Pacific Lamprey

2024 Regional Implementation Plan

for the

North Pacific Ocean

Regional Management Unit

Primary Authors	Primary Editors
North Pacific Ocean Lamprey Technical Working Subgroup	North Pacific Ocean Lamprey Technical Working Subgroup

This page left intentionally blank

I. Status and Distribution of Pacific Lamprey in the RMU

A. General Description of the RMU

The North Pacific Ocean Regional Management Unit (RMU) is vast, encompassing all populations of Pacific Lamprey originating from rivers across all 15 of the other RMUs in California, Oregon, Idaho, Washington, and Alaska (USFWS 2018), and other international areas, from Baja, Mexico, north to the Bering and Chukchi Seas between Alaska and Russia (Renaud 2008, 2011; Orlov et al. 2009), and south to Hokkaido and Honshu Islands, Japan (Yamazaki et al. 2005). Research, monitoring, and management needs have been identified in land-based RMUs, which are being addressed (USFWS 2018, PLCI 2024). However, the foci of these projects are only on the freshwater life stages of the Pacific Lamprey life cycle.

The marine (juvenile) phase of the Pacific Lamprey is clearly an important stage because it is where they attain their maximum body size, which correlates with behavior and fitness in freshwater (including passage efficiency at dams, upstream migration distance, and the number of eggs a female produces; reviewed in Clemens et al. 2019). The ocean phase of the Pacific Lamprey life cycle may be more important than the freshwater life stages for population recruitment (e.g., see Murauskas et al. 2013). Dedicated efforts since 2017 to collect Pacific lamprey from marine waters and analyze them using a variety of methods has greatly increased our understanding of lamprey use of the North Pacific Ocean RMU, with much more to come.

B. Status of Species

Conservation Assessment and New Updates

Every five years the Pacific Lamprey Conservation Initiative (PLCI), through the RMUs, revise the Pacific Lamprey Assessment (PLCI 2024). The Assessment utilizes local stakeholder knowledge and expertise to evaluate Pacific Lamprey distribution, population demographics, and threats at the 4th field HUC watershed level. This information is used to inform NatureServe, a diagnostic tool that characterizes the conservation risks of Pacific lamprey. The status of lamprey in the North Pacific Ocean RMU is unknown, because Pacific Lamprey are relatively rare in marine waters, with tens or hundreds of thousands (if not millions) of other fish caught for every lamprey caught (Weitkamp et al. 2023). The North Pacific Ocean RMU also fundamentally differs from freshwater RMUs because anadromous individuals from all freshwater regions use this RMU.

Research using neutral genetic markers on collections of Pacific Lamprey from British Columbia, Washington, Oregon, and California indicates that they exhibit a low level of genetic stock structure, with intermediate rates of gene flow across large geographical areas (Goodman et al. 2008; Spice et al. 2012). The presence of some allelic diversity in West Coast Pacific Lamprey suggests limited dispersal to non-natal freshwater systems while lamprey are in marine waters (Spice et al. 2012, Hess et al. 2022). Recent genetic studies using both neutral and adaptive genetic markers have identified five genetically distinct groupings: 1) Northern British

Columbia, 2) Vancouver Island and Puget Sound, 3) the lower Columbia River basin, 4) the interior Columbia River, and 5) the southern West Coast (Hess et al. 2022). Differentiation of lamprey destined for the lower versus interior Columbia River basin suggests some common evolutionary selective force(s) operating at the general geographical demarcation of the Cascade Mountain Range, and between other coastal regions (Hess et al. 2013, 2015, 2022). Genetic methods also indicates high levels of genetic structuring with regards to body size (Hess et al. 2013).

Distribution and Connectivity

Along the West Coast of British Columbia and the continental US, Pacific Lamprey are primarily caught from Cape Mendocino in California (40.5°N) north to Haida Gwaii, British Columbia (54°N), with a few individuals as far south as southern California (~33°N; Weitkamp et al. 2023). In Alaskan waters, the highest occurrences of Pacific Lamprey are in the slope area of the Bering Sea, with some lamprey caught around the Gulf of Alaska, from southeast Alaska to the eastern Aleutian Islands across and into Russian waters off the Kamchatka peninsula (Orlov et al. 2008). The NOAA Alaska Fisheries Science Center consistently caught Pacific Lamprey during the discontinued Bering Slope bottom trawl survey, but rarely on the Bering shelf or Gulf of Alaska bottom trawl surveys (Siwicke and Seitz 2017).

Growing evidence suggests that some groups of Pacific lamprey may undertake long (>3,000 km) migrations in marine waters, while other groups may be more sedentary. Genetic analysis of lamprey caught in West Coast marine waters suggest that lamprey originating from the Columbia River rapidly disperse from the area in spring, while lamprey from rivers south of the Columbia remain along the West Coast throughout the summer and fall (J. Hess, CRITFC, unpublished data). Where these Columbia-origin lamprey go is not known, but at least a few individuals migrate to the Bering Sea. Proof of this comes from one Pacific Lamprey caught and PIT tagged in the Bering Sea that was subsequently detected in the Columbia River (Murauskas et al. 2019). Another lamprey collected in the Bering Sea was the full sibling of an individual caught at Willamette Falls (Hess et al. 2022). In addition, unexpectedly few intermediate sized (350-500 mm TL) lamprey are caught off the West Coast, a size that is present in the Bering Sea (Orlov et al. 2008, Weitkamp et al. 2023). Continued collections of lamprey from around the North Pacific Ocean should help document potential population-specific migratory behavior.

In the ocean, Pacific Lamprey are found throughout the water column, between the surface and 1,485 m but typically at depths of less than 500 m (Orlov et al. 2008). Pacific lamprey caught by midwater (fishing above the bottom) trawls targeting Pacific hake were caught at a mean depth of 238 m in water that was 467 m deep (Weitkamp et al. 2023). Bottom depth for lamprey caught by bottom trawls targeting groundfish averaged 312 m, while those caught by shrimp trawls was 151 m (Weitkamp et al. 2023). In the Straits of Georgia and near Vancouver Island, Pacific Lamprey were most commonly found at 31 – 100 m depth, followed by 101 – 500 m (Wade and Beamish 2016).

Additional topics relative to distribution and connectivity that are not well-studied include: feeding dynamics related to Pacific Lamprey ocean entry and return from marine waters; recruitment to the population (= marine survival); dispersal at sea; and patterns in genetic diversity.

C. Threats

Summary of Major Threats

Key limiting factors for lamprey in the North Pacific Ocean RMU (Clemens et al. 2019) include: 1) availability of host species, 2) contaminant loads of hosts, 3) predation and fisheries bycatch, and 4) lack of information. Key threats include: 1) climate change, 2) unfavorable oceanographic regimes, 3) influences of interactions between climate change and oceanographic regimes, and 4) pollution. Research is currently underway to better understand many of these threats and limiting factors. For example, recent research has identified fisheries with high Pacific lamprey bycatch (Siwicke and Seitz 2017, Weitkamp et al. 2023); best practices are being developed to maximize post-release survival (L. Weitkamp, NOAA, unpublished data). Studies are also investigating lamprey host use (described under *Restoration and Research Actions*, below).

A new potential threat to Pacific lamprey is offshore wind energy development, which may impact marine habitats, cause physiological or physical effects, alter fish (i.e., host) abundances and distributions, and change ecosystem and climate interactions (NMFS 2024). How offshore wind energy will affect Pacific lamprey specifically is not known, but could cause general disturbance (noise, vibration) during construction, affect the distribution of hosts, increase contaminants (from spills), and underwater power lines will create magnetic fields that could impact lamprey sensory abilities. Because fishing will be limited around offshore wind sites, these areas may beneficially serve as refugia for Pacific lamprey.

Pacific Lamprey are not targeted for ocean harvest for recreational or commercial uses, although they may be caught incidentally in fisheries targeting other species. However, this species is harvested for cultural use in at least one estuary (e.g., see PetersonLewis 2009). The lack of harvest paired with general rarity in marine waters has resulted in little consistent monitoring within this RMU.

Restoration and Research Actions

Since 2017, coordinated research on Pacific Lamprey in the ocean has been undertaken by members of the Ocean Phase subgroup of the Lamprey Technical Workgroup. This research is detailed in Table 1. In collaborative efforts, Pacific Lamprey are collected from the ocean by NOAA Fisheries staff and shared with interested researchers. These lamprey were caught by Alaska Fisheries Science Center (AFSC) and Northwest Fisheries Science Center (NWFSC) fishery-independent stock assessment surveys for groundfish in the Gulf of Alaska and Bering Sea shelf and slope and along the US West Coast, as well as midwater surveys for Pacific hake (whiting), and pelagic surveys for juvenile salmon. Fisheries observers on West Coast commercial hake, shrimp, and groundfish boats have also collected lamprey specimens as part of this effort (see Weitkamp et al. 2023 for details). Surveys by Russian biologists also occur in the western North Pacific, which collect information on Pacific Lamprey (e.g., Orlov et al. 2008).

These biological specimens and accompanying data have been used to address questions related to use of the North Pacific Ocean RMU by Pacific lamprey. For example, data from over 2000 individual Pacific lamprey caught from southern California to Alaska was used to document the basic marine biology of West Coast Pacific lamprey (e.g., size, growth, location, habitat associations, host use), greatly increasing what is known (Weitkamp et al. 2023). Genetic stock identification of ocean-caught specimens has been used to address sources of recolonization following dam removal in the Elwha River (Hess et al. 2020), the success of Columbia River adult translocation programs (Hess et al. 2022, 2023), and group-specific movements described under *Distributions and Connectivity* above (J. Hess, CRITFC, unpublished data). Samples have been collected to determine contaminant (L. Porter, CRITFC, unpublished data) and microplastics (S. Traylor, Portland State University, unpublished data) levels in Pacific lamprey throughout the ocean phase. Ocean-caught lamprey were also used to determine that statoliths ("ear bones") are a useful indicator of freshwater age but not ocean age (Pelekai et al. 2023). A related study showed that stable isotope analyses of lamprey eye lenses do document changes in trophic level over the life of lamprey (Pelekai 2021).

One exciting result of increased attention to Pacific lamprey use of the North Pacific Ocean RMU is a marked increase in what is known about host use in marine waters using both traditional methods and modern tools. Pacific Lamprey have been documented to prey upon 39 species of marine mammals and fishes in marine waters based on the presence of characteristic round lamprey wounds or observations of lamprey attached to hosts (Clemens et al. 2019, Weitkamp et al. 2023, L. Weitkamp, unpublished data). Careful examination of fish caught during NOAA stock assessment surveys for both hake and groundfish indicate lamprey wounds were most frequently observed on Pacific hake, although a wide diversity of fishes were observed with lamprey wounds (Clemens et al. 2019, Weitkamp et al. 2023).

Two complementary projects initiated in 2024 using ocean lamprey collections will greatly increase our understanding of lamprey feeding behavior using modern tools when completed in 2025 or 2026. The first project uses naturally occurring stable isotopes as food web tracers at longer temporal scales (weeks to months). This project will examine likely sources of variation in stable isotope signatures (e.g., by size, location, habitat use, year, or season) to indicate variation in host/prey use (K. Frick, NOAA NWFSC, unpubl. data). The second project uses many of the same specimens but employs genetic methods on gut contents to detect host DNA, reflecting shorter temporal scales (day-week). Initial results from the genetic gut content analysis have confirmed many known hosts (i.e., from visual observation of wounds), including the importance of Pacific hake as a primary host (C. Goodfellow, Oregon State University, unpubl. data). This analysis has also doubled the number of known hosts, which includes fin and humpback whales, but also many small-bodied fishes suggesting predation rather than parasitism. The results of both projects should greatly increase our understanding of trophic interactions of lamprey during the entire marine phase. They should also inform statistical associations observed between the relative abundance of likely hosts and the abundance of adult Pacific Lamprey returning to the Columbia River Basin (e.g., Murauskas et al. 2013).

Despite this new research, many knowledge gaps (mentioned above) exist for Pacific Lamprey in the North Pacific Ocean. These gaps are largely due to the difficulty of collecting and conducting lamprey specific research in the ocean. Given progress to date, we will continue collection efforts.

Table 1. Inventory and description of oceanic research conducted on lampreys, primarily Pacific Lamprey (but also Western River Lamprey).

Title	Dates	Scientific scope	Geographic scope	Partners
Microplastics in Pacific Lamprey	2021-2024	Microplastics in Pacific Lamprey study. Publication pending (Traylor et al. in prep).	North Pacific Ocean	Summer Traylor (PSU); Elise Granek (PSU); Laurie Weitkamp (NOAA)
Contaminants in Pacific lamprey	2017-2024	Tissues have been collected to determine contaminant levels in West Coast Pacific lamprey.	North Pacific Ocean	Laurie Porter (CRITFC); James Willacker (USGS); Collin Eagles-Smith(USGS); Laurie Weitkamp (NOAA)
Document hosts of Pacific Lamprey	2014-present	Document species, size, and location of fish with lamprey wounds caught by commercial fisheries (Pacific Hake) and stock assessment surveys (Pacific Hake, groundfish).(Weitkamp et al. 2023)	North Pacific Ocean	Laurie Weitkamp (NOAA); Aaron Chappell (NOAA); Alicia Billings (NOAA)
Characterization of ocean-phase migration patterns of mixed-natal-origin Pacific Lamprey	2017-ongoing	Ocean migration patterns appear to vary among lamprey from different natal origins. Exploration of these patterns has required extensive baselines of full-sibling families collected among larval and juveniles from rotary screw traps. Full-sibling baselines can then be used to identify natal-origins to precise locations upstream of screw trap sites. Continuing to collect adults for future studies e.g. Hg, PCBs, metabarcoding.	Natal origins among Pacific Lamprey collected from Pacific Hake surveys and fisheries along the U.S. West Coast. (2017 – present)	Jon E. Hess (CRITFC); Laurie A. Weitkamp (NOAA)
Genetic methods to elucidate natal origins and document recolonization in Pacific lamprey	2017 - 2021	Demonstration of three genetic methods and their effectiveness for determination of natal origins of Pacific Lamprey: Genetic Stock Identification, Parentage Analysis, and Sibship Analysis. Used a case study in the Elwha River post dam-removal to document the reintroduction and accomplish natal	Fine spatial scale (natal origins within the Elwha River Basin); intermediate spatial scale (natal origins among basins of the Olympic Peninsula, WA); broad spatial scale (natal origins along the U.S. West Coast)	Jon E. Hess (CRITFC); Rebecca L. Paradis (LEKT); Mary L. Moser (NOAA); Laurie A. Weitkamp (NOAA); Thomas A.

		origin objectives relevant to management. (Hess et al. 2022)		Delomas (IDFG); Shawn R. Narum (CRITFC)
Genetic methods to elucidate natal origins, sources and sinks of abundance, and document adult return of Columbia River Pacific lamprey	2011 - 2022	Application of Parentage and Sibship analyses to determine natal origins across broad geographic regions. Used the translocation programs from NPT, CTUIR, and YN to identify returning adult offspring back to Bonneville Dam and other areas of the Columbia River. Refined models that incorporated ocean duration to predict future returns of Pacific Lamprey to the Columbia River.	Fine spatial scale (natal origins from Columbia River basin), broad spatial scale (natal origins across basins throughout species range)	Jon Hess (CRITFC); Ralph Lampman (YN); Aaron Jackson (CTUIR); Tod Sween (NPT); Lyman Jim (CTWS); Nathan McClain (USACOE); Greg Silver (CRITFC); Laurie Porter (CRITFC); Shawn Narum (CRITFC)
PIT tagging ocean-caught lamprey	2017 – present	Lamprey in good condition caught by the NOAA/NWFSC hake survey are anesthetized, tagged with a PIT tag, allowed to recover, and released back into the ocean. To date 14 lamprey have been tagged (10 in 2024) but none have been subsequently detected at Bonneville Dam.	North Pacific Ocean	Laurie Weitkamp (NOAA); Alicia Billings (NOAA); Christina Wang (USFWS)
Size, condition, gut fullness, and distribution of Pacific Lamprey and Western River Lamprey	2017 – 2022	Size, gut fullness, timing, and location of Lampreys caught by commercial fisheries (hake, shrimp) and stock assessment surveys (hake, ground fish, salmon). (Weitkamp et al. 2023)	North Pacific Ocean	Laurie Weitkamp (NOAA); Alicia Billings (NOAA); Vanessa Tuttle (NOAA); John Buchanan (NOAA); Jon Hess (CRITFC)
Trophic biomarkers of Pacific Lamprey	2019-present	Using trophic biomarkers (stable isotopes, fatty acids) to explore feeding histories of lamprey and determine the importance of lamprey body size and where and lamprey was caught (which fishery, location, season, etc.).	North Pacific Ocean	Laurie Weitkamp (NOAA); Kinsey Frick (NOAA)

Natal origins and age of Pacific Lamprey	2020-2022	Isotopic signatures in statoliths and eye lenses of out-migrating juveniles have the potential to define natal origin of Pacific lamprey. Goals are to identify: 1) biogeochemical tracers to ascertain Pacific Lamprey natal origin; 2) some potential natal areas or characteristics of natal areas of Pacific Lamprey returning to the Columbia River, and 3) use of statoliths to predict age. Understanding natal areas that contribute to adult production will help assess population dynamics and population structure. Results could guide conservation and translocation decisions for Pacific lamprey from local to landscape scales and could inform stream management decisions. (Pelekai et al. 2023)	Samples are collected from the Columbia River Basin and elsewhere in Oregon and Washington. Additional samples of out-migrating juveniles are welcomed from other locations in WA, OR, and CA.	Julianne Harris (USFWS); Jessica Miller (OSU); Jon E. Hess (CRITFC)
Host use by Pacific lamprey	2017-present	Use metabarcoding of ocean-caught lamprey gut contents to detect DNA of species that were hosts or prey. Required development of blocking primers (against lamprey DNA).	Samples from the North Pacific Ocean, also Columbia River, Klamath River	Claire Goodfellow (OSU); Taal Levi (OSU); Jon Hess (CRITFC); Laurie Weitkamp (NOAA); Greg Silver (CRITFC)

II. Status for the RMU

Not yet applicable.

References

Clemens, B. J., L. Weitkamp, K. Siwicke, J. Wade, J. Harris, J. Hess, L. Porter, K. Parker, T. Sutton, and A. M. Orlov. 2019. Marine biology of the Pacific Lamprey *Entosphenus tridentatus*. Reviews in Fish Biology and Fisheries. 29: 767 – 788.

Goodman, D. H., S. B. Reid, M. F. Docker, G. R. Haas, and A. P. Kinziger. 2008. Mitochondrial DNA evidence for high levels of gene flow among populations of a widely distributed anadromous lamprey *Entosphenus tridentatus* (Petromyzontidae). Journal of Fish Biology. 72: 400 – 417.

Hess J. E., N. R. Campbell, D. A. Close, M. F. Docker, and S. R. Narum. 2013. Population genomics of Pacific Lamprey: adaptive variation in a highly dispersive species. Molecular Ecology. 22: 2898 – 2916.

Hess, J. E., N. R. Campbell, M. F. Docker, C. Baker, A. Jackson, R. Lampman, B. McIlraith, M. L. Moser, D. P. Statler, W. P. Young, A. J. Wildbill, and S. R. Narum. 2015. Use of genotyping by sequencing data to develop a high-throughput and multifunctional SNP panel for conservation applications in Pacific Lamprey. Molecular Ecology Resources. 15: 187–202.

Hess, J.E., R. L. Paradis, M. L. Moser, L. A. Weitkamp, T. A. Delomas, and S. R. Narum. 2020. Robust recolonization of Pacific Lamprey following dam removals. Trans. Am. Fish. Soc. DOI: 10.1002/tafs.10273

Hess, J.E., T. A. Delomas, A. Jackson, M. J. Kosinski, M. L. Moser, L. Porter, G. Silver, T. Sween, L. A. Weitkamp, and S. R. Narum. 2022. Pacific Lamprey translocations to the Snake River boost abundance of all life stages. Trans. Am. Fish. Soc. 151:263–296; Doi: 10.1002/tafs.10359

Hess, J.E., R. T. Lampman, A.D. Jackson, T. Sween, L. Jim, N. McClain, G. Silver, L. Porter, and S. R. Narum. 2023. The return of the adult Pacific Lamprey offspring from translocations to the Columbia River. N. Am. J. Fish. Manage. 43:1531–1552, DOI: 10.1002/nafm.10922

Murauskas, J. G., A. M. Orlov, and K. A. Siwicke. 2013. Relationships between the abundance of Pacific Lamprey in the Columbia River and their common hosts in the marine environment. Transactions of the American Fisheries Society. 142: 143 – 155.

Murauskas, J. G., A. M. Orlov, L. Keller, O. A. Maznikova, and I. I. Glebov. 2019. Transoceanic migration of Pacific lamprey, *Entosphenus tridentatus.* Journal of Ichthyology. 59: 280 – 282.

National Marine Fisheries Service (NMFS). 2024. NMFS West Coast Offshore Wind Energy Strategic Science Plan. National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center, Seattle, Washington; Southwest Fisheries Science Center, La Jolla, California; West Coast Region, Long Beach, California. https://doi.org/10.25923/5dmm-8z74

Orlov, A., R. Beamish, A. Vinnikov, and D. Pelenev. 2009. Feeding and prey of Pacific Lamprey in coastal waters of the Western North Pacific. Pages 875 – 877 In: L. R. Brown, S. D. Chase, M. G. Mesa, R. J. Beamish, and P. B. Moyle (editors), Biology, management, and conservation of lampreys in North America. American Fisheries Society, Symposium 72, Bethesda, Maryland.

Orlov, A. M., V. F. Savinyh, and D. V. Pelenev. 2008. Features of the spatial distribution and size structure of the Pacific Lamprey, *Lampetra tridentata* in the North Pacific. Russian Journal of Marine Biology. 34: 276 – 287.

Pacific Lamprey Conservation Initiative (PLCI). 2024. Pacific Lamprey (*Entosphenus tridentatus*) Status Assessment. June 2024. 114 pp. + Appendices. Available: https://www.pacificlamprey.org/assessment/.

Pelekai, K. N. 2021. Evaluation of Pacific lamprey *Entosphenus tridentatus* anatomical structures as records of age and isotopic histories. Master's Thesis, Oregon State University, Corvallis.

Pelekai, K. N., J. E. Hess, L. A. Weitkamp, R. Lampman, and J. A. Miller. 2023. Evaluation of Pacific Lamprey Entosphenus tridentatus statoliths for growth and ageing. North American Journal of Fisheries Management 43:1610–1622. DOI: 10.1002/nafm.10920

Renaud, C. B. 2008. Petromyzontidae, *Entosphenus tridentatus*: southern distribution record, Isla Clarión, Revillagigedo Archipelago, Mexico. Check List. 4: 82 – 85.

Renaud, C. B. 2011. Lampreys of the world: An annotated and illustrated catalogue of lamprey species known to date. Food and Agriculture Organization of the United Nations, Rome. Species Catalogue for Fishery Purposes No. 5. 109 pp.

Siwicke, K. A., and A. C. Seitz. 2017. Spatial differences in the distributions of Arctic and Pacific Lampreys in the eastern Bering Sea. Transactions of the American Fisheries Society. *In Press*.

Spice, E. K., D. H. Goodman, S. B. Reid, and M. F. Docker. 2012. Neither philopatric nor panmictic: microsatellite and mtDNA evidence suggest lack of natal homing but limits to dispersal in Pacific Lamprey. Molecular Ecology. 21: 2916 – 2930.

USFWS (U. S. Fish and Wildlife Service). 2018. Pacific Lamprey *Entosphenus tridentatus* assessment. August 27, 2018 Draft for external review. Available: https://www.fws.gov/pacificlamprey/AssessmentMainpage.cfm

Wade, J., and R. Beamish. 2016. Trends in the catches of River and Pacific Lamprey in the Strait of Georgia. Pages 57–72 *in* A. M. Orlov, and R. J. Beamish, editors. Jawless fishes of the world, volume 2. Cambridge Scholars Publishing, New Castle upon Tyne, UK.

Weitkamp, L. A., V. Tuttle, E. J. Ward, D. Kamikawa, A. Billings, J. Buchanan, and J. E. Hess. 2023. Pacific Lamprey and Western River Lamprey marine ecology: insight from new ocean collections. North American Journal of Fisheries Management 43:1492–1510. https://doi.org/10.1002/nafm.10936.

Yamazaki, Y., N. Fukutomi, N. Oda, K. Shibukawa, Y. Niimura, and A. Iwata. 2005. Occurrence of larval Pacific Lamprey *Entosphenus tridentatus* from Japan, detected by random amplified polymorphic DNA (RAPD) analysis. Ichthyological Research. 52: 297 – 301.