Namitz, S.N. and Markle, D.F., 2009. Approaches for monitoring Pacific Lamprey spawning populations in a coastal Oregon stream. In *American Fisheries Society Symposium* (Vol. 72, Chapter 12). https://doi.org/10.47886/9781934874134.ch12

Clabough, T.S., Johnson, E.L., Keefer, M.L., Caudill, C.C., Noyes, C.J., Garnett, J., Layng, L., Dick, T., Jepson, M.S., Frick, K.E., Corbett, S.C., & Burke, B. J., 2015. Evaluation of adult Pacific Lamprey passage at lower Columbia River dam and behavior in relation to fishway modifications at Bonneville and John Day dams–2014. Report by the University of Idaho and National Marine Fisheries Service for the US Army Corps of Engineers, Portland District. Draft Technical Report 2015-10, Portland, Oregon. https://usace.contentdm.oclc.org/digital/collection/p16021coll3/id/638/

Clemens, B.J., 2019. A call for standard terminology for lamprey life stages. *Fisheries*, *44*(5), pp.243-245. https://doi.org/10.1002/fsh.10227

Clemens, B.J., 2022. Warmwater temperatures (≥ 20 °C) as a threat to Pacific lamprey: Implications of climate change. *Journal of Fish and Wildlife Management*, *13*(2), pp.591-598. https://doi.org/10.3996/JFWM-21-087

Clemens, B.J., Arakawa, H., Baker, C., Coghlan, S., Kucheryavyy, A., Lampman, R., Lança, M.J., Mateus, C.S., Miller, A., Nazari, H. and Pequeño, G., Sutton, T.M., and Yanai, S., 2021. Management of anadromous lampreys: Common threats, different approaches. *Journal of Great Lakes Research*, *47*, pp.S129-S146. https://doi.org/10.1016/j.jglr.2020.09.005

Clemens, B.J., Binder, T.R., Docker, M.F., Moser, M.L. and Sower, S.A., 2010. Similarities, differences, and unknowns in biology and management of three parasitic lampreys of North America. *Fisheries*, *35*(12), pp.580-594. https://doi.org/10.1577/1548-8446-35.12.580

Clemens, B.J., Harris, J.E., Starcevich, S.J., Evans, T.M., Skalicky, J.J., Neave, F. and Lampman, R.T., 2022. Sampling methods and survey designs for larval lampreys. *North American Journal of Fisheries Management*, *42*(2), pp.455-474. https://doi.org/10.1002/nafm.10762

Clemens, B.J. and Schreck, C.B., 2021. Microhabitat use by prespawning Pacific Lamprey *Entosphenus tridentatus* differs by year, river segment, and availability in a large, regulated mainstem river. *Environmental Biology of Fishes*, *104*, pp.325-340. https://doi.org/10.1007/s10641-021-01079-7

Clemens, B., Schreck, C., van de Wetering, S. and Sower, S., 2016. The potential roles of river environments in selecting for stream-and ocean-maturing Pacific Lamprey, *Entosphenus tridentatus* (Gairdner, 1836). *Jawless fishes of the world*, *1*, pp.299-322.

Clemens, B.J., Van De Wetering, S., Kaufman, J., Holt, R.A. and Schreck, C.B., 2009. Do summer temperatures trigger spring maturation in Pacific lamprey, *Entosphenus tridentatus*? *Ecology of Freshwater Fish*, *18*(3), pp.418-426. https://doi.org/10.1111/j.1600-0633.2009.00358.x

Clemens, B.J. and Wagner, C.M., 2024. Stream and river flows mediate adult lamprey spawning migrations: Considerations for management. *River Research and Applications*, *40*(8), pp.1447-1468. https://doi.org/10.1002/rra.4322

Clemens, B.J., Weitkamp, L., Siwicke, K., Wade, J., Harris, J., Hess, J., Porter, L., Parker, K., Sutton, T. and Orlov, A.M., 2019. Marine biology of the Pacific Lamprey *Entosphenus tridentatus*. *Reviews in Fish Biology and Fisheries, 29(*4), pp.767-788. https://doi.org/10.1007/s11160-019-09578-8

Close, D. A., Currens, K. P., Jackson, A., Wildbill, A. J., Hansen, J., Bronson, P., and Aronsuu, K., 2009. Lessons from the reintroduction of a noncharismatic, migratory fish: Pacific lamprey in the upper Umatilla River, Oregon. In *American Fisheries Society Symposium* (Vol. 72, Chapter 14). https://doi.org/10.47886/9781934874134.ch14

Close, D.A., Fitzpatrick, M.S. and Li, H.W., 2002. The ecological and cultural importance of a species at risk of extinction, Pacific lamprey. *Fisheries*, *27*(7), pp.19-25. https://doi.org/10.1577/1548-8446(2002)027<0019:TEACIO>2.0.CO;2

Columbia River Inter-Tribal Fish Commission (CRITFC), 2014. Master Plan: Pacific Lamprey Artificial Propagation, Translocation, Restoration, and Research—Conceptual Phase to Address

Step 1—Master Plan Review Elements. CRITFC, Portland, Oregon. https://www.critfc.org/wp-content/uploads/2018/04/20180327-Master-Plan-Pac-Lamprey.pdf

Columbia River Intertribal Fish Commission (CRITFC), 2025. 2025 Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. https://critfc.org/wp-content/uploads/2025/05/ReportPost_CRITFC_etal2025A.pdf

David, M.M., 2023. Evaluation of adult Pacific Lamprey upstream passage effectiveness through the Clackamas River Hydroelectric Project (FERC No. 2195), 2023 Annual Report. Prepared for Portland General Electric Company, Portland, Oregon.

David, M.M., 2025. Evaluation of adult Pacific Lamprey upstream passage effectiveness through the Clackamas River Hydroelectric Project (FERC No. 2195), 2025 Annual Report. Prepared for Portland General Electric Company, Portland, Oregon.

Dawson, H.A., Quintella, B.R., Almeida, P.R., Treble, A.J. and Jolley, J.C., 2014. The ecology of larval and metamorphosing lampreys. In *Lampreys: biology, conservation and control: volume 1* (pp.75-137). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-017-9306-3_3

Frick, K.E., Corbett, S.C. and Moser, M.L., 2017. Climbing success of adult Pacific lamprey on a vertical wetted wall. *Fisheries Management and Ecology*, *24*(3), pp.230-239. https://doi.org/10.1111/fme.12225

Gephard, S., 2019. Restoration of anadromous sea lamprey to the Connecticut River and adjacent watersheds. *From catastrophe to recovery: Stories of fishery management success*, pp.185-210. https://doi.org/10.47886/9781934874554.ch8

Gephard, S., 2023. Transplantation of prespawn adult Sea Lampreys as an important restoration strategy. *North American Journal of Fisheries Management*, *43*(6), pp.1584-1595. https://doi.org/10.1002/nafm.10941

Goodman, D.H. and Reid, S.B., 2017. Climbing above the competition: innovative approaches and recommendations for improving Pacific Lamprey passage at fishways. *Ecological Engineering*, *107*, pp.224-232. https://doi.org/10.1016/j.ecoleng.2017.07.041

Gunckel, S.L., Jones, K.K. and Jacobs, S.E., 2009. Spawning distribution and habitat use of adult Pacific and western brook lampreys in Smith River, Oregon. In *American Fisheries Society Symposium* (Vol. 72, Chapter 10). https://doi.org/10.47886/9781934874134.ch10

Harmon, T.S., 2009. Methods for reducing stressors and maintaining water quality associated with live fish transport in tanks: a review of the basics. *Reviews in Aquaculture*, *1*(1), pp.58-66. https://doi.org/10.1111/j.1753-5131.2008.01003.x

Hess, J.E., Campbell, N.R., Close, D.A., Docker, M.F. and Narum, S.R., 2013. Population genomics of Pacific lamprey: adaptive variation in a highly dispersive species. *Molecular Ecology*, *22*(11), pp.2898-2916. https://doi.org/10.1111/mec.12150

Hess, J.E., Caudill, C.C., Keefer, M.L., McIlraith, B.J., Moser, M.L. and Narum, S.R., 2014. Genes predict long distance migration and large body size in a migratory fish, Pacific lamprey. *Evolutionary applications*, *7*(10), pp.1192-1208. https://doi.org/10.1111/eva.12203

Hess, J.E., Delomas, T.A., Jackson, A.D., Kosinski, M.J., Moser, M.L., Porter, L.L., Silver, G., Sween, T., Weitkamp, L.A. and Narum, S.R., 2022. Pacific Lamprey translocations to the Snake

River boost abundance of all life stages. *Transactions of the American Fisheries Society*, *151*(3), pp.263-296. https://doi.org/10.1002/tafs.10359

Hess, J.E., Lampman, R.T., Jackson, A.D., Sween, T., Jim, L., McClain, N., Silver, G., Porter, L. and Narum, S.R., 2023. The return of the adult Pacific Lamprey offspring from translocations to the Columbia River. *North American Journal of Fisheries Management*, *43*(6), pp.1531-1552. https://doi.org/10.1002/nafm.10922

Hess, J.E., Paradis, R.L., Moser, M.L., Weitkamp, L.A., Delomas, T.A. and Narum, S.R., 2021. Robust Recolonization of Pacific Lamprey Following Dam Removals: Pacific Lamprey Recolonization. *Transactions of the American Fisheries Society*, *150*(1), pp.56-74. https://doi.org/10.1002/tafs.10273

Holub, R., Bravener, G. and McLaughlin, R., 2022. A management-scale investigation of consistent individual differences in behaviour and trapping bias in sea lamprey (*Petromyzon marinus*). *Canadian Journal of Fisheries and Aquatic Sciences*, *79*(1), pp.97-110. https://doi.org/10.1139/cjfas-2019-0448

Jackson, A.D. and Moser, M.L., 2012. Low-elevation dams are impediments to adult Pacific Lamprey spawning migration in the Umatilla River, Oregon. *North American Journal of Fisheries Management*, *32*(3), pp.548-556. https://doi.org/10.1080/02755947.2012.675950

Jackson, A.D., Moser, M.L., Onjukka, S.T., LaPatra, S., Lujan, K.M., Samson, C., White, M.G., Blair, M., Rhodes, L., Lampman, R. and Maine, A.N., 2019. Occurrence of pathogens in Pacific lamprey (*Entosphenus tridentatus*). *Reviews in Fish Biology and Fisheries*, *29*(3), pp.653-668. https://doi.org/10.1007/s11160-019-09572-0

Johnson, E.L., Caudill, C.C., Keefer, M.L., Clabough, T.S., Peery, C.A., Jepson, M.A. and Moser, M.L., 2012. Movement of radio-tagged adult Pacific Lampreys during a large-scale fishway velocity experiment. *Transactions of the American Fisheries Society*, *141*(3), pp.571-579. https://doi.org/10.1080/00028487.2012.683468

Johnson, N.S., Buchinger, T.J. and Li, W., 2014. Reproductive ecology of lampreys. In *Lampreys: biology, conservation and control: Volume 1* (pp. 265-303). Dordrecht: Springer Netherlands.

Jolley, J.C. and Lujan, K.M., 2019. Pathogens of Pacific lamprey detected through routine fish health screenings. *Journal of Fish and Wildlife Management*, *10*(2), pp.517-524. https://doi.org/10.3996/122018-JFWM-119

Jolley, J.C., Silver, G.S., Harris, J.E. and Whitesel, T.A., 2018. Pacific lamprey recolonization of a Pacific Northwest river following dam removal. *River Research and Applications*, *34*(1), pp.44-51. https://doi.org/10.1002/rra.3221

Keefer, M.L., Caudill, C.C., Clabough, T.S., Jepson, M.A., Johnson, E.L., Peery, C.A., Higgs, M.D. and Moser, M.L., 2013. Fishway passage bottleneck identification and prioritization: a case study of Pacific lamprey at Bonneville Dam. *Canadian Journal of Fisheries and Aquatic Sciences*, *70*(10), pp.1551-1565. https://doi.org/10.1139/cjfas-2013-0164

Keefer, M.L., Daigle, W.R., Peery, C.A., Pennington, H.T., Lee, S.R. and Moser, M.L., 2010. Testing adult Pacific lamprey performance at structural challenges in fishways. *North American Journal of Fisheries Management*, *30*(2), pp.376-385. https://doi.org/10.1577/M09-099.1

Keefer, M.L., Jepson, M.A., Clabough, T.S. and Caudill, C.C., 2021. Technical fishway passage structures provide high passage efficiency and effective passage for adult Pacific salmonids at eight large dams. *PloS one*, *16*(9), p.e0256805. https://doi.org/10.1371/journal.pone.0256805

Keefer, M.L., Moser, M.L., Boggs, C.T., Daigle, W.R. and Peery, C.A., 2009. Effects of body size and river environment on the upstream migration of adult Pacific lampreys. *North American Journal of Fisheries Management*, *29*(5), pp.1214-1224. https://doi.org/10.1577/M08-239.1

Kemp, P.S., Tsuzaki, T. and Moser, M.L., 2009. Linking behaviour and performance: intermittent locomotion in a climbing fish. *Journal of Zoology*, *277*(2), pp.171-178. https://doi.org/10.1111/j.1469-7998.2008.00525.x

Kirk, M.A., Caudill, C.C., Tonina, D. and Syms, J.C., 2016. Effects of water velocity, turbulence and obstacle length on the swimming capabilities of adult Pacific lamprey. *Fisheries Management and Ecology*, *23*(5), pp.356-366. https://doi.org/10.1111/fme.12179

Kock, T.J., Ferguson, J.W., Keefer, M.L. and Schreck, C.B., 2021. Review of trap-and-haul for managing Pacific salmonids (Oncorhynchus spp.) in impounded river systems. *Reviews in Fish Biology and Fisheries*, *31*(1), pp.53-94. https://doi.org/10.1007/s11160-020-09627-7

Lampman, R.T., 2011. Passage, migration behavior, and autoecology of adult Pacific Lamprey at Winchester Dam and within the North Umpqua River basin, Oregon, USA. Master's Thesis, Oregon State University, Corvallis, Oregon. https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/qv33s100b

Lampman, R.T., Maine, A.N., Moser, M.L., Arakawa, H. and Neave, F.B., 2021. Lamprey aquaculture successes and failures: A path to production for control and conservation. *Journal of Great Lakes Research*, *47*, pp.S201-S215. https://doi.org/10.1016/j.jglr.2020.10.006

LTWG (Lamprey Technical Workgroup). 2020. Best management guidelines for native lampreys during in-water work. Original Version 1.0, May 4, 2020. https://www.pacificlamprey.org/ltwg/

LTWG (Lamprey Technical Workgroup). 2021. Overview of eDNA and applications for lamprey research and monitoring. Original Version 1.0, February 2021. https://www.pacificlamprey.org/ltwg/

LTWG (Lamprey Technical Workgroup). 2022a. Practical guidelines for incorporating adult Pacific Lamprey passage at fishways, Version 2.0. White Paper. https://www.pacificlamprey.org/ltwg/

LTWG (Lamprey Technical Workgroup). 2022b. Review of factors affecting larval and juvenile lamprey entrainment and impingement at fish screen facilities. Original version 1.0, June 2022. https://www.pacificlamprey.org/ltwg/

LTWG (Lamprey Technical Workgroup). 2023. Comparison of Pacific Lamprey and Pacific Salmon Life Histories, Habitat and Ecology. March 8, 2023. https://www.pacificlamprey.org/ltwg/

Liedtke, T.L., Harris, J.E., Blanchard, M.R., Skalicky, J.J. and Grote, A.B., 2023. Synthesis of larval lamprey responses to dewatering: State of the science, critical uncertainties, and management implications. *North American Journal of Fisheries Management*, *43*(6), pp.1475-1491. https://doi.org/10.1002/nafm.10924

Miehls, S., Dawson, H.A., Maguffee, A.C., Johnson, N.S., Jones, M.L. and Dobiesz, N., 2021. Where you trap matters: Implications for integrated sea lamprey management. *Journal of Great Lakes Research*, *47*, pp.S320-S327. https://doi.org/10.1016/j.jglr.2020.06.023

Moser, M.L., Almeida, P.R., Kemp, P.S. and Sorensen, P.W., 2015b. Lamprey spawning migration. In *Lampreys: Biology, Conservation and Control: Volume 1* (pp.215-263). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-017-9306-3_5

Moser, M.L., Almeida, P.R., King, J.J. and Pereira, E., 2021. Passage and freshwater habitat requirements of anadromous lampreys: Considerations for conservation and control. *Journal of Great Lakes Research*, *47*, pp.S147-S158. https://doi.org/10.1016/j.jglr.2020.07.011

Moser, M.L., Butzerin, J.M. and Dey, D.B., 2007. Capture and collection of lampreys: the state of the science. *Reviews in Fish Biology and Fisheries*, *17*(1), pp.45-56. https://doi.org/10.1007/s11160-006-9037-3

Moser, M.L., Corbett, S.C., Keefer, M.L., Frick, K.E., Lopez-Johnston, S. and Caudill, C.C., 2019a. Novel fishway entrance modifications for Pacific lamprey. *Journal of Ecohydraulics*, *4*(1), pp.71-84. https://doi.org/10.1080/24705357.2019.1604090

Moser, M.L., Hume, J.B., Aronsuu, K.K., Lampman, R.T. and Jackson, A.D., 2019b. Lamprey reproduction and early life history: insights from artificial propagation. In *Lampreys: Biology, Conservation and Control: Volume 2* (pp.187-245). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-024-1684-8

Moser, M.L., Jackson, A.D., Lucas, M.C. and Mueller, R.P., 2015a. Behavior and potential threats to survival of migrating lamprey ammocoetes and macrophthalmia. *Reviews in Fish Biology and Fisheries*, *25*(1), pp.103-116. https://doi.org/10.1007/s11160-014-9372-8

Moser, M.L., Keefer, M.L., Corbett, S.C., Frick, K.E., Caudill, C.C. and Tackley, S.C., 2021. Providing refuges for adult Pacific lamprey *Entosphenus tridentatus* inside fishways. *Aquaculture and Fisheries*, *6*(2), pp.144-150. https://doi.org/10.1016/j.aaf.2019.03.003

Moser, M.L., Keefer, M.L., Pennington, H.T., Ogden, D.A. and Simonson, J.E., 2011. Development of Pacific lamprey fishways at a hydropower dam. *Fisheries Management and Ecology*, *18*(3), pp.190-200. https://doi.org/10.1111/j.1365-2400.2010.00773.x

Moser, M., Maine, A., Shonat, T. and Jackson, A., 2023. Oxygen consumption of sexually mature adult, first-feeding larval, and yearling Pacific Lampreys. *North American Journal of Fisheries Management*, *43*(6), pp.1664-1672. https://doi.org/10.1002/nafm.10938

Moser, M.L. and Mesa, M.G., 2009. Passage considerations for anadromous lampreys. In *American Fisheries Society Symposium* (Vol. 72, Chapter 5). https://doi.org/10.47886/9781934874134.ch5

Moser, M.L. and Paradis, R.L., 2017. Pacific Lamprey restoration in the Elwha River drainage following dam removals. *American Currents*, *42*, pp.3-8. https://www.webapps.nwfsc.noaa.gov/assets/2/9031_10212019_165725_Moser.and.Paradis.2017-Am-Currents-42-2.pdf

Moser, M.L., Pennington, H.T. and Roos, J.M., 2008. Grating size needed to protect adult Pacific lampreys in the Columbia River basin. *North American Journal of Fisheries Management*, *28*(2), pp.557-562. https://doi.org/10.1577/M07-126.1

Oregon Department of Fish and Wildlife (ODFW). 2020. Coastal, Columbia, and Snake conservation plan for lampreys in Oregon: Pacific lamprey, western river lamprey, western brook lamprey, and Pacific brook lamprey. Final. February 2020. https://www.dfw.state.or.us/fish/CRP/coastal_columbia_snake_lamprey_plan.asp

PLCI (Pacific Lamprey Conservation Initiative). 2024. Pacific Lamprey (*Entosphenus tridentatus*) Status Assessment. June 2024. https://www.pacificlamprey.org/assessment/

Parker, K.A., Hess, J.E., Narum, S.R. and Kinziger, A.P., 2019. Evidence for the genetic basis and epistatic interactions underlying ocean-and river-maturing ecotypes of Pacific Lamprey (*Entosphenus tridentatus*) returning to the Klamath River, California. *Molecular Ecology*, *28*(13), pp.3171-3185. https://doi.org/10.1111/mec.15136

PGE (Portland General Electric), 2011. Clackamas River Project (FERC No. 2195) Pacific Lamprey trap and haul program, Completion Report for Portland General Electric, Portland, Oregon.

Portz, D.E., Woodley, C.M. and Cech Jr, J.J., 2006. Stress-associated impacts of short-term holding on fishes. *Reviews in Fish Biology and Fisheries*, *16*(2), pp.125-170. https://doi.org/10.1007/s11160-006-9012-z

Radtke, G. and Kuczyński, T., 2020. A handy trap for capturing of the adult river lamprey in streams. *Fisheries & Aquatic Life*, *28*(3). https://doi.org/10.2478/AOPF-2020-0023

Reid, S.B. and Goodman, D.H., 2016a. Free-swimming speeds and behavior in adult Pacific Lamprey, *Entosphenus tridentatus*. *Environmental Biology of Fishes*, *99*(12), pp.969-974. https://doi.org/10.1007/s10641-016-0537-2

Reid, S.B. and Goodman, D.H., 2016b. Pacific Lamprey in coastal drainages of California: occupancy patterns and contraction of the southern range. *Transactions of the American Fisheries Society*, *145*(4), pp.703-711. https://doi.org/10.1080/00028487.2016.1159615

Reid, S.B. and Goodman, D.H., 2020. Natural recolonization by Pacific lampreys in a Southern California coastal drainage: Implications for their biology and conservation. *North American Journal of Fisheries Management*, *40*(2), pp.335-341. https://doi.org/10.1002/nafm.10412

Reinhardt, U.G., Eidietis, L., Friedl, S.E. and Moser, M.L., 2008. Pacific lamprey climbing behavior. *Canadian Journal of Zoology*, *86*(11), pp.1264-1272. https://doi.org/10.1139/Z08-112

Schuldt, R.J. and Heinrich, J.W., 1982. Portable trap for collecting adult sea lampreys. *The Progressive Fish-Culturist*, *44*(4), pp.220-221. https://doi.org/10.1016/j.jglr.2021.03.014

Siefkes, M.J., 2017. Use of physiological knowledge to control the invasive sea lamprey (*Petromyzon marinus*) in the Laurentian Great Lakes. *Conservation Physiology*, *5*(1), p.cox031. https://doi.org/10.1093/conphys/cox031

Silva, A.T., Lucas, M.C., Castro-Santos, T., Katopodis, C., Baumgartner, L.J., Thiem, J.D., Aarestrup, K., Pompeu, P.S., O'Brien, G.C., Braun, D.C. and Burnett, N.J., Zhu, D.Z., Fjeldstad, H.P., Forseth, T., Rajarathnam, N., Williams, J.G., and Cooke, S.J., 2018. The future of fish passage science, engineering, and practice. *Fish and Fisheries*, *19*(2), pp.340-362. https://doi.org/10.1111/faf.12258

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*(3), pp.225-232. https://doi.org/10.1898/1051-1733(2006)87[225:OONCSH]2.0.CO;2

Ward, D.L., Clemens, B.J., Clugston, D., Jackson, A.D., Moser, M.L., Peery, C. and Statler, D.P., 2012. Translocating adult Pacific Lamprey within the Columbia River basin: state of the science. *Fisheries*, *37*(8), pp.351-361. https://doi.org/10.1080/03632415.2012.704818

Zobott, H., Caudill, C., Keefer, M., Budwig, R. and Moser, M., 2013. Pacific Lamprey Passage Structures at Bonneville Dam: Design guidelines and catalog of qualitative hydraulic conditions, hydraulic modeling, and integrating diverse information sources with 3D visual models to create a fish passage WIKI. Master's Thesis, University of Idaho, Moscow, ID, 90 pp. https://verso.uidaho.edu/esploro/outputs/graduate/PACIFIC-LAMPREY-PASSAGE-STRUCTURES-AT-BONNEVILLE/996638335301851

APPENDIX A. Case Studies for Trap and Haul for Adult Lampreys

The following are examples of T&H operations for adult lampreys. The first five are specific to Pacific Lamprey in the Pacific Northwest. The latter are examples of T&H operations for other anadromous lampreys that have been conducted elsewhere. While Pacific Lamprey are the focus of this review, the differences and similarities highlighted by these case studies help foster an understanding of the fundamental requirements of T&H operations across all lamprey species. Many thanks to these contributors for sharing the details and pictures of their operations. This is a living document; as new T&H techniques for lamprey are developed, representative case studies can be added. Citations in the case studies can be found in the Literature Cited.

Transfer of Pacific Lamprey from below Lower Columbia River Dams to Interior Basin Spawning Habitats

Contributors: Laurie Porter and Greg Silver (Columbia River Inter-Tribal Fish Commission [CRITFC]), Ray Ellenwood and Tod Sween (Nez Perce Tribe [NPT]), Aaron Jackson (Confederated Tribes of the Umatilla Indian Reservation [CTUIR]) and Ralph Lampman (Yakama Nation [YN])

Background

Starting in the late 1990's, tribal biologists with the CTUIR initiated efforts to translocate adult Pacific Lamprey past lower Columbia River dams (Bonneville [BO], The Dalles [TD], and John Day [JD] dams, Figure A1) to boost production in CTUIR ceded lands (Close et al. 2009). Early on, these fish were salvaged during dewatering operations at John Day Dam (Columbia RKM 348). The success of this program led to coordination with the U.S. Army Corps of Engineers (dam operator) and the eventual ability to obtain adults from fishways at all three of these lower Columbia River dams.

From its humble beginnings in the late 1990s, the tribal translocation program has grown and is now conducted annually by CRITFC and the CTUIR, NPT and YN (Ward et al. 2012; Figure A2). This led to the eventual establishment of safe handling and holding protocols by CRITFC. Collection numbers have increased in recent years, due in part to new and effective collection methods at BO and TD, resulting in record numbers of fish collected for the program in 2023 (over 11,000) and 2024 (over 17,000) with extremely low mortality (0.03-0.4%). Use of genetic methods (parentage-based tagging using single nucleotide polymorphisms) has established that this program boosts larval distribution, abundance, and recruitment in the upper parts of the Columbia and Snake river basins (Hess et al. 2022). Moreover, it has resulted in contributions to the population of downstream-migrating juveniles and ultimately the return of pre-spawning adults to the Columbia River (Hess et al. 2023). The lessons learned from over 25 years of lamprey T&H operations are summarized from interviews by program leaders at the CRITFC, the CTUIR, the YN and the NPT.

Methods

Currently, Pacific Lamprey adults used for the CRITFC-Tribal translocation program are trapped at lower Columbia River dams by CRITFC biologists and technicians and then transported to the Oregon Department of Fish and Wildlife (ODFW) Bonneville Hatchery Captive Brood Building (CBB). This facility is located immediately downstream from BO on the Oregon shore of the Columbia River (a 10-20-minute drive from trapping locations at BO). At the CBB, fish are held until they can be transported to upstream holding and release sites by NPT, CTUIR and YN staff. Fish are transported by CRITFC staff from the three dams to the CBB in an insulated 1,135-L (~300-gallon) truck tank that is filled to near the top at the beginning of each trip with well water at 10 °C (50 °F) and maintained at 80-150% dissolved oxygen saturation. Water temperature in the transport tank ranges from about 11-15 °C (~52-59 °F) over the course of the day, depending on weather conditions. A meter is used to monitor temperature and oxygen levels throughout each trip.

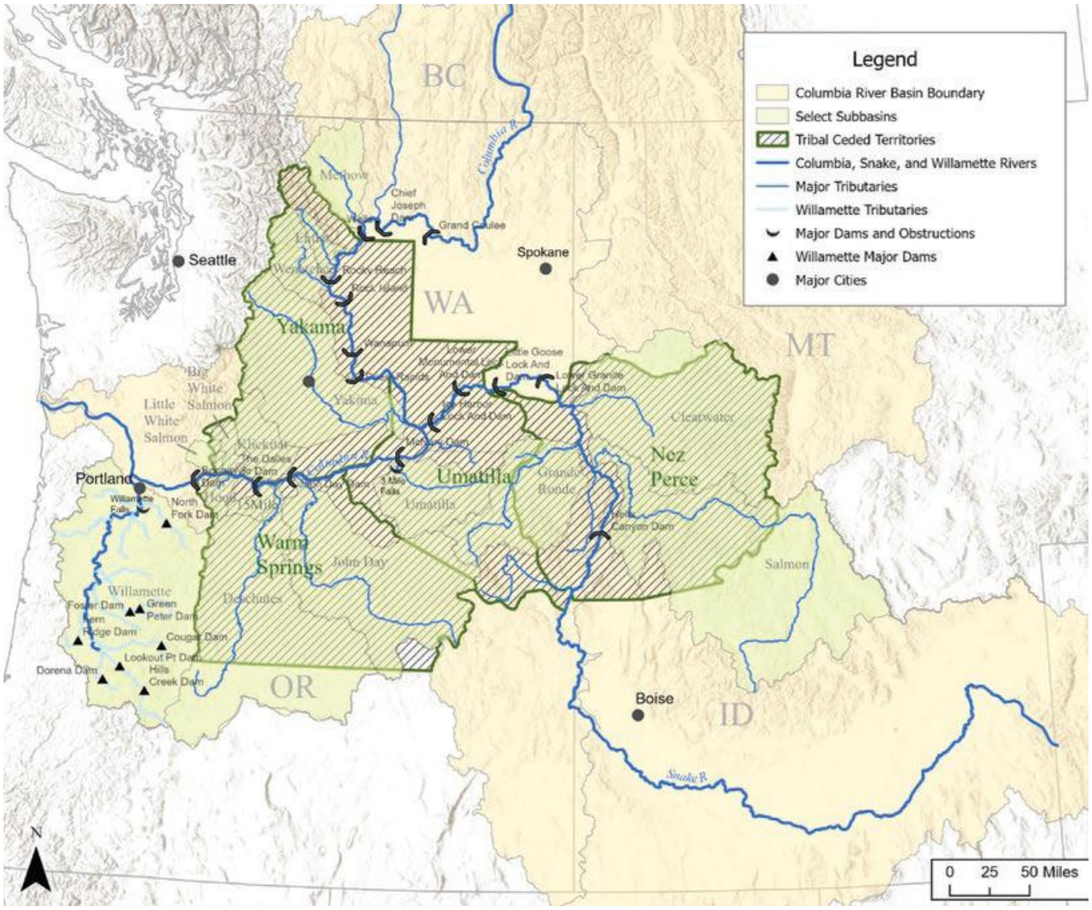

Figure A1. Map of Columbia and Snake River dams and tribal ceded lands where Pacific Lamprey translocations occur to bolster upstream populations (From CRITFC 2025).


Figure A2. Early Nez Perce holding facilities used to overwinter adult Pacific Lamprey captured at lower Columbia River dams (Photo Credit T. Sween, NPT).

Trapping operations are different at the three dams according to the unique requirements of the traps operated and the structure, design, and location of the fishways at each dam and the logistics of accessing suitable (and approved) trapping locations within them. CRITFC staff trap adult lamprey seven days per week during the lamprey migration season, typically from early June through early September. Currently, the CRITFC collection crew travels first from the CBB to JD (Columbia RKM 347) each morning. On the south shore at JDA (Oregon shore), there is a trap integrated into the South Fishway count station (Figure A3). This trap collects lamprey as they approach the count station window by guiding them into a collection gallery that leads to a trap box with a mechanical hoist (jib crane). The trap is hoisted, opened, and lamprey are transferred by hand (cotton gloves over latex gloves) into net buckets (15- 20 lamprey/bucket, depending on conditions) for transport to the tank truck. Net buckets are placed inside the truck tank for transport to the CBB.

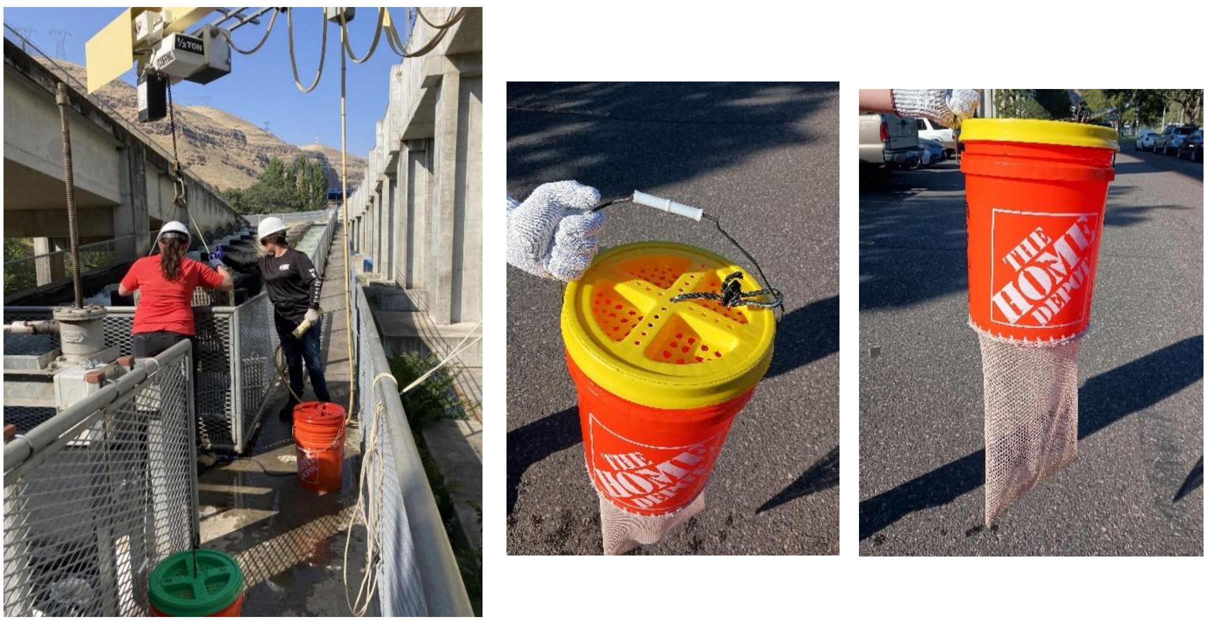

Figure A3. South fishway trap being lifted with a mechanical hoist at John Day Dam south fishway (left) and photos of net-buckets (right) used to transport adult Pacific Lamprey short distances from the trap to the transport vehicle. Note, net buckets are nested in regular 20-L (5-gallon) buckets with water until ready to be dewatered and carried in air to the truck tank (Photos by G. Silver, CRITFC).

On the north shore at JD (Washington shore), lamprey are collected using individual traditional lamprey pots or tube traps (eelpots, n = 3) deployed in the North Fishway count station and tied off to railings. In addition, there is a Lamprey Passage System (LPS) near the north fishway entrance (Moser et al. 2019a) that terminates in a trap box on the tailrace deck. Lamprey are removed from the LPS trap box with a dipnet, placed into net buckets which are transported in an insulated wheeled tote containing river water to the dam elevator. The tote is taken up in the elevator to the transport tank on the roadway level.

At the next dam downstream, TD (RKM 308), an LPS in the East Fish Ladder (Oregon shore) junction pool terminates in a trap box at the tailrace level. Fish are removed from the trap box by dipnet, placed into net buckets (up to 15 lamprey/bucket), and transferred to the truck transport tank. After emptying the trap box, the crew proceeds back downstream to the CBB. At the CBB, net buckets are transferred from the truck transport tank to holding tanks supplied with groundwater/well water (typically at ~10 °C [50 °F]). Once all net buckets of fish from JD and TD are removed from the truck transport tank, the crew proceeds to BO (RKM 235).

At BO, lamprey are collected from traps operated in the Bradford Island fishway on the south (Oregon) shore, mid-river in the Cascades Island fishway, and in the Washington shore ladder on the north shore (Figure A4). Tube traps are deployed above picket leads in auxiliary water supply (AWS) channels in the Bradford Island fishway on the Oregon shore near the count station window, in the Cascades Island AWS and in the Washington shore ladder near the count station window. Fish collected in tube traps are removed by hand or dumped into net buckets that are then transferred to the truck transport tank. LPS traps are also operated in all three locations. The first is positioned near the Bradford Island B-Branch fishway entrance and terminates in a trap box near the spillway (Figure A4, Moser et al. 2019a). The second is in the Cascades Island fishway AWS (just upstream of the upstream migration tunnel junction). The third is in the Washington-shore fishway at the exit channel of the Adult Fish Facility building. Fish are removed from the LPS trap boxes with a dipnet, placed into net buckets, and carried in air (dewatered) approximately 50-200 meters (depending on the trap location) from the trap boxes to the truck transport tank (about 30-45 seconds out of the water).

Figure A4. CRITFC technicians remove lamprey from the trap boxes at the Bonneville Dam Bradford Island B-Branch Lamprey Passage Structure (left) and at the Bonneville Washington Shore Adult Fish Facility trap integrated into the fishway (right). (Photos by G. Silver, CRITFC).

All fish are transferred to the truck tank and transported approximately 10-20 minutes from the Washington shore to the CBB holding tanks. At the CBB, each lamprey is administered an antibiotic injection of oxytetracycline (0 .05 cc Liquamycin (LA-200) / 500 g wet weight) to help minimize any potential stress-induced bacterial infection. Lamprey are held in separate tanks at the CBB according to collection location, typically with one holding tank each for BO, TD, and JD. At the CBB, large circular tank size is 6,673 L (1,763 gallon) and the flow rate delivered to each tank is 223 L/min (59 gallon/min). Each tank can accommodate up to 881 adult Pacific Lamprey.

Fish are generally held in tanks at the CBB for one to two weeks, but in some cases may be held over a month before transport upstream. All adults are tissue sampled (dorsal or caudal fin clip) prior to release (Figure A5) for eventual genotyping and parentage and sibship analysis (Hess et al. 2022).

Figure A5. Fin clips for genetic analysis are taken from the first dorsal fin of an adult Pacific Lamprey (Photo by M. Moser, Moserworks, LLC).

Transport to upstream release or holding sites is conducted by biologists from individual tribes (NPT, YN and CTUIR). Over many years of long-haul (> 4 hours) operations, the hauling methods have been refined to reduce mortality. Use of the CBB holding tanks provides cold well-oxygenated water (Figure A6) for rapid recovery and has greatly reduced mortality, as fish are not stressed at the start of their journey.

The NPT hauls adults for the longest distance and time. Transport is either to tribal hatchery holding facilities for overwintering or to Snake River tributaries for immediate release. Hence, it is critical to test all equipment before hauling and to schedule periodic/routine equipment checks throughout the trip. Small failures can lead to lost time or aborted trips. Backups of equipment and a well-stocked tool kit with duct tape, electrical tape and plenty of airline tubing are essential. The oxygen regulator is a particularly weak link, so have a backup in the event of failure, if possible. Airstones, nets, tubing, hoses, all can get damaged with weather exposure.

It is important to remember that lamprey can escape through very small gaps and can even work their way into hose inlets and thereby block water supplies. Use of many tank clamps will ensure that lids stay securely fastened and screening of water sources (even those above the water surface) and outlets will keep escapes from creating even larger problems. Elimination of small gaps between tank dividers and the tank are important precautions.

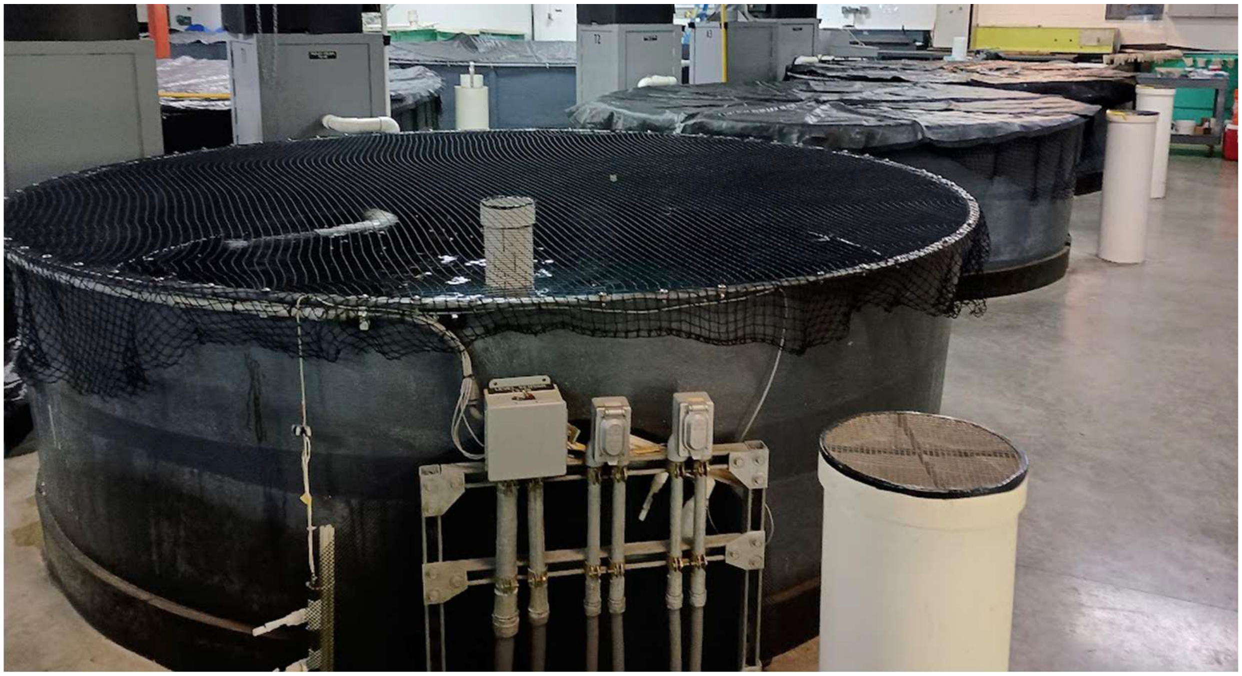

Figure A6. Holding facility for Pacific Lamprey at the ODFW Bonneville Hatchery Captive Broodstock Building. Tanks are supplied with well water at approximately 10 °C (50 °F) and 100% oxygen saturation (Photo by G. Silver, CRITFC).

A reliable hauling vehicle is a must. However, even with a well-maintained truck, things can go wrong. Be prepared for Plan B and Plan C. If there is a breakdown, be ready for additional hours of holding time in warm temperatures. Frozen 8-12 L (2-3 gallon) buckets of hatchery water will melt slowly and keep fish cool. In an emergency, store-purchased bagged ice will work, but it drops the temperature very rapidly. Always carry an extra oxygen bottle and keep dissolved oxygen saturation near 150% for long hauls (> 4 hours).

Pacific Lamprey are easily stressed at low dissolved oxygen levels (Moser et al. 2023) and high temperatures (special care is needed when source water is > 20 °C [68 °F]). A WiFi monitoring system can be integrated into a truck transport tank and allows for constant checks of water quality while on the road, minimizing the number of stops and ensuring that problems are discovered immediately. Use of rock salt or Instant Ocean to elevate the salinity to approximately 3-5 ppt can help to preserve the lamprey mucous layer and reduce stress in very warm conditions.

Reducing both the duration and intensity of handling will also help decrease stress. Soft nets remove less mucous and net buckets are a very useful tool (Figures 9 and A3). The use of net buckets floated in the truck transport tank also allows for ease of sorting fish at the terminus of each trip. Net buckets allow for full water exchange when floating in the tank, provide a lamprey attachment site, reduce the weight of normal buckets for human workers, and keep lamprey contained and separated to avoid multiple chase/capture cycles with a dipnet. Colored lanyards (or duct tape labels on the lids) allow for easy identification of release groups.

Transport distances for the CTUIR and YN can also involve long hauls on rough roads (and in hot weather conditions) to deliver fish to over-wintering sites or release locations. Caution is advised when source or receiving water temperatures exceed 20 °C (68 °F). Lowering the water temperature with ice buckets and saturating the water with dissolved oxygen will help stressed fish to recover prior to and during transport.

Density during transport should be limited to one adult lamprey / 3.8 L (1 gal), if possible. However, experienced biologists successfully transport adult lamprey at densities of 1.3 lamprey / 3.8 L (1 gal) when water temperature is < 20 °C (68 °F). Hence, for a 600-L (150-gallon) insulated tote, density can be up to 200 adults if oxygen saturation is 100 % and temperatures are lower than 15 °C (59 °F). Experienced lamprey haulers have noted increased mortality when more than 225 individuals are transported in a 600-L (150-gallon) tote, even under ideal conditions. For very short hauls (< 1 hour) or hauls with few fish, lamprey can be transported with aeration and cooling in 20-L (5-gallon) buckets or large coolers. However, an adult lamprey can consume all of the dissolved oxygen in 20-L in just a few hours (Moser et al. 2023). Room to attach out of the water near the top of the container (10-13 cm [4-5 inches]) will keep lamprey calm if water quality starts to deteriorate, provided that the container lid is not air-tight.

Release into receiving waters can be simplified with use of a flume directly connected to the transport tank outlet (Figure A7). This technique eliminates the need to carry fish from the tank to the receiving water. If this method is not possible, transfer of fish from the transport tank to the river can be accomplished most easily with the use of net buckets or perforated buckets that reduce weight of transport by draining while in transit (Figure A3). A large dipnet also works for short trips (Figure A7).

Figure A7. Confederated Tribes of the Umatilla Indian Reservation biologists release adult Pacific Lamprey using a modified flume (left) and dip net and bucket transfer (right) (Photo by A. Jackson, Confederated Tribes of the Umatilla Indian Reservation).

Clackamas River Translocation to Stimulate Adult Pacific Lamprey Migration

Contributors: Maggie David and Dan Cramer, Portland General Electric (PGE)

Background

This project uses T&H to increase numbers of Pacific Lamprey spawning above a partial barrier, to increase numbers of larvae and enhance adult lamprey attraction to the area. The long-term goal is to restore volitional passage at the North Fork Dam fishway. T&H is used as an interim measure to increase lamprey distribution and population in the upper Clackamas River while ongoing evaluations of the fish ladder are conducted to identify appropriate improvements.

The Clackamas River is an impounded tributary of the Willamette River in western Oregon. Clackamas River dams (River Mill and North Fork dams constructed in 1911 and 1958, respectively) historically had poor adult Pacific Lamprey passage. Starting in 2006, the River Mill Dam fishway was replaced and the new fishway included lamprey-friendly passage improvements. These design elements improved adult Pacific Lamprey passage at this fishway to 84-98% (Ackerman et al. 2016), but radiotelemetry in 2013-16 revealed that passage rates at the next dam upstream (North Fork) were poor (11% in 2015; 0% in 2016) and that only 20-30% of the tagged fish approached the dam fishway entrances (Ackerman et al. 2016). It was hypothesized that poor escapement over many years led to a lack of larval pheromone production upstream and low migration motivation amongst adults in the upper part of this system.

To address this concern, adult lamprey were trapped from the River Mill fishway and transported upstream beginning in 2017. From 2017 through 2025, PGE has hauled 2,360 adult Pacific Lamprey above North Fork Dam. The initial goal was to move up to 250 adults/year to the head of North Fork reservoir. After the first few years this goal was increased to 400/year, though only 20 were hauled in 2024 due to low returns. In 2017 and 2018, 25 of the transported fish were equipped with uniquely coded radio transmitters to track their movements after release. In addition, up to 240 individuals were genetic sampled each year. This program seems to be working. In the 2023 outmigration year (10/01/2023 -9/30/2024), extrapolated outmigrant numbers at the North Fork juvenile sampling facility were greater than 41,000 juveniles and 29,000 larvae collected at North Fork Dam (unpublished data, M. David, PGE). Parentage analysis revealed that there were offspring from transported lamprey amongst these captures (Hess et al 2021). The percentage of pre-spawning adults approaching the North Fork fishway is now 80-90% and radiotelemetry indicated that fish released in the North Fork reservoir dispersed widely and did not exhibit negative consequences of T&H (David 2025).

Methods

Pacific Lamprey are trapped after they enter the fishway at River Mill Dam (Figure A8). The trap is integrated into the top of a weir in this pool and weir fishway (Figure A9). The orifice at the bottom of the weir used for trapping is blocked to increase lamprey capture efficiency; salmon are able to pass over the top of the weir when the trap is in place. The entire trap is lifted via a mechanical hoist.

Lamprey are dip-netted from the trap and placed in a 208-L (55-gallon) container initially. Biologists have found that it is important to be ready with lots of buckets and fresh water, as you do not want to put the trap back down with lamprey in it. They have noted that all lamprey appear to leave and the effectiveness of lamprey trapping is low for 24 h or more. Moreover, biologists have observed that lamprey in shallow pools during dewatering will quickly start to

Figure A8. Pacific Lamprey trap location (block arrow) in the River Mill dam fishway on the Clackamas River, Oregon (from Ackerman et al. 2019).

Figure A9. Weir crest lamprey trap at the River Mill Dam fishway (PGE 2011).

panic when freshwater inflow is stopped (this has been observed during stranding events and may be useful for release methods).

Immediately after dip-netting adult lamprey from the trap, they are anaesthetized with eugenol (0.1 ml/L [~7-8 drops/gallon]) for 5 min to allow for measurements and genetic sampling. A shade cloth is used to protect people and lamprey from the sun at the sampling location. For transfer to the transport truck, biologists use 20-L (5-gallon) buckets that are perforated down to about the 11-L (3-gallon) level so that lamprey can stay in water during pick up and drop off at the release site. Screw on lids are also perforated and left on each bucket during transit (5-10 adults/bucket). The buckets are suspended in the transport tank for ease of transfer at the release location at the head of the North Fork reservoir.

The distance from the trapping location at River Mill dam fishway to head of North Fork reservoir is ~14.5-16 km (9-10 miles; Figure A10). North Fork Reservoir water is used to fill a 758-L (200-gallon) transport trailer tank. The temperature is not checked, but the transport tank is insulated, and no obvious temperature problems have occurred (water temperatures peak at 68°F in summer, 20 °C [68 °F]). Oxygen tanks equipped with air stones are used for oxygenation in the fish trailer.

Figure A10. Clackamas River study area with trapping location at River Mill dam and release location at the head of the North Fork reservoir (from PGE 2023).

North Fork Toutle River, Washington: Salvage and Transport of Lamprey Collected Opportunistically

Contributors: Monica Blanchard and John Serl, Washington Department of Fish and Wildlife (WDFW)

Background

After the eruption of Mount Saint Helens in 1980, the North Fork Toutle Fish Collection Facility (FCF) was built by the Army Corps of Engineers in the 1980's, along with the Sediment Retention Structure (an obstacle to fish passage). These structures were transferred to WDFW, who has operated them ever since. Funding for fish translocation over the years has been minimal and operations have relied on one employee (1/4 FTC) and volunteers. Personnel salvage any adult Pacific Lamprey, along with salmonids, that make it up the fishway at the FCF (Figure A11) and into the collection area.

Due to the ravages of time and accumulation of sediment, the facility is due to be rebuilt in the next few years. The plans for the new facility include provisions for adult lamprey passage, along with the traditional fish ladder. Perhaps this will allow better evaluation of the numbers of Pacific Lamprey that are attempting to pass this obstacle. In 2023, electrofishing downstream from Pullen Creek (upstream of the FCF) produced multiple size classes of Pacific Lamprey larvae in the sediment plain. This is a clear indication that Pacific Lamprey in Pullen Creek are successfully spawning.

Under some flow conditions, it is possible that Pacific Lamprey are able to volitionally pass over the spillway at the Sediment Retention Structure or over the barrier dam at the Collection Facility. From 2010-present numbers of lamprey were periodically recorded and typically were few (1-6), except in 2017 when 24 were transported (C. Gleizes, Washington Department of Fish and Wildlife, WDFW).

Methods

All fish are dipnetted out of the upper portion of the ladder as the system is dewatered. Long handled dipnets are used to capture fish as they become visible in the shallow water and an additional dipnet is placed in front of the exit to capture any fish trying to leave. Lamprey are transported along with salmonids and are released at the same sites.

All the lamprey recorded by WDFW in the period up to 2023 were moved to Bear or Pullen creeks, about a 30–60-minute drive from the FCF. Flatbed trucks are equipped with two 1,893-L (500-gallon) tanks (one fiberglass and one steel) and have oxygen diffusors designed for transporting fish. No problems have been encountered when transporting adult lamprey along with salmonids (adult salmon and trout).

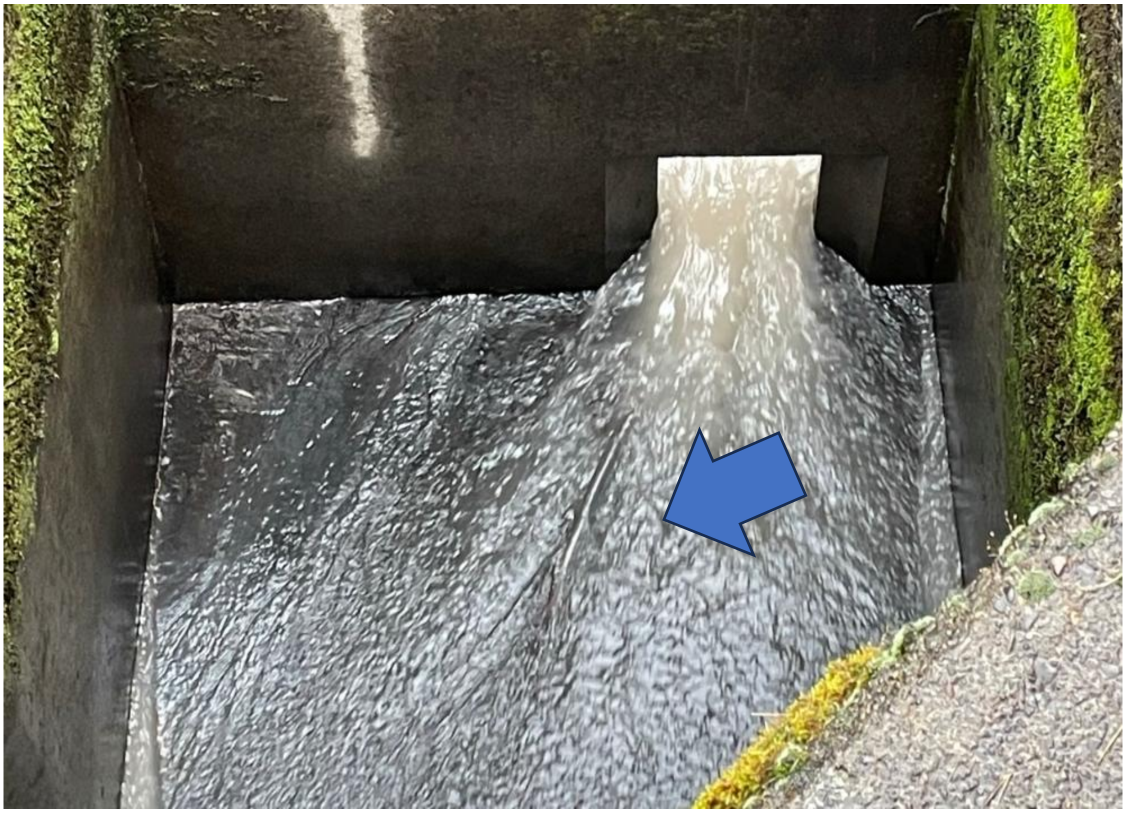

Figure A11. Pacific Lamprey (denoted by blue arrow) navigating the North Fork Toutle Fish Collection Facility fishway during dewatering on October 11th, 2023. This lamprey was netted in the ladder and transported upstream (Photo by M. Blanchard, WDFW).

Fall Creek Reintroduction of Pacific Lamprey into Historical Habitats

Contributor: Brandon Weems (Confederated Tribes of the Grand Ronde (CTGR))

Background

This project used translocation to evaluate the feasibility of reintroducing Pacific Lamprey upstream of a large flood control dam (Fall Creek Dam), with the goal of re-establishing a self-sustaining population above the dam.

The construction of Fall Creek Dam by the U.S. Army Corps of Engineers in the 1960s created a barrier to upstream migrating Pacific Lamprey in the Middle Fork Willamette Basin. Adult lamprey were not entering (or entering but escaping) the Fall Creek adult upstream fish collection facility, designed for the T&H of anadromous salmonids. The absence of Pacific Lamprey above the reservoir, confirmed by initial electrofishing surveys for larval lampreys, reduces attraction of migrating adult lamprey into the collection facility. To assess the feasibility of reintroducing Pacific Lamprey to habitats upstream of Fall Creek Dam, the Confederated Tribes of the Grand Ronde conducted a reintroduction study from ~2013- 2019 with 3 primary goals:

1. determine whether adult Pacific Lamprey can successfully spawn above Fall Creek Reservoir after being transported from Willamette Falls,
2. determine whether lamprey above the reservoir will lead to greater attraction of migrating adults at the base of the Fall Creek Dam,
3. determine whether a self-sustaining population of Pacific Lamprey can be re-established above a flood control structure.

The Fall Creek Reservoir is ideally suited to determine whether a self-sustaining population of Pacific Lamprey can be re-established above a flood control structure. The dam already has facilities and operations that could collect and transport adults over the dam. The Fall Creek reservoir currently has a significant seasonal drawdown for outmigrating salmonid juveniles, which could also facilitate the outmigration of juvenile lamprey.

Methods

Adult Pacific Lamprey were collected annually at Willamette Falls near Portland, Oregon, either from the base of the falls, or from the Oregon Department of Fish and Wildlife Fish Ladder at the falls and then transported ~ 201 km (125 mi) upstream via truck and released above Fall Creek Dam and Reservoir. Each year, CTGR targeted collection and transport of 240 fish, of which 40 were implanted with radio-tags for monitoring spawning migrations after release. This goal was not achieved every year due to various reasons, such as high river flows, forest fires, or dangerously high river temperatures.

Lamprey were collected at the base of Willamette Falls by hand using cotton gloves to remove fish from the rocks. Lamprey were transported downstream from the Falls by boat prior to being moved to a truck for transport to Fall Creek. For boat transport, lamprey were released into a 76-L (80-quart) cooler fitted with an Aircycle number 60-A agitator powered by a 12-V lead acid battery to maintain oxygen levels, with a maximum of 10 lamprey at one time. The cooler of lamprey was then emptied into an insulated tote on a pickup truck, which carried a maximum of 50 lamprey. The tote was filled with approximately 492 L (130 gallons) of Willamette River water and fitted with an Aircycle number 60-A agitator to maintain oxygen levels during transport to the release sites on Fall Creek (Figure A12). A YSI model 556 multi probe system was used to continuously monitor water pH, temperature, dissolved oxygen and specific conductivity throughout both boat and truck transport.

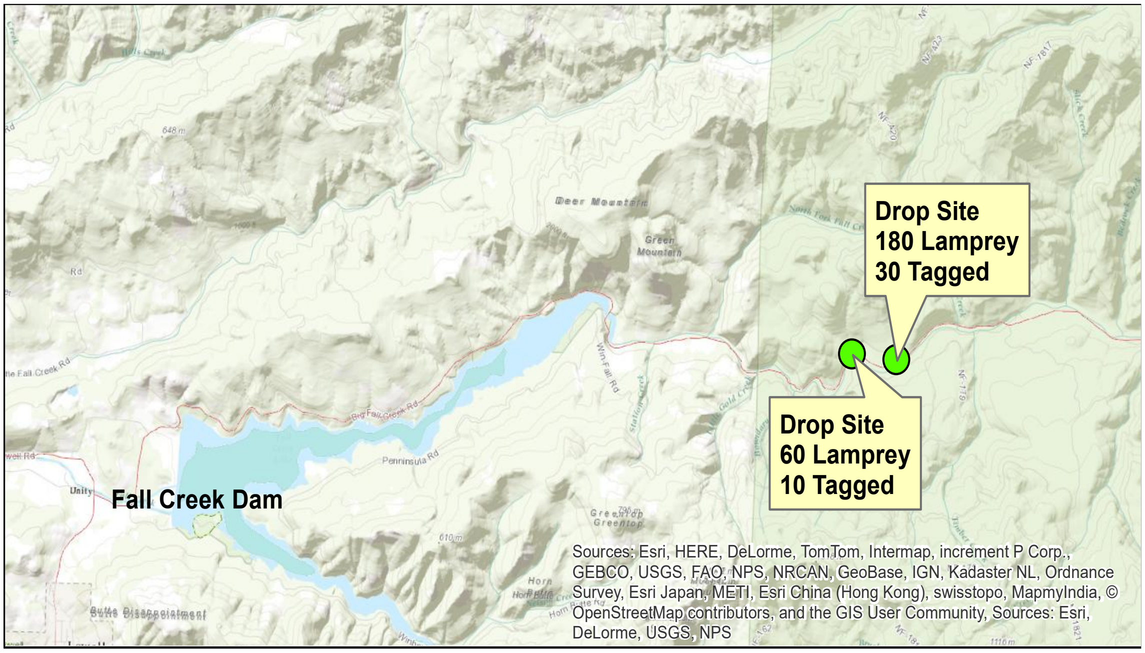

Figure A12. Release sites of translocated Pacific Lamprey above Fall Creek Reservoir, Oregon.

Monitoring included electrofishing to document presence/absence of larval lampreys, and annual redd surveys to document spawning in April – June after adults overwintered in the Fall Creek subbasin. Telemetry monitoring was conducted (transmitters lifetimes of 1.3 yr) to: 1) document dispersal distances migrated by individual lamprey, and 2) help identify areas for future spawning surveys.

Telemetry monitoring indicated that the tagged lamprey were dispersing throughout the Fall Creek subbasin above the dam. One individual was detected 16.1 km (10 mi) upstream from its release site, although most stayed within 3 - 4 km (2- 3 mi) of the release sites (Figure A13). Redd surveys confirmed that the fish survived over the winter to spawn. Electrofishing surveys found larvae in areas where previously only resident Western Brook lamprey had been found. In 2019, the U.S. Army Corps of Engineers operated a screw trap to monitor downstream fish migrations from the reservoir. Large numbers of juvenile Pacific Lamprey were caught in these operations, further documenting the success of lamprey production above Fall Creek Dam (Figure A14).

While this work demonstrates that reintroduction is possible, additional effort is needed to develop an effective T&H at the base of Fall Creek Dam to maintain this population above the dam. Since 2019, efforts to trap adult lamprey at the base of Fall Creek Dam have had limited results. Adult lamprey have returned to the fish collection facility and been transported, but in small numbers ranging from none to 12 fish annually as of 2025. However, there are more adults collected in the trap than years prior to the reintroduction, and efforts to improve T&H facilities for lamprey at Fall Creek Dam continue.

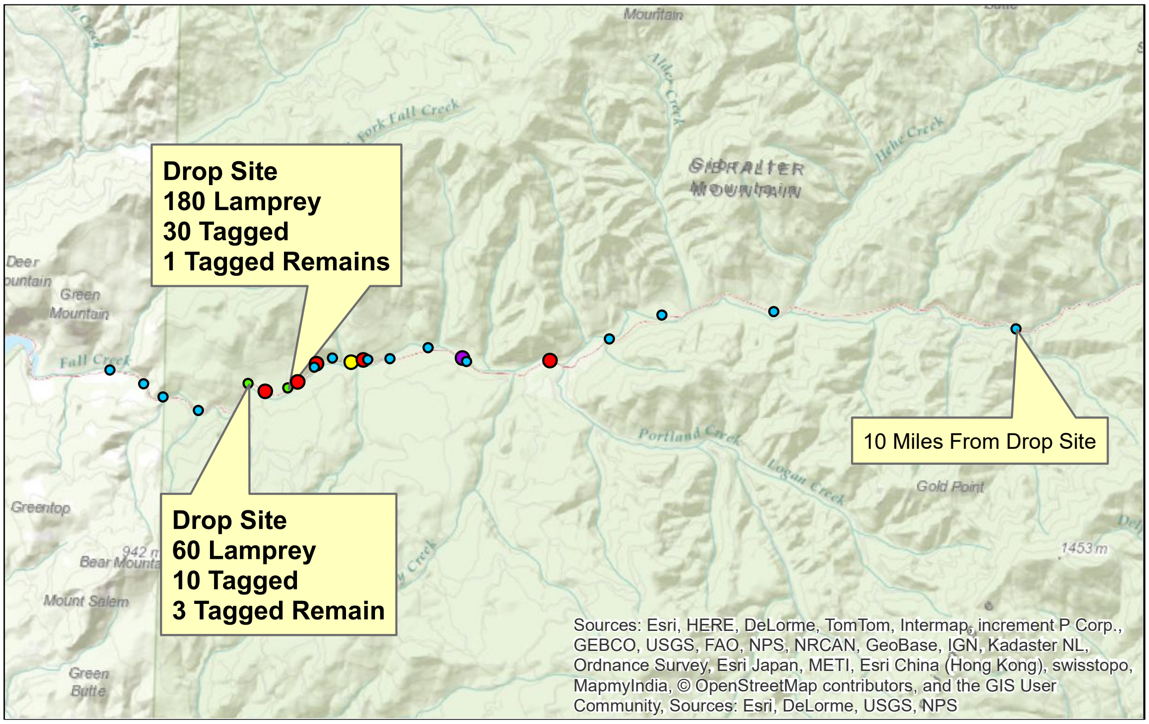

Figure A13. Dispersal of translocated adult Pacific Lamprey above Fall Creek Reservoir, as documented by mobile tracking surveys in 2014. Blue dots indicate a single individual, red is a group of 2, yellow is a group of 3, and purple is a group of 4.

Figure A14. Juvenile Pacific Lamprey were collected in large numbers by the Army Corps of Engineers outmigrant screw trap, as they migrated out of Fall Creek Reservoir in 2019, thus documenting the success of spawning adults and subsequent rearing of larvae above Fall Creek Dam.

Multi-species Trap & Haul at a Restoration Project in a California Tributary

Contributor: Tricia Bratcher (USFWS-Red Bluff Fish & Wildlife Office, Red Bluff, California)

Background

This case study includes the rescue of Pacific Lamprey (all life stages; total lengths ranged from 2-30 cm [~0.75-11 inches]) and other fish species during construction operations. A drawdown for a channel restoration project was needed to create a roughened channel for fish passage over a diversion dam. The salvage occurred during drawdown of the area to be dewatered. Pacific Lamprey were present in greater numbers than any other fish species and were trapped and hauled with other fish species.

The Deer Creek Irrigation District (DCID) Dam Fish Passage Project (Project) is located on Deer Creek, a large tributary to the Sacramento River in Tehama County, east of the town of Vina, California. California Department of Fish and Wildlife (CDFW) Proposition 1 and the U.S Fish and Wildlife Service (USFWS) Anadromous Fish Restoration Program provided funds for the Project, which was implemented by Trout Unlimited. The following paragraphs describe the fish rescue prior to and during de-watering (July 27 – September 6, 2019).

Construction activities during the Project required large sections of the creek to be dewatered, necessitating fish rescues from these areas (Figures A15 and A16). During the initial stages of construction, fish were captured and removed from habitat that was scheduled to be dewatered. Those areas were then filled and re-constructed to build a roughened channel. Efforts focused on removing threatened or endangered fish species including Spring-Run Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley Steelhead (*Oncorhynchus mykiss*), but all aquatic species, including California Species of Special Concern and sensitive reptiles (e.g., Western Pond Turtle (*Emys marmorata*), were captured and released into safe areas.

Figure A15. Aerial image of upstream and downstream extent of the DCID fish passage project fish species assessment survey.

Figure A16. DCID Dam on Deer Creek near Vina, California in 2019. Google map image provided by CDFW.

Fish Rescue

Pre-project snorkel surveys indicated multiple fish species were present in the area to be dewatered; however, no lampreys were seen during these surveys as lamprey are nocturnal and primarily buried in the sediments (fines, sands, and cobbles). However, Pacific Lamprey had previously been observed building redds immediately upstream of the dam.

Drawdown occurred the evening of August 27, 2019, and fish rescue efforts began the following day. Seine nets and dip nets were primarily used during the first 3 days following drawdown to remove fish from the area (August 28-30). Drawdown of the creek was necessary to force fish to congregate and reduce overall depths to ~ 60 cm (~2 feet), which increased the capture efficiency. However, the initial, rapid drawdown of water levels overnight stranded many larval lamprey in the exposed sediments, requiring extensive labor to rescue the stranded, stressed lamprey by hand. Thousands of larval lamprey were estimated to remain burrowed in the exposed sediments and subsequently died. Daytime temperatures at the time approached 38 °C (100 °F).

On September 3, 2019, electrofishers were used to capture and remove any remaining fish in the isolated watered area immediately below the dam. Electrofishing was only effective in smaller water bodies with less than ~60 cm (~2 feet) depth. The use of electrofishing with settings for lamprey was helpful, but they tended to respond very quickly to the shock and then go back into the sediment, making collection/rescue difficult. When lowering water levels, there is a need to

Figure A17. Fish rescue below DCID Dam on Deer Creek (looking upstream), August 28, 2019. Photo provided by CDFW.

balance the collection effectiveness of gear (e.g., nets, electrofishers) with corresponding decline in water quality (e.g., temperatures) as instream flow decreases.

Collected fish were placed into buckets with aerators, using onsite/stream water to maintain water quality, and carried by hand (Figure A17). All fish were identified to species, counted, and released into safe areas away from the restoration site: either upstream of the construction project in the main channel of Deer Creek, within the temporary bypass channel on river right, or downstream of the project area/dewatered channel. Release locations were selected based on proximity to collection site, accessibility, and habitat type (pool, slow riffle). Depending on where fish were rescued, the crew would use the shortest travel time to one of the three release locations.

Drawdown- Planned and Unplanned

On August 27, 2019, the planned drawdown of the pool and reach below the dam began in the late afternoon- water was diverted away from the pool above the dam by an inflatable dam into a temporary bypass channel to bypass flow around the restoration site. This resulted in a quick drawdown: ~10 inches in the first hour, despite the fact that the inflatable dam was about 3 feet short and allowed water around one edge. Upon seeing challenges with controlling instream flow in the dewatered area, onsite biologists requested that a temporary cobble dam (using instream materials) ~122 m (400 feet). downstream of the DCID Dam be installed to separate the Project area from the rest of the stream

On August 29, the requested temporary cobble dam was installed to separate the immediate Project area from the rest of the stream; this dam was located about 8 m (26 feet) upstream of the screen bypass channel that was still running and providing clean water and some streamflow. Dam leakage continued to thwart dewatering processes. A large submersible pump was installed on river right below DCID Dam to reduce water elevation. Initially it appeared to help to dewater the area but ultimately did not help much to minimize effects to lamprey, in particular, as all of the other special status species were not present anymore.

To isolate the area immediately below DCID Dam from the rest of the Project site, bed material was brought in to create another temporary “dam”, but pumps could not keep up with DCID Dam leakage on the south side of the creek. A new plan was developed for controlling water within the Project area, to be implemented on September 3, 2019. USFWS and CDFW staff recommended a plan to slowly fill the area with bed material as per the design; a small channel was maintained right below the dam apron to control dam leakage, with a pump operating on river right. CDFW staff conducted fish rescue on the small, watered channel that ran the length of the active Project area. Multiple passes using nets were used to catch fish or encourage them to move downstream. This area was then filled in with bed material except for a 9 m (30 feet) length at the bottom while the contractor adjusted bed elevation using fill material. The following day (September 5, 2019) CDFW staff and the contractor engineer/biologist conducted fish rescue of primarily lamprey from the remaining 9 m (30 feet) length; this was then filled by bed material. On September 6, 2019, a portion of the watered area between the temporary cobble dam and the filled bed had to be dewatered to adjust the area of bed to be filled; this was unexpected. During this process, the contractor engineer/biologist rescued mostly lamprey and moved them into the area below the temporary cobble dam with nets left onsite by CDFW. Throughout the entire rescue period, temperatures were recorded at 24-26.5 °C (75-79 °F).

Lessons learned

- Hope for the best, plan for the worst.
- Larval lamprey were not detected in pre-project snorkel surveys but were one of the most abundant species in the area and took extensive salvage efforts. At a minimum, lamprey should be assumed present if the stream is occupied elsewhere.
- Lamprey-specific surveys using electroshockers in optimal habitats of the target area may help estimate numbers of lamprey in the area and help with planning- both in terms of numbers of people for fish rescue and planning drawdown. Larval lamprey may be present in various sediments- fines, sand, and cobbles.
- In hindsight, use of electroshockers on recently dewatered but wet sediments (aka “dry electrofishing”) may have been helpful to encourage fish to emerge from the sediments.
- Multiple days are needed to effectively rescue fish from large sections of streams.
- Larval lamprey don’t always emerge from sediments immediately after dewatering; it may be 15 minutes or several hours (and sometimes days) before they emerge.
- While lamprey were found in fine sediments, they were also found in cobble-dominated substates and would be seen emerging from them during electrofishing.
- Have a variety of tools on hand for capturing small fish, in particular, lamprey. Larval lamprey were able to go through most meshes of nets, and staff would have to use small aquarium nets to capture them as they emerged from dewatered sediments.
- Plan on working closely with the contractor during dewatering of any water body, fish may be present where you don’t expect them.

- It is helpful to develop contractor education folders and conduct environmental education training for ALL members of the contractor's team. A (hard copy) folder, including pictures of fish and wildlife species, agency contact info, species-specific resource protection measures, permit requirements, and other relevant information should be left on-site in the contractor's trailer, with their design sheets and plans. It's helpful if one or two of the contractor's crew that show particular interest in the animals can be designated to handle any "emergencies" when animals unexpectedly show up—some permitting processes allow for use of contractor staff who may not happen to be qualified biologists, but this needs to be set up during the project permitting process.
- If a bypass channel is used to temporarily route water around a project site, plan for fish rescues once that channel is no longer used and is dewatered. CDFW and USFWS staff continued to capture more Pacific Lamprey larvae as the bypass channel was dewatered.

Pacific Lamprey Translocations for Passage Studies in the Mid-Columbia

Contributors: Mariah Mayfield, Douglas County Public Utility District (PUD); Mike Clement, Grant County PUD; and Scott Hopkins, Chelan County PUD. All photos provided by M. Mayfield.

Background

This project uses T&H and translocation to provide passage for Pacific Lamprey above several large hydroelectric dams that currently do not provide effective passage. T&H is also used to collect fish for several fish passage evaluations designed to identify specific passage problems.

The mid-Columbia River has five mainstem Columbia River Dams that are managed by public utility districts (PUD): Priest Rapids and Wanapum Dams (managed by Grant County PUD), Rock Island and Rocky Reach Dams (managed by Chelan County PUD), and Wells Dam (managed by Douglas County PUD). As part of the FERC (Federal Energy Regulatory Commission) relicensing process, all three PUDs have mitigation requirements to manage, study, or T&H Pacific Lamprey within the mid-Columbia River basin.

Grant County PUD is required to T&H lamprey from below Priest Rapids dam to above Rock Island dam for four weeks every summer. To support this objective, Grant PUD installed in-ladder weir traps on both fish ladders at Priest Rapids Dam (Figures A18 and A19). In 2018, Douglas PUD and the Wells Dam Aquatic Settlement Work Group decided to expand the program to haul adults above Wells Dam. Douglas PUD has added four additional weeks of trapping to the schedule at Priest Rapids so lamprey are trapped for a total of eight weeks, usually beginning in mid-July.

Trapping at the mid-Columbia dams also occurs to support fish collection for passage studies. In addition to the fish ladder traps at Priest Rapids, Douglas PUD has in-ladder traps that can be launched to collect lamprey at Wells Dam. Most recently, lamprey were collected at Priest Rapids to provide study fish for an adult Pacific Lamprey fishway passage evaluation as part of Chelan PUD's ongoing Rock Island Dam relicensing process. Douglas PUD will be running the Wells Dam traps in 2026 to obtain fish for an upcoming passage study.

Collaboration on T&H between the mid-Columbia PUDs has provided opportunities to support lamprey restoration throughout the region. Resources and knowledge are shared freely among the PUDs and tribal partners, which has led to more opportunities for research related to Pacific Lamprey.

Trapping Methods

The primary adult Pacific Lamprey traps used by the mid-Columbia PUDs are located at Priest Rapids Dam, in both fish ladders (Figure A20). The traps are located on overflow weirs with each trap placed on each side of the weir against the side of the fish ladder walls, approximately 1/3 of the way up each fish ladder. Traps are lowered mechanically at end-of-shift in the evening, fished, and then retrieved at approximately 07:00 the following morning. To encourage lamprey to enter the trap, the bottom orifices of the weir are screened or closed off during trapping operations. Lamprey are removed from the trap using cotton gloves and are immediately placed into coolers and taken to the holding area for up to three days.

Figure A18. Adult Pacific Lamprey trap at Priest Rapids Dam. When trap is not in use, it is held at the top of the side rails, as pictured here.

Figure A19. Lamprey trap at Priest Rapids in place at the top of the concrete weir.

Figure A20. At Priest Rapids Dam, the lower orifices of the weir can be closed while lamprey trap is in place to help encourage lamprey into the trap.

The lamprey traps at Wells Dam are similar to those at Priest Rapids Dam and are located at weir 41 (out of 70). The main difference in trapping operations at Wells Dam is that there is no ability to close off the bottom opening of the weir, due to salmonid passage concerns. Instead, a perforated metal plate is installed along the bottom of the ladder extending from below the bottom orifice and goes through the weir opening. This is to discourage lamprey from being able to easily attach to the bottom of the ladder and make their way through the bottom orifice. In 2024, test trapping occurred with the perforated plating installed and results were good with about 30% of the lamprey entering the trap.

After removal from the trap, lamprey are held in 114-L (30-gallon) coolers with continuous river water flow (15 to 25 fish per cooler). Lamprey are held for no more than three days in the coolers prior to transport. When it is time for transport, lamprey are transferred to black plastic totes using cotton gloves (Figure A21). The totes are 76-L (20-gallon) plastic boxes with locking lids and holes drilled along the sides for water flow. No more than 30 lamprey are placed in a single tote. Zip ties are place on each handle to prevent lamprey from escaping the totes during transport.

Transport Methods

Transport tanks are filled with river water at Priest Rapids Dam immediately prior to loading fish into transport tanks (Figure A22). Oxygen is administered to the tanks via air stones at approximately 1 L/min. Water temperature and oxygen are monitored as needed during transport. For transport from Priest Rapids Dam to Wells Dam (a travel time of about 2.5 hours), a large fiberglass tank (~1700 L [450 gallons]) is used. Fiberglass transport tanks stay much cooler than metal holding tanks and do not need ice blocks for transport; stainless-steel tanks tend to heat up more rapidly during transport and may require more temperature monitoring and ice blocks. When the fish arrive at Wells Dam (or other sampling facilities) fresh water is immediately put into the transport tank. After tagging and biological sampling is completed, lamprey are returned to the transport tank and taken to the final release site. Fish transport totes are then removed from the transport truck and immediately placed in the river for fish release, with an effort made to release fish as deep as safety allows.

Figure A21. Typical transport tote (76-L [20-gallon] capacity).

Figure A22. Fiberglass transport tank (~1700 L [450 gallons]) is mounted on a flatbed truck or trailer.

Connecticut Translocations of Sea Lamprey to Re-establish Populations

Contributor: Stephen Gephard, Connecticut Department Energy and Environmental Protection (retired)

Background

Spawning of Sea Lamprey in tributaries of the Connecticut River is blocked by dams built between 1720 to 1920 (Gephard 2023). Some Sea Lamprey passage has been documented at fishways designed to pass Atlantic Salmon (*Salmo salar*) and American Shad (*Alosa sapidissima*); however, lamprey are often incapable of traversing the entire fishway in one night and frequently fall back downstream.

The Connecticut Department of Energy and Environmental Protection (CT DEEP) recognized the need to restore Sea Lamprey populations and engaged in a public education program to help bolster support for their conservation (Gephard 2023). Sea Lamprey (Figure A23) are now listed as a "Species of Greatest Conservation Need" in most New England State Wildlife Plans.

Gephard (2023) described an experiment to evaluate whether transplanting Sea Lamprey above semi-permeable barriers would help to re-establish spawning runs in two coastal rivers, Naugatuck and Shetucket rivers (Figure A24), where Sea Lamprey had been extirpated for over 100 years. These rivers each have a dam near the head of tide with fishways (Kinneytown Dam Fishway and Greeneville Fish Lift) that were built in the 1990s. However, no lamprey were observed using the fishways or found upstream from the dams. In 2004 and 2005, the CT DEEP transported 110 adult Sea Lamprey from Rainbow Dam on the Farmington River (Figure A24) to areas upstream from Kinneytown Dam (Gephard 2023). The response of Sea Lamprey at the fishway was immediate, with counts at the Kinneytown Dam fishway increasing from one in 2004 to 354 in 2007 (Gephard 2019). Based on this success, 221 adults were released upstream from the Greenville Fishway in 2019. By 2022, 17 adults were reported from the fish lift, after no observations of lamprey there for the period from 1996 to 2019. These results suggest that an upstream pheromone signal is essential to stimulate adult Sea Lamprey entry into river without an extant Sea Lamprey population. Nest surveys confirmed that lamprey spawned after release and even distributed beyond the release sites.

Figure A23. Adult Sea Lamprey collected from a fishway in coastal Connecticut (Photo by S. Gephard, CT DEEP)

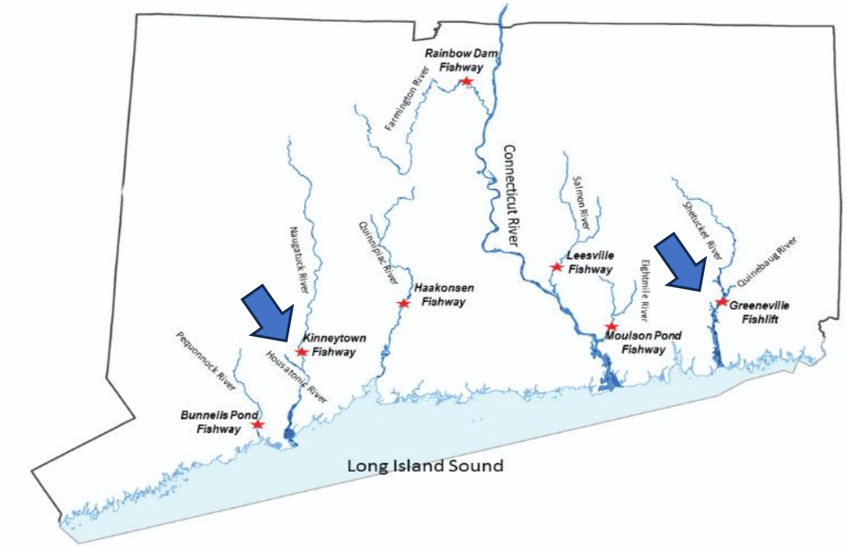

Figure A24. Coastal rivers selected for Sea Lamprey translocation experiment (from Gephard 2023).

Methods

Spawning-phase adult Sea Lamprey for the translocation experiment were captured at the Rainbow Dam Fishway (Figure A25) on the Farmington River, where the annual run typically exceeds 1,000 fish. In May, lamprey ascend the fishway at night and those that have not reached the top of the fishway by dawn use their oral disc to attach to the concrete walls and rest, where they are easy to scoop up with a dipnet (Figure A25). The bag of a dip net was positioned below the dangling fish, and the steel hoop of the net was used to dislodge the fish that then fall into the net. Water temperatures in the fishway were 12-22 °C (~54-72 °F).

The fishway has an adjacent holding tank (fed with fishway water). Captured Sea Lamprey were stockpiled there for up to a week to accumulate suitable numbers for transport. No mortalities during holding were observed. After collection of sufficient numbers, the lamprey were dip-netted from the holding tank into a fish box on the back of a flatbed truck equipped with an oxygen delivery system (Figure A26). Typically, no more than 50 were transported for 1.0 -1.5 h in the truck tank with no mortality. The Sea Lamprey were released by handing loaded dipnets down from the truck tank to a second worker who released them at streamside locations with suitable spawning habitat (Figure A26).

Figure A25. Adult Sea Lamprey at Rainbow Fall fishway are captured with a dipnet (Photo by S. Gephard, CT DEEP).

Figure A26. Sea Lamprey are transported using a fish tank equipped with oxygen and released via dipnets at the upstream release sites (Photo by S. Gephard, CT DEEP).

Sea Lamprey Control in the Great Lakes: Sterile Male Release Program

Contributor: Matt Symbal (USFWS)

Background

Sea Lamprey are native to the Atlantic coasts of North America and Europe; however, they are an invasive species in the Laurentian Great Lakes. In 1955, the Great Lakes Fishery Commission was formed to research and implement methods to control this subspecies (Siefkes 2017). In addition to use of physical barriers and pesticides, the release of sterilized males was researched starting in 1971. This program required collection of large numbers of healthy pre-spawning males, chemical sterilization of them, and subsequent release in targeted streams to see if they would reduce the reproductive potential of targeted populations.

Male Sea Lamprey were captured during their spawning migrations in approximately 30 tributaries to lakes Superior, Michigan, Huron, and Ontario. Timing of T&H was typically mid- to late-May when water temperatures in Lake Huron were around 10 °C (50 °F; M. Symbal, USFWS, Pers. Comm.). The adult lamprey were transported to the U. S. Geological Survey Hammond Bay Biological Station for sterilization and then transported for release into the St. Marys River. Transport times could exceed 4 h in some cases.

Bergstedt et al. (2003) found that the proportion of sterilized males observed spawning and occupying nests was not significantly different than their estimated proportion in the population. Further research indicated that in areas where sterile males were released, the number of eggs hatching in nests was reduced (Bergstedt and Twohey 2007). This supports the concept that adult males that were trapped, hauled two times, held and subjected to the sterilization, and then released in a completely new system were able to compete for mates and successfully spawn. As hoped, the resulting fertilized eggs were not viable due to the sterilization technique and resulted in lower reproductive output for streams where the treated males were released. However, the labor-intensive nature of the program and availability of other methods resulted in the 2011 termination of this program, although regular hauling of Sea Lamprey still occurs to support other research activities (M. Symbal, USFWS, Pers. Comm.).

Methods

All operations are described in the Standard Operating Procedures for Application of the Sterile-Male-Release-Technique in the Great Lakes Fishery Commission Integrated Management of Sea Lampreys Control Program (including detailed maps for holding and release locations; M. Symbal, USFWS, Pers. Comm.). Adult lamprey at the latter stages of their pre-spawning migration were trapped at barriers. Traps were typically integrated into the barrier design (Figure A27-A) or deployed along the bottom of the barrier (Figure A27-B).

Lamprey were held streamside in re-circulating stream water until they were picked up and hauled to the Hammond Bay station for sterilization. Hauling was conducted using Bonar tanks on a trailer or with tanker trucks. A maximum density of 2,500 adult lamprey / 3,785 L (1,000 gallons) was used. Transfer from the trap to the hauling tank depended on the number of lamprey to be transferred. Laundry baskets and dipnets with square bottoms have both been used to reduce weight and stress on lamprey. Survival was best if water was cooled to 5-6 °C (41-43 °F) and highly aerated; dissolved oxygen levels were checked regularly during transit. Maturation state was important because hauling mortality increases as the males near final sexual maturation.

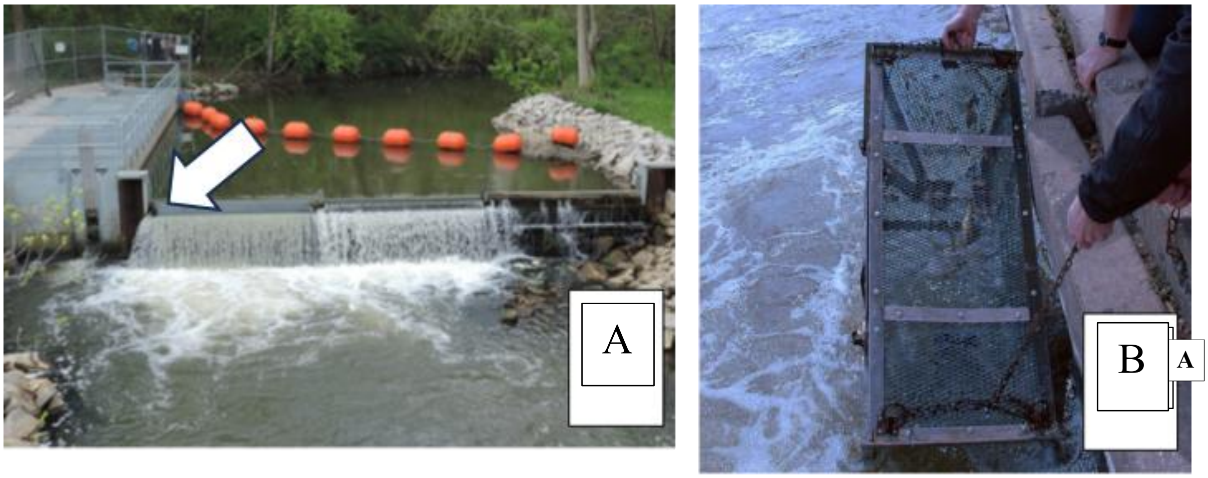

Figure A27. Sea Lamprey trap integrated into a barrier that is designed to block Sea Lamprey spawning migration (denoted by arrow, left photo "A") and a trap deployed along the bottom face of some barriers (right photo "B", from Siefkes 2017).

After sterilization, male adults are held in recovery tanks at the Hammon Bay Station and subsequently hauled to the St Mary's River for release. Release was conducted using hooped net bags, buckets, coolers, or directly from the tank, depending on crew size and the number of lamprey to be released. Tank sides were lined with perforated PVC pegboard to prevent lamprey attachment, and the tank bottoms were concave to allow lamprey to slither back to the tank exit for ease of transfer without the stress of pulling them off when they attach. Disease screening was conducted following established protocols (Siefkes 2017).

Pouched Lamprey Run in the River Derwent, Tasmania (Australia)

Contributor: Jonah Yick (Inland Fisheries Service- Australia)

Background

Since the 1980s, the Inland Fisheries Service (IFS) have operated and managed a juvenile short-finned eel *Anguilla australis* (elver) and adult lamprey trap, situated at the base of Meadowbank Dam on the River Derwent. Historically, October and early November is the best period to capture lamprey in large quantities. The lamprey run in the River Derwent is usually dominated by Pouched Lamprey (*Geotria australis),* with no other sign of other lamprey species (Figure A28).

Figure A28. Adult Pouched Lamprey (*Geotria australis*) oral disc (left) and inside the trap (right) (Photo credits: Inland Fisheries Service).

Migrating lamprey are collected and transported from two Hydro Tasmania (HT) catchments, Meadowbank Dam on the River Derwent and the Trevallyn Tailrace on the Tamar River, into various freshwater courses around the state. This operation is a joint effort through an agreement made between IFS and HT in the late 1990s. HT dams have blocked migratory access to a significant proportion of Tasmania's catchments; therefore, the restocking program allows both eels and lamprey to continue their life cycle further upstream and to re-populate areas of particular ecological value. Since 2007, numbers of adults returning to the trap have increased (Figure A29).

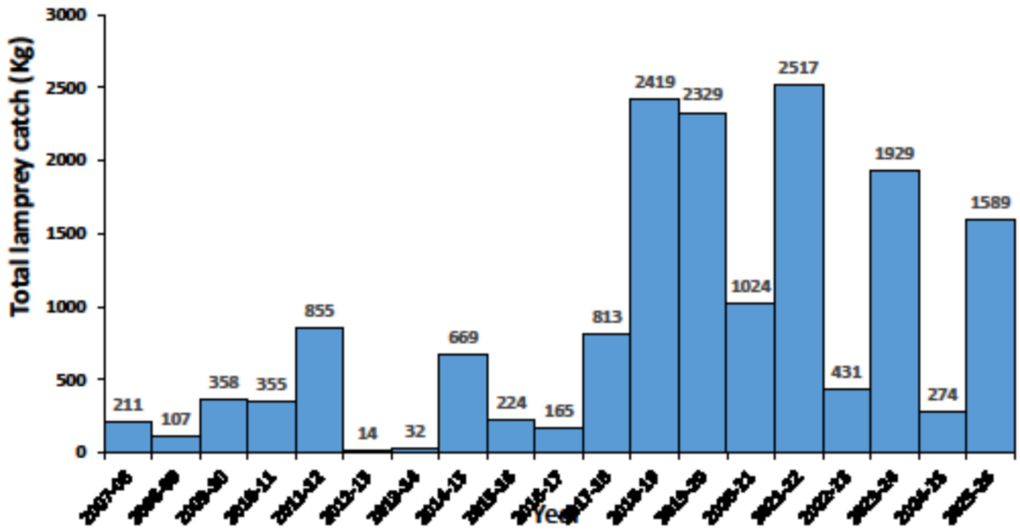

Figure A29. Total adult lamprey captures from the River Derwent (2007-2026).

Methods

At the base of the Meadowbank Dam is a static shore-based trap installed to capture any upstream-migrating elver and lamprey (Figure A30). Two slides, angled to provide adequate water flow and sufficient rest areas, terminate beneath the river surface below the dam wall. These slides lead migratory fish species upstream to a large holding tank where they are entrapped. All lamprey caught in the Meadowbank Dam trap are manually transported over the dam wall and released into the Meadowbank Dam (Figure A31).

Total annual lamprey caught are not representative of overall wild populations (Figure A29), as the numbers are closely linked with when the trap is installed and opened, which can vary from year to year. Although the ideal time to open the trap to coincide with the lamprey migration is in mid-October, this is often delayed due to localized flood events/high river levels which prevents the trap from being installed and opened.

Figure A30. IFS staff servicing the elver and lamprey trap (circled in red), at the base of the Meadowbank Dam (top), Meadowbank Lake elver trap components (bottom two photos) (Photo Credits: Inland Fisheries Service).

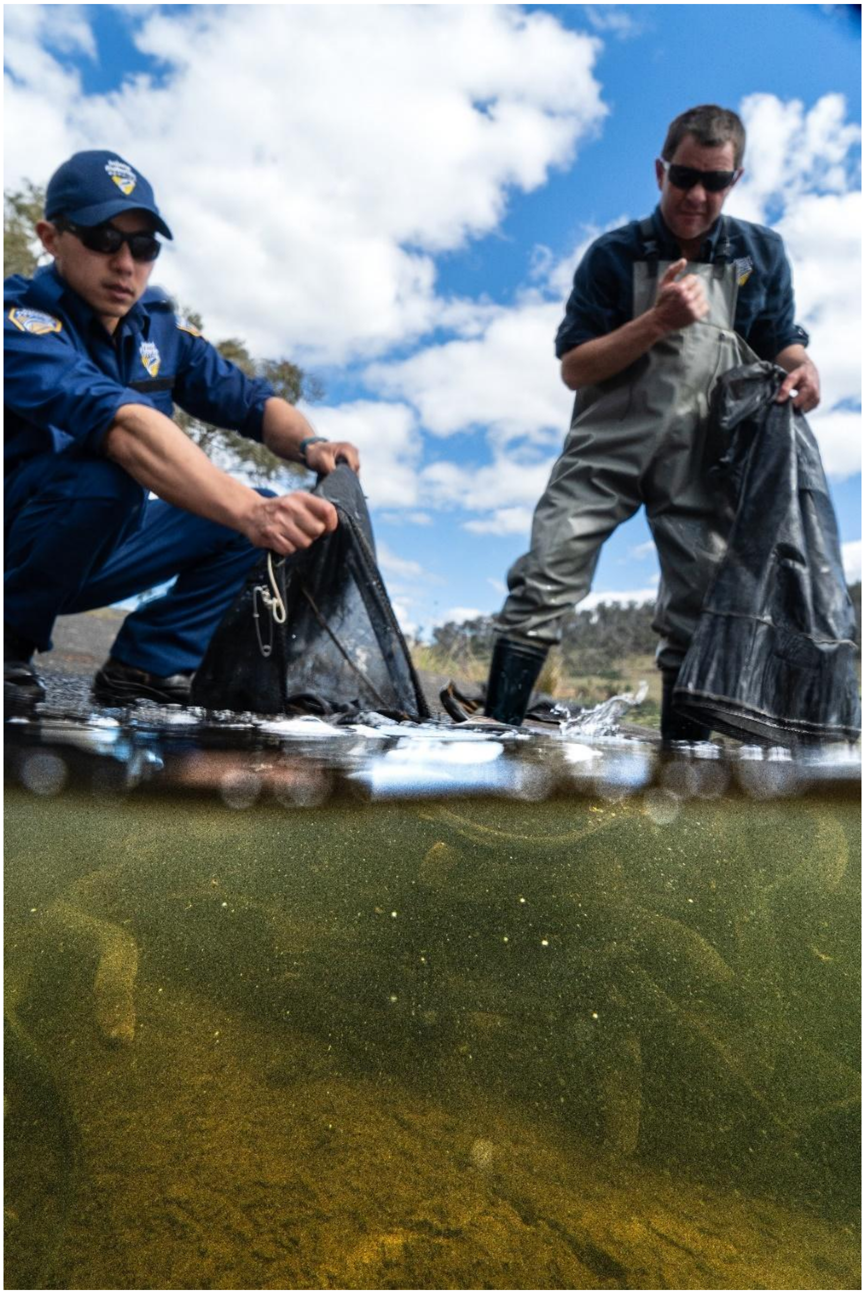

Figure A31. Releasing adult Pouched Lamprey into Lake Meadowbank, after translocating them from the fish trap (Photo by Fraser Johnston- Inland Fisheries Service).

Sea Lamprey Translocation in Portugal during the Spawning Migration: mitigating population decline by enhancing recruitment in key river basins.

Contributors: Pedro R. Almeida[1,2], Catarina S. Mateus [1,2], Sílvia Pedro[1], Carlos M. Alexandre[1], Joana Boavida-Portugal[1] and Inês Oliveira [1]

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Background

The Mondego River basin is one of the most prominent strongholds, at national (and even international) level, for Sea Lamprey. Located near the southernmost limit of the species' global distribution, this basin supports an important fishery for Sea Lamprey, a highly valued gourmet delicacy, representing a significant ecological, cultural and economic resource. The fishery underpins a seasonal commercial network engaging multiple stakeholders — including professional fishers, distributors, restaurants and gastronomic festivals — which, in turn, stimulate regional tourism and associated economic sectors.

Following the implementation of a successful restoration programme that re-established longitudinal connectivity along approximately 60 km of the Mondego River between 2011 and 2015, a substantial increase in the Sea Lamprey population was recorded. Monitoring surveys conducted in the area revealed an approximately 100-fold rise in larval abundance between 2011 and 2017. However, a marked decline has recently been observed in both larval abundance and the number of adults migrating upstream to spawn. The underlying drivers of this are not understood, but it is likely that river fragmentation, migration barriers, overexploitation, illegal fishing, and climate change are acting synergistically. Moreover, processes operating in the marine phase may also be contributing significantly to the species' downturn. While habitat restoration and fisheries regulation have been implemented for many years, population declines have reached a point where these efforts alone may be insufficient.

To address this situation, the most viable strategy to enhance the attractiveness of spawning rivers to migrating adults appears to be increasing the abundance of larvae. One of the most effective approaches to achieve this goal may involve the transfer of migrating adults upstream of existing barriers, thereby ensuring that these fish can reach suitable spawning grounds and maximize their reproductive success.

The pilot T&H initiative currently underway in the Mondego River aims to promote and accelerate the recovery of this species by granting spawning populations access to available upstream habitats. Initially, the programme is planned to run for 2 years - covering two spawning migration seasons -with the first transfer trial conducted in the spring of 2025. If successful, this approach could be replicated in other Portuguese river basins facing similar challenges and ultimately serve as the foundation for an official national lamprey transfer program.

The first trial involved the capture of adult Sea Lampreys over a 35-day period in the Mondego River (Figure A32), within the framework of the LIFE4Lamprey project, an Associated Replication Pilot (ARP) of the Demo site DPS-1 SZIGETKÖZDALIA from the DALIA project (Open Call Rivers Revived from Danube Region Water Lighthouse Action). This activity was carried out in partnership with the Coimbra Intermunicipality Community, local commercial fishermen, distributors and local administration and authorities.

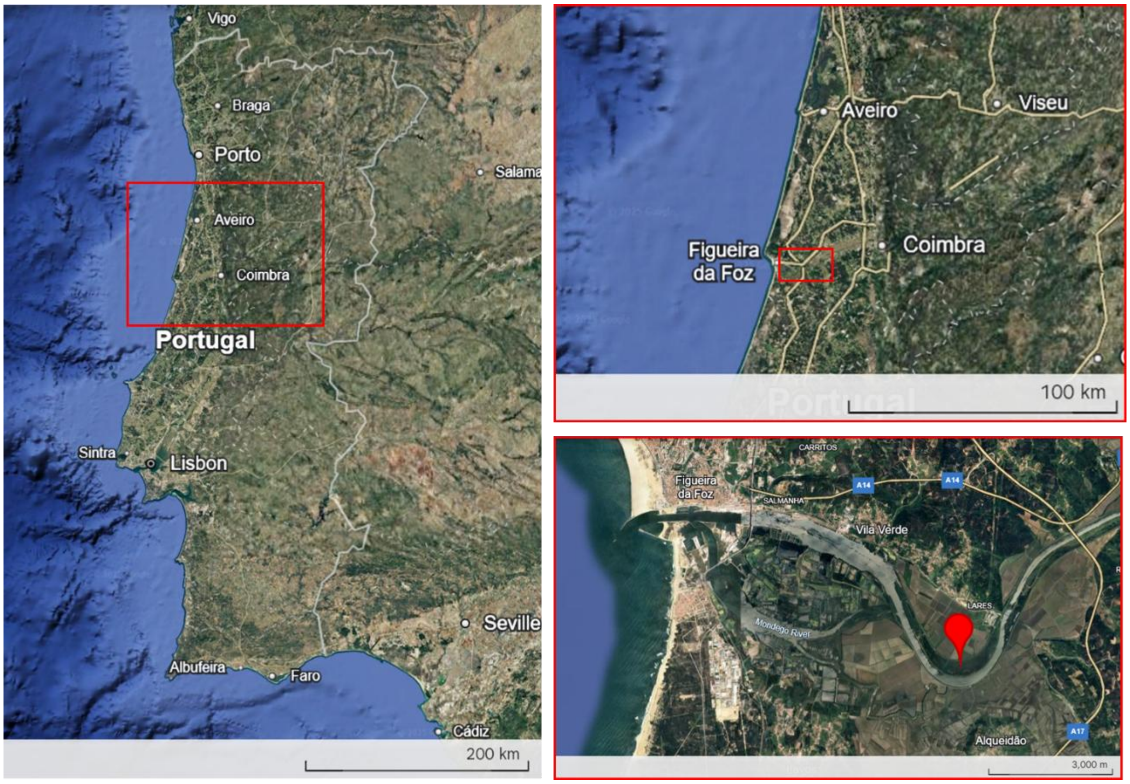

Figure A32. Area of capture (red tear-like icon) of Sea Lamprey spawners entering the Mondego, from mid-March to mid-April 2025.

The first transfer took place on 4 April, when 29 individuals were released in the Penacova area, approximately 55 km upstream from the capture site. Between that date and 20 April, only 6 additional lamprey were captured. The translocation of these adults to upstream areas of the Açude-Ponte dam, located about 40 km upstream from the capture site, was completed on 30 April.

An independent experimental transfer of Sea Lamprey was also carried out in the Douro river basin during the 2025 spawning season. This operation took place downstream of the Crestuma-Lever Dam (Figure A33), during the night of 18 of April, in close collaboration with local commercial fishermen, local authorities and EDP - the main hydroelectrical company in Portugal. The coordination with EDP allowed the capture operations to be synchronised with the dam operation to maximize catch efficiency. Specifically, turbine activity was suspended for two hours (10 pm to midnight) to enable fishers to deploy gillnets safely immediately downstream of the dam, where Sea Lamprey accumulated. The work was conducted by two commercial fishers under the supervision of the Portuguese Maritime Authority. Captured adults were subsequently transferred to tributaries presumed to offer more suitable conditions for Sea Lamprey migration and spawning, namely the Sousa and Paiva rivers.

Figure A33. Capture (yellow polygon) and release (blue pins) sites in the pilot Sea Lamprey translocation action developed in the Douro basin.

A total of 35 adult Sea Lamprey were captured in the Mondego River, despite the concerted efforts of commercial fishermen working in collaboration with the MARE-University of Évora team. Lamprey entering all national basins were remarkably scarce during the 2025 spawning season. The pilot action had initially foreseen the capture and translocation of up to 400 animals per year, with the objective of releasing them into available upstream spawning habitats. In the Douro basin, a total of 23 adult Sea Lamprey were captured. Of these, 15 were released into the Sousa River, 6 into the Paiva River, and the remaining two were considered unfit for release and ended up dying soon after.

The translocation activities were conducted in the Mondego River between mid-March and mid-April 2025, coinciding with the peak of the Sea Lamprey spawning migration. Water temperatures during this period ranged from approximately 12 to 15 °C (~54 to 59 °F), consistent with the thermal window typically associated with upstream migration and spawning activity. Flow conditions were stable, following a series of moderate rainfall events that maintained suitable hydrological connectivity. The independent trial in the Douro basin took place on 18 April 2025, under comparable environmental conditions, with similar temperature and flow regimes and no recorded anomalies in water quality.

Methods

In the Mondego River, professional fishers captured migrating adult lamprey entering the river using previously installed fyke nets (Figure A34). A total of 4 nets were used: 2 in the maritime jurisdiction, and 2 in inland waters. The fyke nets (Figure A35), used in the Mondego River are removable traps composed of a series of cone-shaped chambers mounted on circular rings and extended by guiding wings. They are primarily designed for the capture of Sea Lamprey and shad. By regulation, the nets cannot have either end fixed to dry land, be operated from riverbanks, or obstruct more than half the river´s width.

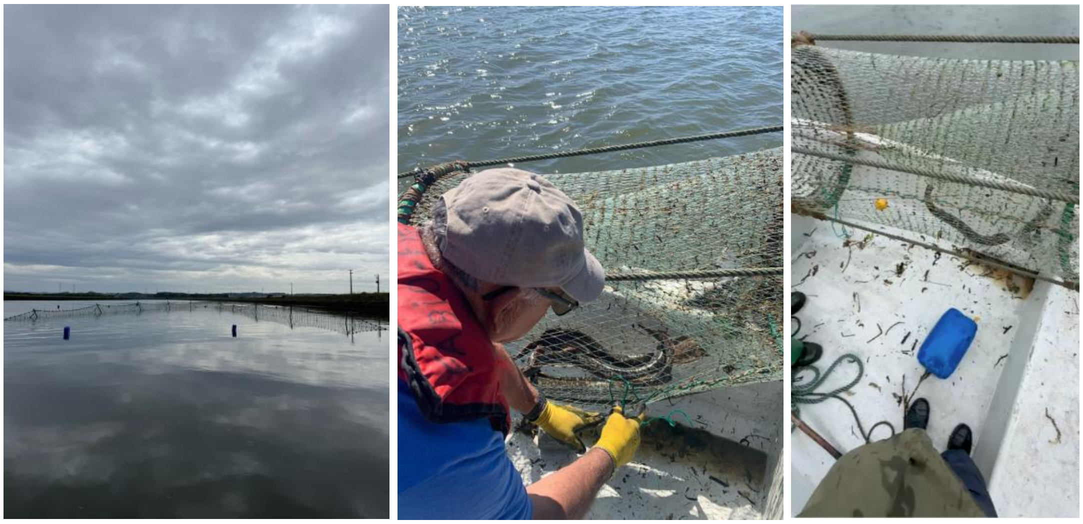

Figure A34. Sea lamprey capture in the Mondego River, with the help of local fishermen. © Univ. Évora/MARE/ARNET

Figure A35. Fyke net © Esmeralda Pereira (Univ. Évora/MARE/ARNET)

In the Douro River, drift trammel nets or gillnets (Figure A36) were employed. These are entangling nets composed of two outer panels of larger mesh and an inner fine-meshed netting. The gear is set to drift with the current, with one end attached to the vessel and is typically set multiple times. This method is commonly used to target Sea Lamprey and other anadromous species, such as Allis Shad (*Alosa alosa*) and Twaite Shad (*Alosa fallax*).

Figure A36. Sea Lamprey capture using gillnets © Sílvia Pedro (Univ. Évora/MARE/ARNET)

For the Mondego operation, given the duration and logistical demands of the fishing effort, all captured Sea Lamprey were temporarily held in aerated tanks located at the facilities of one of the project's collaborators - a licensed lamprey intermediary - until their subsequent release. The holding tanks were maintained in a temperature-controlled environment, ensuring adequate oxygenation and minimising stress during captivity. In contrast, no holding was required in the Douro operation, as the captured individuals were transported and released in the night of capture in nearby tributaries.

The captured Sea Lamprey were transported to the release sites in adapted vehicles equipped with aerated and temperature-controlled tanks to ensure optimal conditions during transit. In the Mondego operation, transport was carried out in collaboration with the licensed fishing intermediary, using the company’s vehicles. In the Douro operation, transport was performed with the project team’s own equipment.

Prior to release, all Sea Lamprey were tagged with Passive Integrated Transponder (PIT) tags to enable individual identification in case of recapture by fishers or potential poachers. In both Mondego and Douro operations, the release procedures were carried out in the presence of local law enforcement and relevant authorities. To safeguard the success of the translocation efforts, these entities reinforced patrolling and surveillance actions in the vicinity of the release sites during the subsequent days to deter illegal fishing.