Restoring Pacific Lamprey in the Umpqua River Basin of Oregon: A workshop summary

Prepared by USGS for the Cow Creek Band of Umpqua Tribe of Indians

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Introduction

The Umpqua River Basin in southwestern Oregon (Figure 1) is part of the lands inhabited by the Cow Creek Band of Umpqua Tribe of Indians and an area of active co-management authority. This Basin supports a unique fish fauna, including important populations of Pacific salmon (*Oncorhynchus* spp.) and steelhead (*O. mykiss*), and other native fishes that are endemic to the region (Mims et al. 2018). Among these species, the Pacific Lamprey (*Entosphenus tridentatus*) is one of the most unique, representing an ancient lineage of jawless fishes that long predates the evolution of any other species of fish in the basin (Clemens et al. 2017, 2021a). The Pacific Lamprey also represents an important cultural and food resource that features prominently in the indigenous practices of the Cow Creek Band of Umpqua Tribe of Indians.

This report provides a select summary of topics related to the conservation of Pacific Lamprey in the Umpqua River Basin. Many of the topics addressed herein were discussed in a workshop co-hosted by the Cow Creek Band of Umpqua Tribe of Indians and the U.S. Geological Survey in April of 2022. This workshop was focused on threats to Pacific Lamprey in fresh waters of the basin. The workshop highlighted science conducted over the past 15 years by local managers and researchers to understand and address these threats and provide new information relevant to the conservation and restoration of Pacific Lamprey. Attendees included staff from the Coquille Indian Tribe, Yakama Nation, Columbia River Inter-Tribal Fish Commission, Partnership for Umpqua Rivers, Rogue River Watershed Council, Curry Watersheds Council, PacifiCorp, Trout Unlimited, Jackson Soil and Water Conservation District, Oregon Department of Fish and Wildlife, Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. Forest Service. This report provides an overview of this workshop and recent science and provides an overview of potential future efforts that could inform restoration of Pacific Lamprey.

This summary is organized into four sections that relate to the main topics of the workshop: 1) The physical habitat template (stream flow, instream wood, sediment, and water temperature), 2) movement barriers and reservoirs, 3) biological invasions, and 4) climate adaptation. These do not represent an exhaustive list of topics related to conservation of Pacific Lamprey in the Umpqua Basin. Before we address these topics, we provide a brief overview of the life cycle and population status of Pacific Lamprey to orient readers who may be less familiar with Pacific Lamprey (see cited literature for additional details)

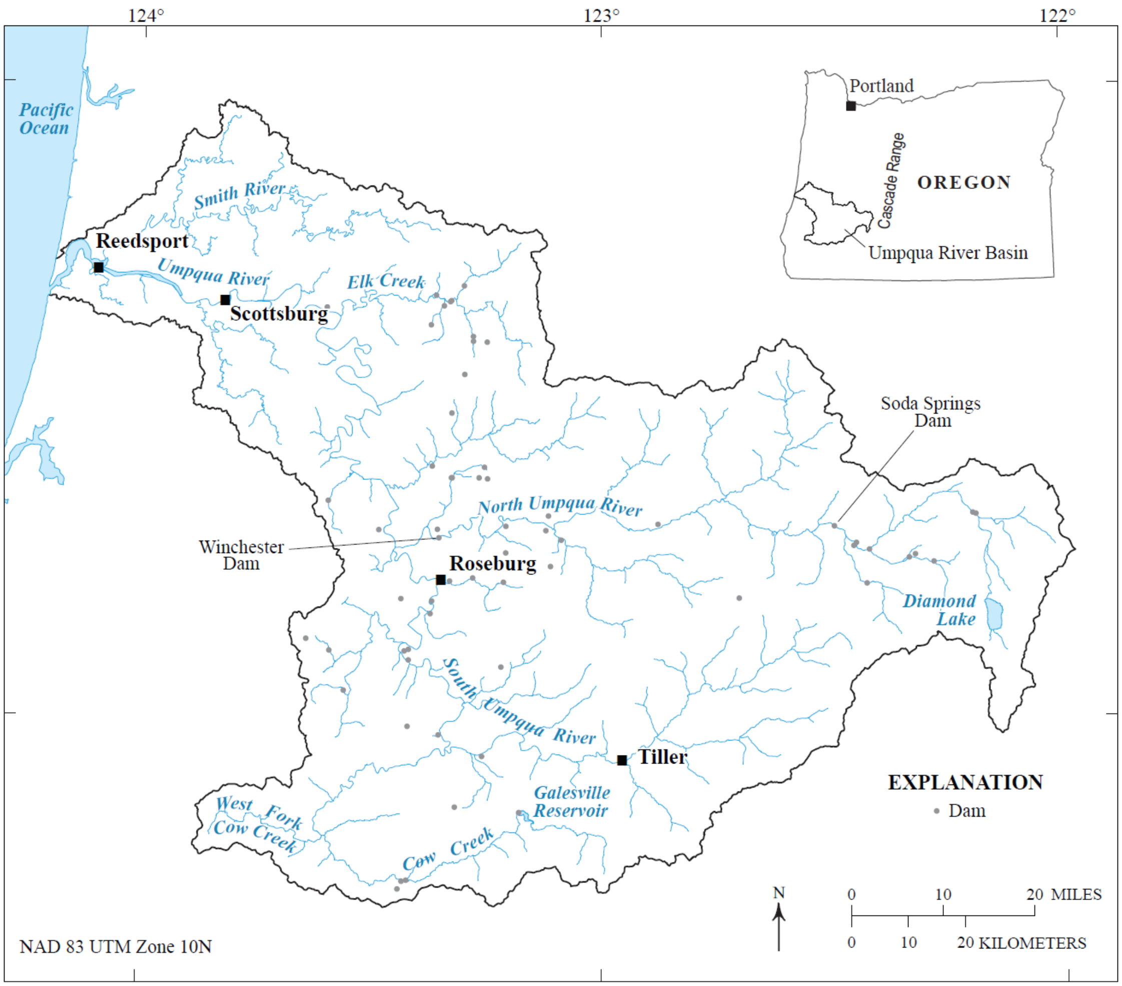

Figure 1. Map of the Umpqua River Basin in southwest Oregon. Major tributaries are shown, as well as larger natural lakes, reservoirs, and points indicating the locations of dams that are 10 feet in height and with water storage of more than 9.2 acre-feet (https://geohub.oregon.gov/datasets/oregon-geo::dam-facilities/about; accessed 25 January 2024).

Pacific Lamprey: life cycle and population status

Details on the life cycle of Pacific Lamprey were addressed by Clemens (2017, 2021a, b; Figure 2). Observed declines in Pacific Lamprey have been documented in the North Umpqua River Basin and many river basins in the Pacific Northwest (Clemens et al. 2021b). These declines have prompted concerns and motivated new actions to restore the species to its former abundance. This includes addressing potential threats to the species throughout its life cycle, including life stages in freshwater and marine environments (Figure 2). Conservation of Pacific Lamprey is the purview of the Pacific Lamprey Conservation Initiative (PLCI), which conducts regional and subregional status assessments for the species and supports conservation actions (Wang and Schaller 2015; U.S. Fish and Wildlife Service 2019). As of 2023, Pacific Lamprey is designated as a "Species of Concern" by the U.S. Fish and Wildlife Service (USFWS 2019) and a "Sensitive Species" in Oregon (ODFW 2020).

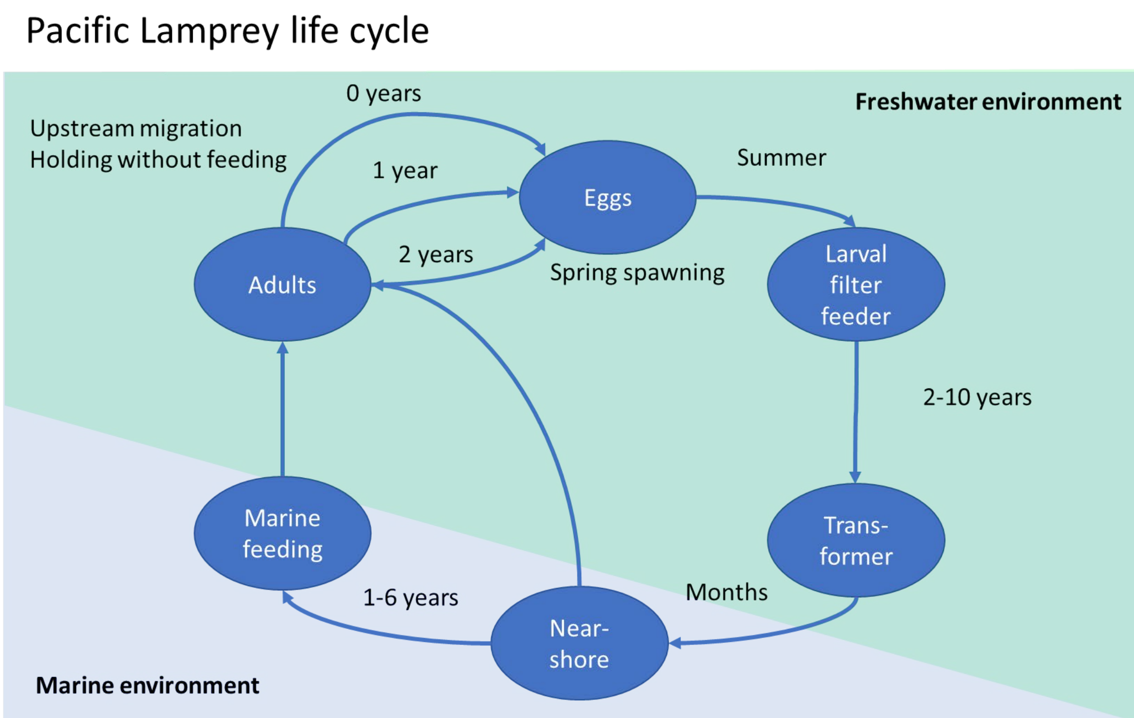

Figure 2. Simplified summary of the life cycle of Pacific Lamprey based on current understanding of the species and conversations with Ben Clemens (Statewide Lamprey Coordinator, Oregon Department of Fish and Wildlife, personal communication; drawn by Jason Dunham, U.S. Geological Survey). This figure/schematic provides an overview of various freshwater and marine components of the life cycle of Pacific Lamprey that may be considered in designing river restoration, climate adaptation, and other activities to benefit the species. The marine components are not further addressed in this document.

The physical habitat template

We begin with a consideration of the physical template, since it provides the foundation upon which biological processes operate (Montgomery 1999, Gordon et al. 2004). Key elements of the physical template include hydrologic processes such as processes generating surface stream flow and flow regimes; geomorphic processes such as sediment and wood dynamics and consequences for substrate composition and stream channel structure; and heat budgets, which drive the dynamics of stream temperature. These processes are often the focus of contemporary stream restoration and motivation for process-based stream restoration (Beechie et al. 2010, Ciotti et al. 2021). Given the complexities of the life history of Pacific Lamprey (Figure 2; Homel et al. 2019, Lamprey Technical Workgroup. 2023), there are multiple life stages that could be influenced by these physical processes or actions that modify them. Studies of relations between streamflow, sediment, wood, water temperature, and Pacific Lamprey are limited in number, however. We briefly summarize the work we are aware of here and their implications for stream restoration or climate adaptation to benefit Pacific Lamprey in the Umpqua River Basin (see also Homel et al. 2019, Lamprey Technical Workgroup. 2023).

Stream flow regimes are widely recognized as important components for the restoration and management of stream ecosystems (Poff et al. 1997). Furthermore, many species have evolved in response to stream flow regimes, which include the magnitude, timing, duration, frequency, and predictability of stream discharges that are experienced by aquatic biota (Lytle and Poff 2004). In many cases, loss of surface flow in streams is occurring in relation to climate warming, drought, and human water uses, and posing threats to the existence of aquatic ecosystems altogether (Datry et al. 2014). Regional studies that include the Umpqua River Basin indicate that 1) relative wetted widths of streams (expressed as a proportion of stream bankfull width) may be declining, 2) modeled stream flows indicate variable declines, and 3) drought conditions appear to be increasing (Dunham et al. 2023). This recent work, along with many detailed studies across the region, indicate that human-caused climate change is strongly influencing stream flow, and that loss of surface flow is a growing concern (Clemens 2021, Halofsky and Peterson 2022).

Whereas it is well-known that many local factors can influence stream flow, only a few detailed studies in the Umpqua River Basin identify which factors are most important or provide implications for management. Riparian and forest vegetation dynamics and composition represent one of many local processes influencing stream flows that could have management implications (Coble et al. 2020). For example, a recent study of stream flows in paired watersheds in the headwaters of the South Fork

Umpqua River suggests that changes in forest vegetation and transpiration may lead to lower surface flows (Perry and Jones 2017). Further work is needed, however, to better understand these processes and implications for management (Coble et al. 2020). Other potential local influences on stream flows include road networks, wildfire, local human uses of ground and surface water, and flow regulation downstream of the reservoirs in the system. Beaver-created ponds could influence storage of water and flows as well, but recent work shows that although Beaver (*Castor canadensis*) are common across the Umpqua River Basin, they rarely construct dams and associated ponds (Stevenson 2023). Consideration of the collective influences of these local factors along with regional (such as climate-related) drivers of stream flows will require more comprehensive assessments (such as Du et al. 2014) than are currently available. Current monitoring of stream flows is often done at fixed gages, which provide detailed time-series at specific locations. This monitoring effort could be expanded by adding more distributed efforts to quantify flow conditions across the Umpqua Basin, which would provide a clearer picture of opportunities for managing stream flows to benefit Pacific Lamprey (such as increased capacity for upstream migration; Clemens et al. 2017, Clemens and Schreck 2021, Clemens et al. 2023) and aquatic ecosystems in general (Kovach et al. 2019, Kampf et al. 2021, Seybold et al. 2023).

In addition to stream flows, associated variability in geomorphic processes, especially sediment and instream wood dynamics, shape habitat for Pacific Lamprey. Locations that offer a potential source of fine sediment (such as silt and sand) for burrowing and provide geomorphic features that allow for retention of sediment can provide suitable habitat for larval Pacific Lamprey (Jones et al. 2020). Recent work on the distribution of suitable burrowing habitat in the Umpqua Basin provides a clear example of how sediment and instream wood can interact to drive the spatial distribution of larval habitat in the system (Jones et al. 2020). Local restoration efforts in the watershed may influence these processes to benefit larval lamprey, as suggested by one study in a tributary to the lower Umpqua River (Little Wolf Creek; Gonzalez et al. 2017; see also Roni 2002). In this case, placement of instream wood led to increased retention of fine sediment and use by larval lamprey. Other work in the Smith River, a major tributary to the lower Umpqua River, identified characteristics of spawning locations used by adult Pacific Lamprey (Gunckel et al. 2009). This work indicated that spawning occurred in gravel-rich locations, but that it was difficult to distinguish these locations from other similar, but unused locations (see also Mayfield et al. 2014). Additional study of Pacific Lamprey in the Smith River indicates that prior to spawning, adults spend a variable time in streams, and may select much larger substrate for holding, such as boulders and bedrock crevices (Starcevich et al. 2014; see also Clemens and Schreck 2021). It is unclear how pre-spawning adult lampreys would use instream large wood during the freshwater holding phase since it was absent from the study reaches in the Smith River (Starcevich et al. 2014), but these and similar structures were found to be important for this life stage in other systems (Clemens and Schreck 2021). Collectively, this work shows that instream wood and substrate requirements vary dramatically by life stage for Pacific Lamprey. The configuration of available habitat types across the Umpqua River network may also be important as Pacific Lamprey are widely distributed (Jones et al. 2020). Specifically, this refers to proximity of habitats that favor different life stages, as well as their redundancy, connectivity, and a host of other spatial processes that may be just as important as local processes (Schlosser 1995). To assist in understanding the relative importance of these processes and identifying locations with the highest potential for protection or restoration, obtaining more spatially continuous information on physical factors such as channel substrate and instream wood is needed (as suggested by Jones et al. 2020).

Stream temperature has a long history of study in the Umpqua River Basin, initially in relation to land management (e.g., Hostetler 1991) and more recently in relation to climate change (Jones et al. 2020, Halofsky and Peterson 2022). Temperature data loggers have made data collection easier (Dunham et al. 2005), which has dramatically increased stream temperature data availability across the region. Notably, there are efforts in place to model and predict annual (Isaak et al. 2017) and even daily temperatures (Siegel et al. 2023). With respect to available habitat for Pacific Lamprey in the Umpqua Basin, application of the annual model predictions (Isaak et al. 2017) indicates that temperature is a primary limiting factor (Jones et al. 2020). This is due in part to the association of warmer temperatures with the establishment of invasive fish, such as Smallmouth Bass (*Micropterus dolomeiu*). In the warmest locations of the Umpqua River, there are potential physiological consequences for Pacific Lamprey (Clemens 2022). As air temperatures warm, wildfires are expected become more likely in the Umpqua Basin, stream flows are expected to decline, and stream temperatures are expected to variably increase (Halofsky and Peterson 2022).

In response to concerns over warming temperatures, restoration actions to slow or counteract the threat of climate change are being evaluated. In one example, Stevenson et al. (2022) evaluated the potential for beaver ponds to reduce stream temperatures, but found instead that ponds warmed streams, with warming persisting downstream for several hundred meters. Other studies show that cooling of stream temperatures is possible in response to beaver-related restoration (Weber et al. 2017). These conflicting outcomes suggest that this action, or any action, requires a detailed, process-based assessment (Nash et al. 2021). More broadly, changes in land use regulations that protect streamside vegetation and shading could be effective in reducing stream temperatures, but results from such measures may take decades to realize (Dunham et al. 2023). To evaluate the effectiveness of any restoration action to reduce or even reverse warming of stream temperatures, more detailed consideration of physical processes that influence heat budgets and thermal sensitivity are needed (Moore et al. 2005, Rey et al. 2023).

Our treatment of the physical template here covers a selected set of primary focal points for stream restoration in the Pacific Northwest, but other important processes could be considered. Another process to consider is the dynamics of stream productivity, which requires an integrated understanding of physical, chemical, and biotic processes (Bellmore et al. 2017). For example, recent study of restoration alternatives revealed that potential outcomes were not controlled by traditional geomorphic approaches that are currently common in river restoration, but rather they were influenced by the food web processes driving instream productivity (Whitney et al. 2020). Such processes may be particularly important for larval Pacific Lamprey, due to their dependence on filter feeding and productivity. To open new pathways and action alternatives for Pacific Lamprey conservation, additional work is needed to consider productivity or other factors not commonly addressed in stream restoration.

Passage and reservoirs

Impairment of fish passage at human-created structures is a major concern for migratory fish, such as Pacific Lamprey (Clemens et al. 2021a, Clemens et al. 2023). Most obvious in terms of human-created barriers to fish movement are large, impassable dams, but the numerous smaller structures across riverscapes, including stream-road crossings, water diversions, and smaller dams, can also be important. In the Umpqua River Basin, two large structures, Soda Springs and Winchester dams, historically blocked passage, but both structures now have passage structures designed specifically to pass upstream-migrating adult Pacific Lamprey. The passage structure designed to pass Pacific Lamprey at Soda Springs Dam was constructed in 2012. Ten years later, the first upstream-migrating adults were observed using the structure to move upstream (R. Grost, Pacific Power, personal communication). Farther downstream on the lower mainstem of the North Umpqua River is Winchester Dam. This dam has a fish ladder designed to facilitate fish passage, but it was not designed with the specific requirements of lamprey in mind. To address this need, a ramp to allow more efficient upstream passage of Pacific Lamprey was installed by the Oregon Department of Fish and Wildlife in 2013. In the years just prior to construction of this ramp (2009-2010), adult Pacific Lamprey were noted upstream of the dam, although upstream passage by radio-tagged adults was low (8% and 19%, respectively) in the two years studied

(Lampman 2011). Many of these fish remained at the base of the dam, residing either with the structure itself or immediately downstream (63% and 67% of tagged fish in 2009 and 2010, respectively). It is unclear today how the new ramp has improved passage over the dam, but increasing numbers of adults counted moving upstream through the fish ladder are encouraging (ODFW 2020, Clemens et al. 2021). Clemens et al. (2021) point to several potential biases and contexts that are important to consider for interpreting these patterns. Given these considerations, more detailed assessments of counts and perhaps direct observations of passage (Lampman 2011) could determine if such increases are sustained and attributable to improvements in passage. In addition to effects of Winchester Dam on upstream passage of adults, populations of larval lamprey occupying the pool upstream of the dam are sometimes impacted by periodic drawdowns of the reservoir for dam maintenance. In addition to larger dams, there are literally hundreds of smaller potential barriers to passage of Pacific Lamprey, primarily at road-stream crossings. New road-crossing designs used to replace these small structures and intended to provide for passage of aquatic organisms have been successful at restoring lamprey passage where they meet contemporary design standards (Chelgren and Dunham 2015).

Removal of movement barriers is one of the first steps to consider in stream restoration (Roni et al. 2002). Regulations in the State of Oregon (https://www.dfw.state.or.us/fish/passage/ accessed 15 December 2023), as well as federal aquatic organism passage and stream simulation guidelines (Gillespie et al. 2014), require that human-created structures offer volitional passage for fish and other species. Prioritization frameworks that include consideration of native lampreys, as well as road infrastructure and hydrogeomorphic processes are available (Reagan 2015). These or other prioritization tools (Garcia de Leaniz and O'Hanley 2022) can be employed to evaluate passage restoration decisions across the Umpqua Basin. Once priorities are identified and potential barrier removal projects are evaluated, limited funding can be allocated to projects anticipated to generate the greatest return on investment, given the objectives in play (such as fish passage, stream simulation, and transportation). Given the extent to which the Umpqua Basin has been colonized by invasive species (such as Smallmouth Bass and many other introduced species), some consideration of isolation versus invasion may also be warranted in many cases (Fausch et al. 2009, Garcia de Leaniz and O'Hanley 2022). This should be most important in portions of the Basin where invasions have yet to take place. Consideration of the future distribution of invaders with warming water temperature may be important as well (Jones et al. 2020).

Invasions

Biological invasions in freshwaters are widely recognized as a threat to aquatic ecosystems (Reid et al. 2019). In the Pacific Northwest, there are a growing number of invasive fish species that could pose problems for native species, including Pacific Lamprey. Among the invaders that pose threats, introduced Smallmouth Bass has received considerable attention. Smallmouth Bass are a warmwater species and are known to prey heavily on native lamprey larvae in the Umpqua River Basin (Schultz et al. 2018). Across the Pacific Northwest, numerous studies have been focused on patterns of invasion by Smallmouth Bass and interactions between this species and native species, including salmon and trout, other native bony fish, and lampreys (Rubenson and Olden 2020).

In the Umpqua River Basin, current angling regulations issued by the State of Oregon allow for unlimited harvest of Smallmouth Bass, but there are many recreational anglers and guides that promote catch and release to preserve the fishery. These conflicting interests are common to many introduced fishes and pose a challenge to effective control (Dunham et al. 2020, Sax et al. 2022). Another challenge to controlling this species is the likelihood that its distribution will increase with climate change. As water temperatures warm, Smallmouth Bass are expected to expand their distribution in the Umpqua River Basin specifically (Jones et al. 2020) as they have throughout the Pacific Northwest (Rubenson and Olden 2020).

In addition to Smallmouth Bass, the Umpqua River Basin supports a host of other invasive fish characteristic of warmer water and with impacts and patterns of invasion that may be similar. These include other members of the sunfish family (Centrarchidae), Striped Bass (*Morone saxatilis*), and Bullhead Catfish (*Ameiurus*, spp.). Other predatory warmer-water species such as Walleye (*Stizostedion vitreum*) and Northern Pike (*Esox lucius*) have successfully invaded other stream systems in the region, but these species have yet to establish in the Umpqua River Basin. In the headwaters of the Umpqua River Basin, introduced coldwater fish such as Brown Trout (*Salmo trutta*) and Brook Trout (*Salvelinus fontinalis*) also pose potential threats. As stream temperatures warm and flow regimes shift to include more winter flooding due to loss of snowpack, however, the ranges and potential impacts of these coldwater species may decline (Wenger et al. 2011).

Given the current status of invasive fish in the Umpqua River Basin, it is difficult to envision the case for conventional control of them through any currently available removal methods. Furthermore, attempts to eradicate many currently established invaders are likely to meet with some social resistance.

Accordingly, unconventional methods of addressing impacts, rather than the invaders themselves may be warranted (Dunham et al. 2020). Impact-based approaches focus on actions that allow native species to persist without requiring direct control of an invader. Although there are examples of these approaches for managing impacts, they are not always directly acknowledged as a means of managing invasive fish because of the overwhelming focus on prevention and control (Dunham et al. 2020). For Pacific Lamprey, efforts to manage stream flows, riparian shading, or other processes that reduce stream temperature may be effective to benefit of Pacific Lamprey without the need to directly control introduced species (ISAB 2007, Jones et al. 2020, Fuller et al. 2022, Halofsky and Peterson 2022). Careful construction and maintenance of movement barriers may also be an option for slowing upstream invasion of introduced fish, but tradeoffs involving isolation for native species are a consideration (Fausch et al. 2009). In practice, a combination of approaches, including elements of prevention, control, and managing impacts may be warranted (Dunham et al. 2020). A more formal and comprehensive assessment of decision alternatives would be needed to explore these possibilities (such as Dunham et al. 2022).

Climate Adaptation

The effects of human-caused climate change are transforming societies and ecosystems across the planet (Malakar et al. 2023). In the Umpqua River Basin, climate change is leading to warmer air and stream temperatures, altered stream flow regimes, and associated ecological responses (Clemens 2022, Halofsky et al. 2022). Recent drought (Zhang et al. 2021) and wildfires (Reilly et al. 2022) experienced regionally and locally in the Umpqua River Basin have brought climate change into focus as a contemporary force.

A recent climate change vulnerability assessment for Pacific Lamprey across the western United States indicated that the Umpqua River Basin is the most vulnerable among all basins assessed (Wang et al. 2020). A more detailed assessment of climate change in the Umpqua River Basin similarly indicated substantial contractions in the extent of potentially suitable habitat for larval lamprey in the system, owing in part to expected warming of stream temperatures and expansion of nonnative smallmouth bass (Jones et al. 2020). Notably, baseline conditions used in this work represented the year 2005, and since then aforementioned impacts of drought and wildfire were not yet realized.

Given the present and future threats posed by human-caused climate change, what can be done to ensure that Pacific Lamprey persist in the Umpqua River Basin? As with many other aquatic species in the region, climate adaptation for Pacific Lamprey fundamentally involves managing thermal and flow regimes in streams (Wang et al. 2020). Addressing these hydrologic responses can involve short-term active interventions, such as managing outflows from storage reservoirs (Stratton-Garvin and Rounds 2022). In cases where water is diverted or pumped directly from stream channels, allocating that water to instream flows is another short-term action that can be effective (Womble et al. 2022). Over longer time frames, restoration of riparian vegetation to provide shade to reduce heating or increasing floodplain connectivity are often cited as action alternatives (Moore et al. 2005).

Where can climate adaptation be most effectively implemented in the Umpqua River Basin? As may be expected, given the overarching importance of cold water and implications for distributions of non-native warmwater species, many of the areas that could act as focal points for climate adaptation to benefit Pacific Lamprey are in portions of the watershed where temperatures are moderated by coastal influences (such as the Smith River and lower tributaries to the mainstem Umpqua River) or in higher elevations with cooler climates and underlying geologies that provide greater moderation of temperatures via increased deep groundwater fluxes (Isaak et al. 2016, Jones et al. 2020, Hare et al. 2021). Protecting these headwaters would be a useful measure to maintain availability of existing higher quality habitat for Pacific Lamprey. Most opportunities for active restoration lie in lower elevations, where human populations and associated water use in the Umpqua River Basin are concentrated (Halofsky et al. 2022).

In concept, climate adaptation planning to benefit Pacific Lamprey in the Umpqua River Basin could involve 1) identifying locations that would benefit key life stages, 2) assessment of conditions within those locations in terms of their present suitability, 3) assessment of potential future conditions, and 4) identification of specific short- and long-term measures to ensure conditions remain suitable for as long as possible. Although existing work has focused on larval lamprey, thermal habitat conditions for other life stages (including migration of transforming larvae and adults, spawning, and incubation) are also important to consider. New work is underway to develop quantitative life cycle models for Pacific Lamprey (D. Gomes, U.S. Geological Survey, personal communication) and these may also be useful for evaluating climate adaptation in a more integrated fashion. To assess current conditions, it is important to recognize that existing assessments of Pacific Lamprey (U.S. Fish and Wildlife Service, 2019, ODFW 2020, Jones et al. 2020, Wang et al. 2020) and aquatic conditions (Halofsky and Peterson 2022, Dunham et al. 2023) are based mostly on spatial datasets that may not fully represent conditions on the ground and reach-scale processes that shape instream habitats. Work in the Umpqua River provides examples of habitat assessments at multiple scales (Gunckel et al. 2009, Starcevich et al. 2014, Gonzalez et al. 2017, Jones et al. 2020). Although it is possible to make decisions based on existing broad-scale assessments, there is value in more detailed assessments of conditions at specific sites. A combination of broad-scale assessments to identify key portions of the landscape to evaluate in more detail can be useful in this regard.

Once specific life stages and current and future conditions are considered, the next step for addressing climate impacts involves identifying what “levers” in the system can be managed to benefit Pacific Lamprey. For example, if a specific reach of stream important to Pacific Lamprey is influenced by barriers to movement (such as road-stream crossings in headwaters or passage over barriers further downstream), relatively short-term benefits can be realized by addressing these factors first. Similarly, cases in which existing patterns of water use (such as instream water use) or storage (such as reservoir operations) overlap with the current or likely distribution of Pacific Lamprey can be useful in the short-term. Over longer time frames, recovery of riparian vegetation, instream wood, and channel form may take decades to centuries without intensive and expensive restoration efforts (Dunham et al. 2023). Some threats, such as invasions by Smallmouth Bass and other nonnative species, may be particularly difficult to address and require novel approaches beyond the conventional means of prevention and control of invaders (Dunham et al. 2020).

Ecological transformation wrought by climate change is leading scientists and practitioners to envision a host of new concepts and action alternatives for climate adaptation, such as those envisioned by the Resist-Accept-Direct concept (Lynch et al. 2021). The essential message from these emerging ideas is that past approaches to restoring streams for species such as Pacific Lamprey may no longer be viable alternatives, or at the least there are new alternatives that can provide successful outcomes that are more in line with addressing an ever-growing list of threats (e.g., Dunham et al. 2022). Finally, it is worth acknowledging that restoration actions for Pacific Lamprey may be very different than restoration actions that benefit other species such as Pacific salmon, although there are examples of habitat restoration benefiting both salmon and lamprey, albeit for apparently different reasons (Gonzalez et al. 2017).

Conclusions

This brief synopsis of the April 2022 workshop on restoration of Pacific Lamprey in the Umpqua River Basin provides a sampling of topics discussed during the event, as well as a review of available scientific literature. Although past efforts to restore streams and habitat for Pacific Lamprey in the Umpqua River Basin have shown promising results (such as restoration of fish passage, responses of larvae to instream wood restoration), it is not clear that existing restoration efforts will be enough to return the species to historical levels of abundance. Fundamental shifts in hydrologic conditions linked to climate change and solutions for addressing invasive species pose growing challenges that may require new approaches.. The good news is that our understanding of the factors and processes influencing lamprey and recovery actions highlighted here has increased dramatically in recent years, due to many new studies investigating Pacific Lamprey and responses to stream restoration.

The multi-scale analysis of Pacific Lamprey conservation opportunities produced by Jones et al. (2020) provides the first picture of where investments in this species are most likely to yield positive returns. Additional work that builds on this, as well as the existing body of research on Pacific Lamprey both in and outside of the Umpqua River Basin, could be useful in helping to identify the consequences of more detailed restoration alternatives for ensuring this species can persist and recover. Specifically, integration of these individual studies into a common life-cycle model (in development, D. Gomes, U.S. Geological Survey, personal communication); spatially-explicit, individual-based models (Seaborn et al. 2023); or even more qualitative approaches (Brignon et al. 2023) could be useful. These approaches allow for integration of existing data on Pacific Lamprey and can be useful for identifying critical uncertainties or information needs and inform management decisions. Approaching conservation of Pacific Lamprey in this way will require participation of all partners with an interest in the species in the Umpqua River Basin. Ideally, this would be implemented as a structured process (such as Gregory et al. 2012, Conroy and Peterson 2013) for delivering the science and engaging everyone with an interest in what it can bring to understanding what can be done to restore Pacific Lamprey.

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