Pacific Lamprey (*Entosphenus tridentatus*) Status Assessment

Pacific Lamprey Conservation Initiative

June 2024

DISCLAIMER

The Pacific Lamprey Assessment was written with the most current information available, gathered at regional meetings hosted throughout the United States range of Pacific Lamprey in 2022. Any new information will be incorporated into subsequent updates of the Assessment and into the Regional Implementation Plans.

RECOMMENDED CITATION

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COVER PHOTO CREDIT

Freshwaters Illustrated

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The 2022 Pacific Lamprey Assessment revision relied on the voluntary participation of federal, state, and local government agencies, Native American tribal entities and members, scientific institutions, consultants, non-profit groups, utility companies, private landowners and many others across the range of Pacific Lamprey, including California, Oregon, Washington, Idaho, and Alaska. The Regional Management Unit (RMU) leads gratefully acknowledge the numerous individuals who participated in the regional meetings related to the 2022 Pacific Lamprey Assessment and/or provided data, information and insight on Pacific Lamprey across all RMUs. For a list of partners who contributed to the 2022 Pacific Lamprey Assessment revision, please see the 2022 Regional Implementation Plans corresponding to each RMU available on the Pacific Lamprey Conservation Initiative website (https://www.pacificlamprey.org/) and Appendix A.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ACRONYM AND SYMBOL LIST

ADFG	Alaska Department of Fish and Game
BKD	Bacterial Kidney Disease
BLM	Bureau of Land Management
BMG	Best Management Guidelines
BOR	U.S. Bureau of Reclamation
BPA	Bonneville Power Administration
CDFG	California Department of Fish and Game
CRBLTWG	Columbia River Basin Lamprey Technical Work Group
CRITFC	Columbia River Inter-Tribal Fish Commission
CSR	Conservation Status Rank
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
DDE	Dichlorodiphenyldichloroethylene
DNA	*Deoxyribonucleic acid*
eDNA	*Environmental DNA*
ESA	U.S. Endangered Species Act
FCRPS	Federal Columbia River Power System
FY	Fiscal Year
GIS	Geographic Information System
HUC	Hydrologic Unit Code
ID	Identification
IDFG	Idaho Department of Fish and Game
IHNV	Infectious Hematopoietic Necrosis Virus
IUCN	International Union for Conservation of Nature
LTWG	Lamprey Technical Workgroup

ACRONYM AND SYMBOL LIST (Continued)

mtDNA	Mitochondrial DNA
NA	Not applicable
N*e*	Effective Population Size
NFHP	National Fish Habitat Partnership
NGO	Non-governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	U.S. National Park Service
NPT	Nez Perce Tribe
ODFW	Oregon Department of Fish and Wildlife
ODHS	Oregon Department of Human Services
PCB	Polychlorinated biphenyls
PGE	Portland General Electric
PLCI	Pacific Lamprey Conservation Initiative
PNNL	Pacific Northwest National Laboratory
qPCR	Quantitative Polymerase Chain Reaction
RKM	River Kilometer
RIP	Regional Implementation Plan
RMU	Regional Management Unit
SIP	Steelhead Intrinsic Potential
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VHSV	Viral Haemorrhagic Septicaemia Virus
WDFW	Washington Department of Fish and Wildlife
YNF	Yakama Nation Fisheries

EXECUTIVE SUMMARY

Overview

Pacific Lamprey *Entosphenus tridentatus* were historically widespread along the West Coast of North America; however, their abundance has declined and their distribution has contracted throughout California, Oregon, Washington, and Idaho (Luzier et al. 2009). Threats to Pacific Lamprey are diverse and occur throughout much of the range of the species including: mainstem and tributary passage barriers, degraded habitat conditions, reduced stream flows, dewatering of habitat, poor water quality, predation by nonnative/invasive species, changing marine conditions and impacts of climate change. These threats in conjunction with reduced distribution and reduced abundance affect the status of Pacific Lamprey.

Pacific Lamprey are culturally important to Indigenous peoples throughout their range, are vital to freshwater and marine ecosystems as prey for mammals, fish and birds, and for nutrient cycling and storage. Reductions of abundance and range of Pacific Lamprey have prompted a collaborative conservation effort by tribes, agencies, and many others, called the Pacific Lamprey Conservation Initiative (PLCI). The PLCI is facilitating opportunities to address threats, restore habitat, increase knowledge, and improve distribution and abundance in California, Oregon, Washington, Idaho, and Alaska. The Initiative has three components: the Pacific Lamprey Assessment (Luzier et al. 2011; Goodman and Reid 2012; USFWS 2018; this update); the Conservation Agreement (PLCI 2012, 2022); and multiple Regional Implementation Plans (https://www.pacificlamprey.org/rmu/).

Every five years partners from each Regional Management Unit (RMU) revise the Pacific Lamprey Assessment (Assessment). The Assessment uses the best scientific information available to identify environmental and human-caused threats and assess the relative risk of extirpation by watershed and geographic region. For each revision, risk of extirpation is re-evaluated with current information on population demographics and threats to assess current status and identify changes that have occurred over the last five years. Results of this Assessment will be used to identify priority threats and data gaps within RMUs and guide the prioritization of conservation measures to address critical threats and uncertainties for Pacific Lamprey.

The same NatureServe model version and conservation factors used in previous Assessments were used to re-evaluate the conservation risk of Pacific Lamprey in 2022. However, minor refinements were made to conservation factors and threats descriptions to promote consistency of interpretation among RMUs.

Key Conclusions

A total of 210 Hydrologic Unit Code 4 (HUC 4) watersheds were assessed in California, Oregon, Washington and Idaho RMUs, including 21 HUCs that were evaluated for the first time in Puget Sound/Strait of Juan de Fuca, Washington Coast, Mid-Columbia and Upper Columbia. NatureServe conservation status ranks (CSRs) changed in 29 HUCs (14%) from the 2018 to 2022 Assessment, improving in 11 HUCs and worsening in 18 HUCs. Watersheds with improved CSRs were attributed to natural increases in population abundance or distribution (i.e., without human intervention), passage improvements, natural recolonization of Pacific Lamprey into historical habitat (e.g., after dam removal), or areas where human-assisted efforts such as adult translocations past barriers have occurred. The worsening of CSRs was due to the absence of lamprey, ranking uncertainty (e.g., partners were unable to rank short-term trend in 52% and population size in 30% of HUCs), the uncertainty in the NatureServe model, or a worsening of threats. Conservation status ranks ranged from Presumed Extirpated (SX) to Vulnerable (S3), with the highest proportion of HUCs falling in the Critically Imperiled (S1; 41%) and Imperiled categories (S2; 27%). The overall pattern of risk is unchanged in the 2022 Assessment. Pacific Lamprey populations at highest relative risk are those in the Upper Columbia, Snake and Mid-Columbia River RMUs. All 53 HUCs in these areas were ranked Presumed Extirpated (13%), Possibly Extirpated (21%) or Critically Imperiled (62%) except for two HUCs in the Mid-Columbia RMU that were ranked Imperiled. Lower risk areas such as parts of the Willamette RMU (Oregon) and several HUCs along the coast of California, Oregon, and Washington are located downstream of major mainstem passage barriers but were still primarily ranked Critically Imperiled or Imperiled. Three HUCs currently ranked at lowest risk in 2022 (Vulnerable; S3), include the Clackamas River (Willamette RMU), Smith River (California North Coast RMU) and San Francisco Coastal South (California South Central Coast RMU). The Assessment was not conducted in Alaska, the Mainstem Columbia/Snake or North Pacific Ocean RMUs; however, an update on available information is provided in chapter 5.

Knowledge of Pacific Lamprey distribution and population demographics in all RMUs has continued to increase over time. Current distribution expanded in 24 HUCs in 2022 due to adult translocation efforts, increased awareness and sampling effort for Pacific Lamprey, and passage improvements. Our ability to estimate the abundance of Pacific Lamprey has also improved. We have quantitative estimates of adult abundance in many HUCs along the coasts of Oregon and Washington, and the Columbia Basin RMUs from nest count information and adult counts at mainstem Columbia River dams. Outside of these locations, there is still high uncertainty regarding adult abundance. Short-term population trend was ranked as "Unknown" in 110 HUCs (52%) due to the lack of continuous, long-term adult count data. Of the 100 HUCs that ranked short-term population trend, ten watersheds are believed to be stable or increasing, whereas 90 are believed to be declining.

High priority threats have remained relatively consistent with those identified in the 2018 Assessment. Mainstem passage is still the most serious threat impacting Pacific Lamprey in the Upper Columbia, Snake and Mid-Columbia RMUs. The cumulative impacts of passage impediments in the mainstem rivers and their tributaries has led to fewer Pacific Lamprey reaching the upper Columbia and Snake Rivers thus, small effective population size was also ranked a high priority threat in these RMUs. Climate change was identified as a high priority threat in all RMUs (68 HUCs) except California where climate change was not ranked in 2022 due to a lack of information. This was a major shift from the 2018 Assessment in which the scope and/or severity of climate change was not ranked due to a lack of information, or ranked as "Unknown" in 41% of watersheds assessed (39 HUCs). Stream and floodplain degradation, lack of awareness and poor water quality were also high-ranking threats in RMUs below Bonneville Dam and outside of the Columbia Basin (excluding some California RMUs). Passage was the principal threat to Pacific Lamprey in California RMUs where the presence of over 59 large, impassable dams collectively blocks 8,954 km (48%) of historical habitat in 4th order or higher streams. Dewatering and flow management and poor water quality were also recognized as high priority threats in California RMUs. Over 40% of HUCs are heavily impacted by urbanization, water withdrawals, water diversions, flow manipulation and drought conditions, potentially leading to or exacerbating impaired water quality conditions.

While data gaps and uncertainties remain, the 2022 Assessment illustrates major changes to population demographics, threats and the relative risk level of populations of Pacific Lamprey over time. Each revision of the Assessment has used the same NatureServe model version and ranking procedures to evaluate conservation risk; however, specific elements of the model have been modified to improve the accuracy and interpretation of conservation factors. For example, the methods for calculating and ranking range extent, area of occupancy and threats were modified in 2018 and the definitions of two threat categories, population size and short-term trend were refined in 2022. Some of these revisions resulted in the direct change (both improvement and worsening) of CSRs in HUCs. Assessment results can also be influenced by the RMU partners who participate in the Assessment ranking process and their interpretation or perception of specific conservation factors or threats. A direct comparison of Assessment results (i.e., 2011 vs 2018 vs 2022) is somewhat challenging given the modifications to NatureServe parameters or potential bias of participants. However, the type of information collected for each Assessment has not changed over time and the quality of information input into the model has improved with each revision. Each Assessment revision builds off the knowledge of previous Assessments and uses the best information available at the time. As conservation measures are successfully implemented and we learn more about Pacific Lamprey population demographics and threats, the NatureServe CSRs will inevitably change to reflect new/improved knowledge and information.

Change of NatureServe CSRs (signifying an improvement or worsening of extinction risk) can occur for many reasons, including a genuine on-the-ground change in the status of a population, NatureServe assignment rules or model uncertainty, or more commonly, a change in the scope/severity values of a threat (e.g., climate change worsened from an "Unknown" threat to a "High" threat in 29 HUCs in 2022). Change in the intensity of threats was typically due to an expanded awareness of threats or a true improvement or worsening of conditions. Threats such as lack of awareness, tributary passage and stream and floodplain degradation have improved slightly over the last decade, while the threats of poor water quality and dewatering have worsened over time, largely due to increasing concerns about climate change. Predation (by nonnative/invasive fish species) and contaminants were also identified as rising concerns for Pacific Lamprey in 2022, but the scope and severity of these threats is not fully known.

Understanding of Pacific Lamprey distribution, population size and threats has expanded considerably over the last ten years due to increased awareness and targeted sampling efforts, but there is still a scarcity of baseline population demographic and threat information in many HUCs across the region. For example, interest and participation within the Alaska RMU has grown substantially over the last five years, but the status of Pacific Lamprey there is still unknown. More work will be needed to continue raising awareness of Pacific Lamprey, building communication networks among partners and compiling baseline information about lamprey across the state. Tribes, states and federal agencies, watershed councils, the PLCI and others have played a significant role in improving Pacific Lamprey awareness through targeted outreach, webinars, ID workshops, informational brochures, technical guidance documents and education events like the Lamprey Information Exchange. A growing number of partners are implementing projects that target or incorporate benefits for Pacific Lamprey, but there is still a need for more awareness regarding the life cycle, species identification, habitat requirements and inclusion of Pacific Lamprey in the design and implementation of fish passage/screening, dredging and disposal actions, and habitat restoration projects. Educating biologists, conservation and fisheries managers, permit reviewers, funding agencies, and the general public about the cultural and ecological importance of Pacific Lamprey will continue to be an essential component of Pacific Lamprey conservation and restoration efforts.

1. INTRODUCTION: PACIFIC LAMPREY CONSERVATION INITIATIVE

Pacific Lamprey Conservation Initiative

The Pacific Lamprey Conservation Initiative (PLCI) is a consortium of partners from tribes, federal, state and local agencies and NGOs from Alaska, California, Idaho, Oregon, and Washington. The goal of PLCI is to achieve long-term persistence of Pacific Lamprey and support traditional cultural use throughout their U.S. historical range. The PLCI promotes implementation of conservation measures for Pacific Lamprey through an adaptive management framework consisting of three elements: the Assessment (Luzier et al. 2011; Goodman and Reid 2012; USFWS 2019; PLCI 2024); Conservation Agreement (PLCI 2012, 2022); and Regional Implementation Plans (https://www.pacificlamprey.org/rmu/).

Pacific Lamprey Assessment

The first Assessment was completed in 2011 to evaluate the status of Pacific Lamprey throughout its U.S. range. At the time, a systematic evaluation of Pacific Lamprey status had not been conducted even though they were designated as a state sensitive species and federally as a species of concern. For decades, the Columbia River tribes had noticed declines in abundance at the usual and accustomed harvest locations (Close et al. 2002). We employed the NatureServe Conservation Status Assessment (Faber-Langendoen et al. 2009; Master et al. 2009) to guide our conservation planning for Pacific Lamprey. The NatureServe method returns a conservation status rank (CSR), or relative risk of extirpation, by factoring population demographic and threat information at discrete geographic scales. By using a consistent approach to gather data on these factors, we are forming a long-term dataset that can be used to inform conservation measures for Pacific Lamprey in an adaptive management framework.

Every five years PLCI conducts the Assessment and this is the third iteration. Previous versions can be found on PLCI's website through the following links: Luzier et al. 2011; Goodman and Reid 2012; USFWS 2019. The purpose of revising the Assessment is to capture changes to conservation risk of Pacific Lamprey as restoration actions are implemented in the Regional Management Units (RMUs). Information for the Assessment is collected through a series of RMU meetings. This information is summarized to assess overall threat patterns, calculate relative risk, and guide the identification and prioritization of conservation priorities, actions, and data collection efforts for Pacific Lamprey in conjunction with the RMU's Regional Implementation Plans.

Conservation Agreement

The Agreement represents a cooperative and voluntary commitment by tribes, federal, state and local agencies and NGO partners to leverage available resources (human and capital) to reduce or eliminate threats to Pacific Lamprey in the face of climate change and to improve important habitats and connectivity among those habitats, so that the species can express its full life cycle. Goals of the Agreement are to achieve long-term persistence of Pacific Lamprey and to support treaty-reserved tribal harvest and traditional tribal use of Pacific Lamprey throughout their historical range. The parties envision a future where threats to Pacific Lamprey are reduced, and the historical geographic range and ecological roles of Pacific Lamprey are restored. First signed in 2012 by 33 signatories and 12 supporters, the Agreement is reviewed every five years. In 2022, the Agreement went through a comprehensive review and update by PLCI partners to reflect operational changes within and progress made through PLCI. Thirty-seven partners signed on to the new Agreement and 17 more submitted letters of support. The 2022 Agreement can be found on PLCI's website (https://www.pacificlamprey.org/conservation-agreement/).

Regional Implementation Planning

There are 18 RMUs spanning the U.S. range of Pacific Lamprey from Alaska to California, including the North Pacific Ocean. The RMUs are made up of local partners who share data and information that informs the Assessment, collaborative projects and Regional Implementation Plans (RIPs). The RIPs identify local threats, priorities, and research and conservation measures needed to conserve and protect Pacific Lamprey and their habitats. RMUs meet annually to update their RIPs. More information about the RMUs and current and past RIPs can be found on PLCI's website (https://www.pacificlamprey.org/rmu/).

Lamprey Technical Workgroup

The Lamprey Technical Workgroup (LTWG) is the technical committee for the PLCI serving the U.S. range of Pacific Lamprey. The LTWG provides technical review and develops white papers, peer reviewed publications and best management guidelines on a variety of topics affecting Pacific Lamprey. More information about the LTWG, its 12 subgroups, and recent publications can be found on the PLCI website (https://www.pacificlamprey.org/ltwg/).

Funding Sources

PLCI receives project funding through Bonneville Power Administration's Pacific Lamprey Conservation Initiative Columbia Basin Project and the National Fish Habitat Partnership (NFHP) (http://www.fishhabitat.org/). Since 2018, BPA has funded more than 40 lamprey research, conservation and restoration projects in the Columbia Basin RMUs. PLCI became a NFHP partnership in 2016 and started receiving project funding in 2022. Approximately 20 projects have been funded through NFHP and implemented across all RMUs. Projects for both funding sources are selected annually through an open proposal process and address conservation and research priorities identified in the RIPs.

Conservation Efforts and Accomplishments

PLCI partners have accomplished many conservation and research projects for Pacific Lamprey since the last Assessment. Examples of the many ongoing and completed projects include: distribution and occupancy studies; passage assessments in tributaries and mainstem habitats; habitat restoration projects and monitoring; large and small dam and diversion removals; fish ladder modifications and installation of lamprey passage structures; temperature tolerance studies; new information on marine ecology; implementation of artificial propagation programs; lamprey translocation, supplementation, reintroduction and monitoring; evaluation of larval/juvenile entrainment at irrigation diversions and other barriers and screen improvements; water quality evaluations; climate change vulnerability assessments; predation studies; habitat assessments; incorporation of lamprey into restoration design and implementation; lamprey identification training workshops; education and outreach to stakeholders, resource managers and community members; development of regional and local lamprey working groups.

Strengthening partnerships was a priority during the last five years. In December 2022, the PLCI convened Lamprey Summit V. Since 2004, partners have convened every four to five years to revisit the current science and status of Pacific Lamprey and to recommit to collaboration. Lamprey Summit V, attended by 150 PLCI partners, featured inspiring keynote addresses and a ceremonial signing of the Agreement during which many partners expressed their support for PLCI's collaborative conservation efforts. PLCI formed the Lamprey Communication Committee in partnership with the Great Lakes Fishery Commission and other partners. The committee discusses ways to work collaboratively on native lamprey conservation and promotion of healthy ecosystems.

Increasing awareness of Pacific Lamprey and providing outreach and education continued to be at the forefront of PLCI. Since 2017, the Lamprey Technical Workgroup has hosted an annual Lamprey Information Exchange where hundreds of participants learn about and discuss emerging lamprey science and conservation. PLCI partners have convened lamprey sessions at national, regional and local meetings and participated in numerous other workshops and outreach events. PLCI's website, pacificlamprey.org, continues to provide a wealth of information to our partners and the general public. Our listserv has over 1500 subscriber contacts and continues to grow.

2. BACKGROUND

Importance of Lamprey

***Cultural Significance* —** Pacific Lamprey play a key role in indigenous cultures. As a First Food, Pacific Lamprey are a source of subsistence, medicine, and tradition to the tribes (CRITFC 2011). Without the continued opportunity to fish for lamprey, tribes would lose the ability to pass down valuable traditions to younger members, which would result in loss of indigenous knowledge (Close et al. 2002; CRITFC 2011; Sheoships 2014; FiveCrows et al. 2023). As a tribal trust species and species of high conservation risk, it is critical to elevate the urgency and support for addressing lamprey threats across their current and historical distribution to ensure the cultural connection to lamprey is not lost.

***Ecosystem Services* —** Pacific Lamprey play a key role in the ecosystem (Close et al. 2002; CRITFC 2011). At every life stage they have unique and important relationships with other species and the communities to which they belong. In their nests, eggs, embryos and pro-larvae are a rich food for aquatic species including benthic invertebrates, drift-feeding fishes and even certain amphibians. The larval stage of lampreys is of particular importance because in streams where they are abundant, they can comprise a large portion of the biomass and they process, store and cycle nutrients (Kan 1975; Beamish 1980; Merritt et al. 1984; Close et al. 2002). The protracted larval phase ensures a constant source of nutrients to the food web and provides various other ecosystem services (Close et al. 2002; Shirakawa et al. 2012; Boeker and Geist 2016). In a study assessing impacts on the physical and geochemical factors in the streambed, Shirakawa et al. (2012) found that the feeding and burrowing behavior of two species of Lethenteron lamprey "increased oxygen levels, maintained softness and increased abundance of fine particulate organic matter in and on the streambed." Boeker and Geist (2016) explored the contribution of burrowing lampreys to bioturbation and overall ecosystem health. They found that bioturbation caused by lamprey burrowing resulted in a strong increase in oxygen availability and nitrate concentrations in the interstitial water between sediment particles, as well as a shift in the microbial community composition to one dominated by aerobic bacteria. Larval lampreys clearly play an important role as 'ecosystem engineers' (Shirakawa et al. 2012; Hogg et al. 2014; Boeker and Geist 2016).

As juveniles, Pacific Lamprey migrate to the ocean during winter and spring freshets and along their journey become a primary food source for multiple fishes and birds (Arakawa and Lampman 2020). Lampreys comprise approximately 70% of the diet of some gulls and terns in the mainstem Columbia River (Merrell 1959). Juveniles migrating downstream may buffer salmonids from predation by birds, mammals, and other fishes (Close et al. 2002). Pacific Lamprey juveniles in the oceans are both prey and parasites. They parasitize a large variety of fish and mammal hosts (e.g., Clemens et al. 2019, Weitkamp et al. 2023). Pacific Lamprey have 32 documented hosts ranging from salmon and rockfish species to mackerel, herring and five species of whales (Clemens et al. 2019; Quintella et al. 2021) and 6 new species have recently been documented (Weitkamp et al. 2023), bringing the total to 38.

Adult Pacific Lamprey returning upstream are an important food for freshwater fishes, birds, and mammals. They may act as a predation buffer at this life stage as well, being a preferred food source for marine mammals due to their high caloric value (Close et al. 1995). Caloric values for lamprey range from 5.92 to 6.34 kcal/g wet weight (Whyte et al. 1993); whereas salmon average 1.26 to 2.87 kcal/g wet weight (Stewart et al. 1983). The most abundant dietary item in seals and sea lions in the Rogue River, Oregon was found to be Pacific Lamprey (Roffe and Mate 1984). In their final act of service to the ecosystem, adult Pacific Lamprey die after spawning, leaving the marine-derived nutrients in freshwater streams during the time that salmon carcasses are absent (Beamish 1980).

Geographic Distribution

Historical — The range of Pacific Lamprey historically extended from Hokkaido Island, Japan; and around the Pacific Rim including Alaska, Canada, Washington, Oregon, Idaho; and California to Punta Canoas, Baja California, Mexico (Vogt 1988; Beamish and Northcote 1989; Swift et al. 1993; Moyle et al. 1996; Ruiz-Campos and Gonzalez-Guzman 1996; Ruiz-Campos et al. 2000; Chase 2001; USFWS 2004a; Hamilton et al. 2005; Yamazaki et al. 2005; Renaud 2008). In North America, their distribution included major river systems such as the Fraser, Columbia, Klamath-Trinity, Eel, and Sacramento-San Joaquin rivers, along with most moderately sized coastal drainages, >20 km2 (Reid and Goodman 2015). Pacific Lamprey are the most widely distributed lamprey species on the west coast of the United States.

Current — In Japan, Pacific Lamprey have been documented in the Naka River on Honshu Island, as well as in other river systems on Hokkaido Island (Yamazaki et al. 2005). Population status in British Columbia is unranked but may be secure (Renaud et al. 2009). Status is still unknown in Alaska, but observations of Pacific Lamprey have been documented since 2019 in the Susitna River tributaries and in the Gulkana River in the Copper River watershed (Sutton, Garcia, Cathcart and Shink 2023). Anecdotal and empirical information suggests that Pacific Lamprey populations have declined or been locally extirpated in parts of California, Oregon, Washington, and Idaho (Close 2001; Moser and Close 2003; Luzier et al. 2009; Moyle et al. 2009; Swift and Howard 2009). In these states, Pacific Lamprey have declined in their distribution along all coastal streams and large rivers, including the Columbia River Basin. They are extirpated in parts of Southern California, and across their range above dams and other impassable barriers. Although known data on historical distribution are limited, availability of current distribution data has increased in Oregon, Washington, and Idaho with the development of a regional Pacific Lamprey distribution geodatabase (USFWS, 2016). This database includes data from targeted lamprey surveys, incidental observations during other stream surveys or monitoring efforts, and salvage during in-stream work. Although not exhaustive, data are continually added to augment and maintain an updated database of observations and distribution. Because of expanded distribution information, initial assessments have been possible for many watersheds in western Washington. In the Puget Sound/Strait of Juan de Fuca RMU, the amount of known occupied habitat increased by 70% over 2017 data. An additional 3373 km^2 of occupied habitat was added to the current distribution from 2017-2022. For the most part, these changes do not represent expansions of Pacific Lamprey distributions, but rather new observations or mining existing data sources. For example, in the Lower Columbia, Washington Coast, and Puget Sound RMUs, the large expansions in current distributions were driven by Pacific Lamprey documented in salmonid focused spawning ground surveys, which had previously not been included in the distribution geodatabase. However, in the Upper Columbia RMU, the change in current distribution was indeed driven by expansions into historically occupied reaches due to tribal translocation programs. These translocations moved Pacific

Lamprey into eight subbasins, including the Okanogan River where current distributions increased by over 300%. Data availability has increased in California due to a California distribution database populated and maintained by Reid and Goodman (2017). Natural recolonizations of the Santa Margarita River have expanded the current distribution of Pacific Lamprey further south. Available historical and current Pacific Lamprey distribution is presented for each RMU in the annual RIPs (www.pacificlamprey.org/rmu/).

Biology Overview

All lampreys are jawless fishes and considered part of a large, ancient super class (Agnatha) that dates back about 450 million years ago (Purnell 2001). Pacific Lamprey are largely nocturnal, anadromous, and semelparous (Figure 1). Larval Pacific Lamprey are ~8 mm at hatch and largely remain burrowed in fine sediment deposits, where they filter feed on particulate matter in freshwater habitats for up to ~10 years (Dawson et al. 2015; Hess et al. 2022). As they grow, the larvae migrate downstream throughout the year, often facilitated by high river flows (Dawson et al. 2015; Moser et al. 2015). Physiological and environmental cues trigger transformation to parasitism (McGree 2008), which typically begins during the summer months and lasts for several months. In the ocean, Pacific Lamprey grow to a relatively large size (up to ~830 mm) over a period of about 1-7 years, and are parasitic on many species of fishes and marine mammals (Beamish 1980; Clemens et al. 2019; Hess et al. 2023; Weitkamp et al. 2023).

Pacific Lamprey typically re-enter freshwater in Spring (April-June) and reside there anywhere from a few weeks to a few years prior to spawning (Clemens et al. 2013). Upstream migration occurs in summer (July-September; Luzier et al. 2006). Migration distance and habitat use of pre-spawning adults varies by year (e.g., river flow, temperature, etc.), river segment, and availability (Clemens and Schreck 2021). Spawning generally occurs in the spring and summer, often in pool tail-outs and deeper riffles with gravel and cobble substrates (Stone et al. 2006; Gunckel et al. 2009; Clemens et al. 2010).

For more information about the biology, life history, and habitat use of Pacific Lamprey, please see the following documents:

- Comparison of Pacific Lamprey and Pacific Salmon Life Histories, Habitat and Ecology; (Lamprey Technical Workgroup 2023; www.pacificlamprey.org/ltwg/).
- Pacific Lamprey *Entosphenus tridentatus* Assessment – 2018 Revision (U.S. Fish and Wildlife Service 2019; www.pacificlamprey.org/assessment/).
- Best management guidelines for native lampreys during in-water work (Lamprey Technical Workgroup 2020; www.pacificlamprey.org/ltwg/).

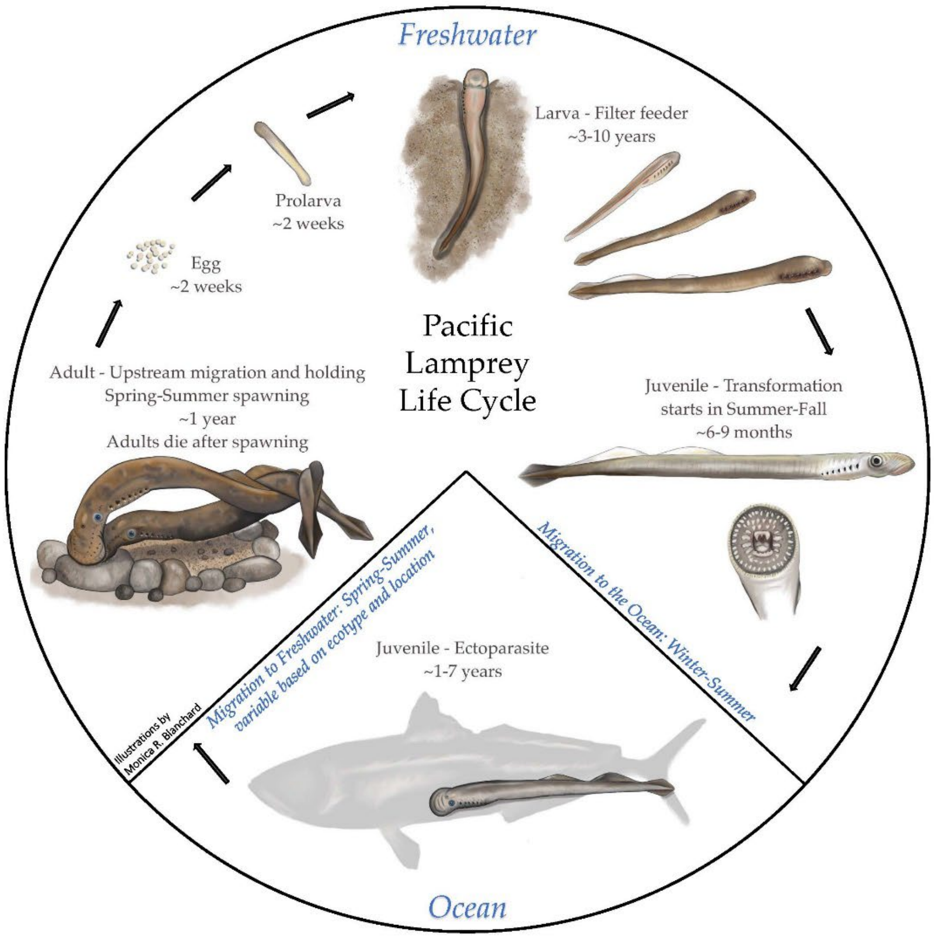

Figure 1. Life history cycle of Pacific Lamprey (Lamprey Technical Workgroup 2023). Please note, this assessment uses the following life history terminology for Pacific Lamprey: larva, transformer, juvenile, and adult, as indicated in Clemens 2019.

Population Structure

There are several major patterns in population genetic structure that have been described for Pacific Lamprey, which have led to the following interpretations:

1) Pacific Lamprey are panmictic: neutral genetic structure indicates relatively high levels of connectivity across the species range and lack of strict natal site homing compared to salmonids (Goodman et al. 2008; Docker 2010; Spice et al. 2012; Hess et al. 2013);
2) Regional genetic differences exist across the range: adaptive genetic structure indicates regional optimization of fitness traits and relatively higher levels of genetic differentiation compared to neutral genetic structure (Lin et al. 2008; Hess et al. 2013; Parker et al. 2019; Hess et al. 2020a); and
3) Pacific Lamprey are not panmictic: despite high levels of gene flow, they do exhibit preferences for homing back to natal river basins (Hess et al. 2022, 2023).

First, Goodman et al. (2008), Docker (2010), Spice et al. (2012), and Hess et al. (2013) all found low levels of genetic differentiation among sites across the Pacific Lamprey species range based on a variety of neutral genetic markers. These studies indicate a high level of historical gene flows among regions even on a broad scale; however, they also showed the potential for low levels of genetic differentiation at some locations. Hess et al. (2013) characterized the following three large geographic regions that represented populations for the NE Pacific range of the Pacific Lamprey: Northern British Columbia, Vancouver Island/Puget Sound, and the West Coast of the U.S. and the Columbia River. These populations have broader distributions (i.e., greater connectivity) compared to populations described for salmonids that overlap in species ranges with Pacific Lamprey (e.g., Chinook salmon; Narum et al. 2010; Moran et al. 2012; and steelhead; Blankenship et al. 2011).

Second, in contrast with neutral genetic structure, there has been adaptive variation (regions of the genome under natural selection) identified in Pacific Lamprey that is associated with fitness traits (e.g., maturity, Parker et al. 2019; body size, Hess et al. 2014, 2020). Characterization of adaptive genetic variation across the Pacific Lamprey species range shows there is both spatial correlation of fitness traits (e.g., coast versus interior basin contrasts), as well as a temporal correlation (within season variation).

Third, Pacific Lamprey appear to display subtle preferences for migration routes such that Snake River origin adults return at higher rates to Bonneville Dam relative to Willamette Falls and areas outside the Columbia River basin (Hess et al. 2023). The extent of homing observed in the Columbia River is not enough to lead to population differentiation as high as observed for anadromous salmonids. It is worth emphasizing that population genetic structure develops on a much larger time scale (e.g., as measured by F_{ST} in Spice et al. 2012) compared to the scale of dispersal measured by Hess et al. (2023).

Thus, there is still much to learn about population structure of Pacific Lamprey. Where there was once thought to be one large panmictic population from Alaska to California, further genetic analysis now suggests there are at least 3 populations across this range (Hess et al. 2013). Each of these populations occupies a much larger geographic area compared to anadromous salmonids in the Pacific Northwest. Even more recent information now indicates homing to natal subbasins and low but detectable dispersal rates across subbasins within the Columbia River (Hess et al. 2023), which may explain the evidence for regional optimization of fitness traits despite the maintenance of high genetic connectivity across broad geographic regions.

Threats/ Reasons for Decline and Current Restoration Activities

Pacific Lamprey are confronted with an array of threats at their various life history stages, and no single threat can be isolated as the primary reason for their apparent decline. Threats include artificial barriers to migration, poor water quality, predation by native and nonnative species, stream and floodplain degradation, loss of estuarine habitat, declines in prey, changes in ocean conditions, dredging, dewatering, climate change, and lack of awareness (Close et al. 1995; Jackson et al. 1996; BioAnalysts, Inc. 2000; Close et al. 2002; Nawa et al. 2003; Clemens et al. 2017a; Schaller et al. 2017; Clemens and Wang 2021).

The complex interactions of these threats and the extent of their impact on Pacific Lamprey populations are still largely unknown. However, in concert, these threats have resulted in the widespread decline in Pacific Lamprey across watersheds. Below the state of the science is summarized for the main threats identified for Pacific Lamprey across their range (Luzier et al. 2011). There are ongoing aquatic conservation and restoration activities that are directed at Pacific Lamprey or are designed for other fish species that indirectly help address these threats. More information on threats and the details of specific, ongoing, and planned conservation and restoration activities are provided in the annual RIPs developed for each RMU.

Passage (dams, culverts, water diversions, tide gates, other barriers)— Artificial barriers impact distribution and abundance of Pacific Lamprey by impeding upstream migrations by adult lamprey (LTWG 2022a) and downstream movement of larvae and juveniles (Close et al. 1995; Vella et al. 1999; Ocker et al. 2001; Lucas et al. 2009). Upstream adult migrations are blocked by dams without suitable passage alternatives or attraction to fish ladder entrances (Moser et al. 2002). Fish ladders designed to pass salmonids may not provide upstream lamprey passage, particularly if they have sharp angles (Keefer et al. 2010) and high water velocities (Moser et al. 2002; Mesa et al. 2003), which prevent lamprey from navigating the structure by using burst-and-attach behavior. Culverts and other low-head structures are impassable for a variety of reasons including high velocities, sharp angles, insufficient resting areas, lack of suitable attachment substrate, and long distances to traverse (LTWG 2020; LTWG 2022). Tide gates can also block upstream migration of adult lampreys for many of the same reasons (PLCI 2021). Once upstream passage is no longer possible, most Pacific Lamprey populations persist for only a few years above impassable barriers before becoming locally extirpated (Beamish and Northcote 1989). Larson et al. (2020) described one population of Pacific Lamprey persisting in a landlocked area for over 40 years before presumably becoming extirpated.

In some watersheds, translocation of Pacific Lamprey adults is used as a tool for reintroduction, augmentation (e.g., Ward et al. 2012), and as an interim measure while primary limiting factors such as passage are addressed in the longer term. Translocation can be defined as the movement of wild-caught fishes from one place to another within their known range (George et al. 2009) and is applied when freshwater habitats have been restored but cannot be re-colonized naturally. In an effort to get more adult Pacific Lamprey further upstream in the Columbia Basin, past the mainstem dams, and as part of CRTIFC's Master Plan (CRITFC et al. 2018), translocation has been conducted in the Upper Columbia, Snake River, and Mid-Columbia RMUs. These projects began in 2007 in the Clearwater River watersheds and Asotin Creek and have expanded to many subbasins in the regions (see RIPs for additional information). Hess et al. (2022) summarizes the Snake River translocation project achievements, including boosted larval abundance, increased juvenile production, and successful out migration, as well as the valuable biological data gained from these long-term programs.

Juvenile and larval lamprey typically travel deeper in the water column (no air bladder) compared to salmonids; thus, the use of surface spill to provide passage for lamprey is possibly less beneficial (Moursund et al. 2003); however, surface collectors on the Clackamas River in Oregon have had success in collecting downstream migrants near the surface (PGE 2018). Downstream migrating lamprey that enter juvenile bypass systems have demonstrated high survival rates (Moursund et al. 2003). However, often downstream migrating juvenile lamprey are entrained in water diversions, turbine intakes, and fish exclusion screens (Moursund et al. 2000; Moursund et al. 2002; Moursund et al, 2003; Dauble et al. 2006; Rose and Mesa 2012; Lampman et al. 2014) and can be inadvertently collected and transported downstream with salmonid smolts with unknown, but potentially detrimental impacts (Moser and Russon 2009). Juvenile lampreys are not likely to be harmed by changes in pressure and shear conditions present during turbine passage (reviewed in Moser et al. 2015); however, sublethal impacts from elevated total dissolved gas levels due to increased spill could have substantial impacts on larvae and juveniles (Liedtke et al. 2023a).

Passage barriers often change flow patterns and block the downstream movement of large wood and coarse sediments, as well as upstream delivery of marine-derived nutrients. As a result, passage barriers affect and potential magnify other threats to lamprey, such as water quality, predation, toxicity, dewatering, stream and floodplain degradation, and small effective population size, which are discussed in subsequent sections.

Large scale dam removals, including on the Elwha River, White Salmon River, and currently ongoing on the Klamath River, have reopened historically blocked passage for anadromous fish. Pacific Lamprey have readily recolonized these environments (Jolley et al. 2012; Hess et al. 2020b) and highlight the benefit of barrier removal (Storch et al. 2022). Where removal is not possible, there are multiple, ongoing efforts to improve passage conditions at dams for migrating adult lamprey, including those at Federal dams on the mainstem Columbia River and other non-federal, hydroelectric dams in California, Oregon, and Washington (Keefer et al. 2012; LTWG 2022a). Modifications to regular fishways to improve lamprey passage include 1) installation of lamprey passage structures that bypass the regular fishways, 2) flow reductions within the fishway, 3) rounding of sharp corners to provide for continuous attachment, and 4) screen modifications (Rose and Mesa 2012; Keefer et al. 2012; LTWG 2022b). Dams that are dependent on trap and haul operations to move adult salmonids often do not have lamprey specific traps or inadvertently or purposefully exclude migrating adult lamprey. While there has been significant progress, much work remains to design structural or operational solutions to these passage obstacles and expeditiously implement appropriate solutions.

Many small passage barriers (e.g., culverts, small dams, tide gates) are addressed through site-specific actions identified in recovery plans for listed salmonid species, such as Salmon and Steelhead (from National Marine Fisheries Service (NMFS)), and Bull Trout (from USFWS). These actions include installation/improvements to fishways where present, the removal of dams, and/or culvert modifications or replacement. When such actions are implemented, they typically can incorporate lamprey passage in the design phase for little or no extra cost; however, additional information and guidance are needed to ensure lamprey passage is incorporated for all actions across the species range.

Numerous regional inventories (completed and ongoing) throughout the western states identify fish passage barriers and unscreened/inadequately screened water diversions that affect anadromous fish species. These inventories are used to prioritize restoration work (e.g., removal or modification) at these barriers to ensure compliance with state codes and improve fish passage conditions, which should benefit lamprey. However, depending on the state, inclusion of lamprey into inventories, priorities, and designs is not universal.

For more information, see the below documents:

- Barriers to Adult Pacific Lamprey at Road Crossings: Guidelines for Evaluating and Providing Passage (LTWG 2020): summary of factors affecting adult passage and recommendations on how to improve and retrofit structures to facilitate adult lamprey passage. Available: www.pacificlamprey.org/wp-content/uploads/2022/02/LTW_2020_LampreyPassage@RDXings_Final_062920.pdf

- Practical Guidelines for Incorporating adult Pacific Lamprey Passage at Fishways (LTWG 2022a): Lamprey swimming and climbing performance and how to build or retrofit fishways that provide upstream access to migrating adults. Available: www.pacificlamprey.org/wp-content/uploads/2022/08/2022.06.06-Lamprey-Psg-White-Paper.pdf
- Design Guidelines for Pacific Lamprey Passage Structures (Zobott et al. 2015): Focused recommendations for Lamprey Passage Structures. Available: www.pacificlamprey.org/wp-content/uploads/2022/02/Zobott-et-al-2015-5-LPS-Design-Criteria_FINAL.pdf
- Barriers to Tidal Connectivity for Native Lamprey Species: Summary of the state of the science related to passage structures, osmoregulation, and estuary habitat use. Data gaps and next steps identified for incorporating lamprey into tidal passage structures. Available: https://www.pacificfishhabitat.org/wp-content/uploads/2022/01/Report_Lamprey_Barriers_Tidal_Connectivity_December_2021.pdf

Stream and Floodplain Degradation ***(channelization, loss of side channel habitat, scouring, dredging)*** **—** Stream and floodplain degradation refers to the simplification of river habitats. Lampreys require various habitat types to complete their life cycle (see Life History Characteristics). Human activities have resulted in simplified channels with disconnected stream habitats. These actions include:

- Construction of dams alters the natural hydrograph (changes to seasonal base flows and temperature regimes; frequency, magnitude, and duration of peak flows) and disconnects sediment and large wood sources, which are important to the creation and maintenance of complex riverine and riparian habitats.
- Channelization of rivers to reduce/redirect flooding, including construction of levees, rip rap bank stabilization, and channel strengthening.
- Dredging, including for flood control, gravel mining, agricultural water management, or navigation.
- Past forestry practices, including log drives, splash dams, removal of riparian vegetation, removal of existing large wood, and reduced large wood recruitment to stream habitats.
- Urbanization and agricultural development within the floodplain, including changes to water quantity and quality (increased storm runoff, increased contaminant inputs), bank stabilization, road building, and removal of riparian vegetation.

These practices have contributed to loss of complex riverine and riparian habitats and have reduced the quality and quantity of spawning and rearing habitats (USFWS 2010; Clemens et al. 2017a).

Within the Pacific Lamprey's historic range, widespread stream and floodplain restoration has been conducted to restore federal Endangered Species Act (ESA) listed Pacific Salmonid species. Since 1991, when the first salmonid species (Snake River Sockeye) was listed, a total of 28 populations of salmonids across five species and four states have been protected as

Threatened or Engendered. As required by the ESA, these listings have resulted in Salmon Recovery Plans, which outline threats, set recovery goals, recommend recovery actions, and identify partners to collaborate during the recovery efforts. Over the past 25 years, hundreds of millions of dollars have been spent on actions to try to restore these populations. While these actions and plans are targeted towards anadromous salmonids, many of the activities will benefit lamprey species, including actions that protect or restore habitat complexity and watershed processes and improve water quality and quantity. Likewise, information gathered during development of the recovery plans could help identify threats that exist for all anadromous fishes in those geographic areas, including Pacific Lamprey.

In addition to ESA-driven conservation actions, state agencies and tribes are involved in watershed planning processes and in-water work reviews, which allow biologists to provide recommendations or require protections for fish, wildlife, and habitats that are not protected under the federal ESA framework but are in decline or are otherwise of concern. To better conserve and protect lampreys while implementing salmonid recovery actions or other watershed improvements, the projects should incorporate the needs of lamprey throughout project development and implementation, including project scoping and prioritization, design, fish salvage, and monitoring (Crandall and Wittenbach 2015; LTWG 2022c).

For more information, see the following documents:

- A Best Management Guidelines for native lampreys during in-water work (LTWG 2022c): This document highlights protection measures for lamprey that can be incorporated into any stream disturbing activity, including habitat restoration. Available: https://www.pacificlamprey.org/wp-content/uploads/2022/10/BMGs-for-Native-Lampres-During-In-Water-Work-Final-Updated-2022-2.pdf
- Pacific Lamprey Habitat Restoration Guide (Crandall and Wittenbach 2015): Description of the biology, ecology, and cultural significance of lamprey, threats, and best management practices to protect and restore populations. Available: http://www.methowsalmon.org/Documents/PacificLampreyRestorationGuide_web.pdf)
- Monitoring and minimizing effects of dredging on lampreys (LTWG 2021): Summarizes state of the science and data gaps related to dredging impacts on lampreys. Available: https://www.pacificlamprey.org/wp-content/uploads/2022/02/Dredging_-and_Lampreys_03.19.21.pdf.
- Comparison of Pacific Lamprey and Pacific Salmon Life Histories, Habitat, and Ecology (LTWG 2023): This document details the similarities and differences between Pacific Lamprey and Pacific Salmonids with the intent of educating stream restoration practitioners and fish biologist. Available: https://www.pacificlamprey.org/wp-content/uploads/2023/08/LTWG-Restoration_Lamprey-Salmon-Comparison_030823.pdf
- Exploring Techniques to Reduce Lamprey and Salmonid Entraining into Canals (Lampman and Beals 2019): Design considerations, as well as monitoring and salvage techniques for protecting fish in irrigation canal environments. Available: https://www.pacificlamprey.org/wp-content/uploads/2022/02/Exploring-Techniques-to-Reduce-Lamprey-and-Salmonid-Entrainment-Canals_YNF-BOR_2019.pdf

Dewatering and Stream Flow Management (reservoirs, water diversions, instream projects)—
Rapid fluctuations in reservoir and stream water levels from irrigation diversions, power hydropeaking operations, and instream channel activities that isolate and dewater stream habitats can impact lamprey. These activities can strand all life stages and isolate them from flowing water. Rapid dewatering events can kill large numbers of lamprey leaving them stranded and subject to desiccation and predation (Kostow 2002; Streif 2009; Lampman and Beals 2019; Liedtke et al. 2015; Liedtke et al. 2023b)

Suitable habitat for larval lamprey is often at stream margins in areas of low velocity with fine substrate (Claire 2003; Pirtle et al. 2003; Graham and Brun 2005; Torgerson and Close 2004), which are often the first areas dewatered when water surface elevations drop. Larval lamprey do not segregate themselves by age (King et al. 2008) so a single event can affect multiple year classes, significantly impacting a local lamprey population. Channel reconstruction or barrier removal projects targeting the restoration of salmonids can result in rapid and sometimes extensive dewatering of existing channels, thus stranding larval lamprey. Larval lamprey may burrow deeper into the sediment during dewatering events to stay wet and behavioral responses to dewatering vary by larval size (Kostow 2002; Hardisty 2006, Liedtke et al. 2023b). While larval lamprey can rely on cutaneous respiration in the moist sediments for several days (Potter et al. 1996), these larvae will die once the habitat dries up. The rate of dewatering, the slope of the substrate, and the environmental conditions (shade, temperature, humidity) can all impact larval lamprey survival during dewatering events (Liedtke et al 2023b). Attempts to salvage boney fish prior to in-water work typically do not included specific efforts to rescue larval lamprey (including electrofishing settings, shocking dewatered sediments, and small mesh nets), which may emerge from the sediment well after salvage/rescue efforts cease and no water remains in the channel (Beals and Lampman 2016; Lampman et al. 2015, 2016; Liedtke et al. 2015; Lampman and Beals 2019; Liedtke et al. 2023b).

Reduced flows from water withdrawals during summer and fall can impede adult lamprey migration by restricting flow into an exposed, shallow river channel or creating a thermal block. Migration timing and holding behavior in freshwater have been correlated to water temperatures and discharge (Keefer et al. 2009; Clemens et al. 2012) and anthropogenic alterations in both of those factors can limit the ability of adult lamprey to safely hold and reach spawning grounds. Nests are often constructed in low gradient stream reaches, in gravel, and at the tailouts of pools and riffles (Mattson 1949; Pletcher 1963; Kan 1975). These areas are vulnerable when flows drop suddenly, which is common during irrigation season and power hydropeaking, and results in desiccated nests.

Screens associated with water withdrawals or hydropower turbines also pose a threat to lampreys, even if they are designed to meet screening criteria to protect juvenile salmonids (NMFS 2011). Lamprey at various life stages can become entrained and impinged on screening infrastructure, resulting in delayed migration, injury, and mortality (Moursund et al. 2002; Mesa et al. 2017; Jackson et al. 2019; LTWG 2022b). Screen type, screen opening size, approach velocity, sweeping velocity, and size and life stage all influence the impact of the screen on an individual lamprey (Rose and Mesa 2012; Mesa et al. 2017; LTWG 2022b). Current research suggests that smaller screen openings protect more size classes of lamprey than larger screen openings, though more studies are needed to assess impingement rates for smaller larvae with finer mesh openings (LTWG 2022b). Screens parallel to flow with high sweeping velocities also protect more lamprey from entrainment and impingement. There are still large data gaps in understanding how operational changes, such as those that consider attraction or avoidance behaviors, could be applied to minimize impacts of flow management infrastructure on lamprey. Additionally, there are also many thousands of unscreened diversions that likely have a large and unquantified impact on lamprey across their range.

Since multiple life stages can be present in a stream year-round, completely avoiding impacts to lamprey during dewatering activities may be difficult or impossible. Typical in-water work timeframes are set in the summer to avoid impacts to spawning, incubating, and migrating salmonids. However, these timeframes often overlap with Pacific Lamprey spawning, incubation, and the initiation of juvenile transformation, so all life stages from eggs to adults can be present at a project site during that time. However, there are options to protect lamprey during in-water work or dewatering (see above; LTWG 2022c), including salvaging lamprey using lamprey electrofishing settings and small mesh nets as the water is drawn down. It is also important to prevent predation by separating lamprey from predatory boney fish and relocating lamprey to suitable, undisturbed habitat. Reducing dewatering speed can allow lamprey to volitionally escape from dewatered substrates and move to wetted areas. A slow dewatering rate in combination with salvage efforts can reduce negative impacts on lamprey (Clemens 2017). More information is needed to understand the seasonality of movement into regularly dewatered environments (i.e., reservoir habitats), which could be used to further reduce stranding of lamprey (Blanchard et al. 2023).

For more information see the following document:

- Review of Factors Affecting Larval and Juvenile Lamprey Entrainment and Impingement at Fish Screen Facilities (LTWG 2022b). Summary of studies and guidance document on current state of science regarding screening impacts on lamprey. Available: www.pacificlamprey.org/wp-content/uploads/2022/10/Review_of_Factors_Affecting_Lamprey_Entrainment_Impingement__2022.pdf

***Water Quality* —** High water temperatures negatively impact growth, migration, survival, and spawning success of Pacific Lamprey. Clemens et al. (2016) found that temperatures of 20°C or higher were synonymous with stress, tissue damage, and potential mortality. Water temperatures of 22°C have caused mortality and deformation of eggs and early-stage larvae under laboratory conditions (Meeuwig et al. 2005). Mortalities of migrating pre-spawning and spawning adult Pacific Lamprey have been documented at stream temperatures above 20°C (Clemens 2022). Water temperatures of 22°C or higher are common in degraded streams during the early-to-mid-summer period of lamprey spawning and larval development. Further, changes in natural temperature regimes may alter the timing of seasonal activities (migration, spawning, embryotic development), which could negatively affect lamprey populations (Maitland et al. 2015; Clemens et al. 2016; Baer et al. 2018; Clemens and Schreck 2021; Clemens 2022). There is some evidence that larval lampreys can withstand elevated stream temperatures; however, there may be costs to fitness and long-term survival (Carilli 2020), which warrant further examination.

Pacific Lamprey are exposed to toxins and contaminants with unknown impacts to their populations and ecosystems. High levels of mercury and polychlorinated biphenyls (PCBs) have been detected in migrating adult Pacific Lamprey in the Columbia River basin which initiated a recent consumption advisory to reduce risk to human health (CRITFC 2022). Contaminants detected in adults are suspected to have bioaccumulated during juvenile parasitic feeding in the ocean, which has been identified as a marine-related limiting factor and an area of needed research. Previously, Pacific Lamprey adults sampled in the Willamette River (the lower portion is designated as a Superfund Site) had levels of dieldrin, total PCBs and arsenic that were above acceptable tissue concentrations, and as a result, consumption restrictions were recommended to Siletz Tribal members (ODHS 2005). Toxins in lampreys can be transported to spawning areas and have unknown impacts on the individuals themselves and their ecosystems more generally (e.g., predators, water chemistry, etc.).

Larval lamprey appear to avoid burrowing in contaminated and toxin-laden stream substrates when possible (Unrein et al. 2016). However, Pacific Lamprey larvae appear to ingest and accumulate toxins during the prolonged freshwater residency as filter feeders in the substrate (Clemens et al. 2017) and several sources found that they bioaccumulate fire retardants, mercury and pesticides at levels that may be deleterious to individual and population health (Bettaso and Goodman 2008, 2010; Maitland et al. 2015; Nilsen et al. 2015; Linley et al. 2016). In the Trinity River, Pacific Lamprey larvae were found to have 12 to 25 times higher mercury levels when compared to Western Pearlshell Mussels *Margaritifera falcata* and were found to have 70% higher mercury levels in a historically mined area when compared to a non-mined reference reach (Bettaso and Goodman 2008). Multiple age classes of larvae can concentrate in areas of suitable habitat (King et al. 2008), which makes them susceptible to localized contaminant sources, chemical spills, or chemical treatment (e.g., rotenone) targeting other species. Research into the sublethal effects of various toxins on individuals and populations are needed.

Little is known about how other water quality impairments, such as low dissolved oxygen levels, eutrophication, or turbidity, impact Pacific Lamprey. Recent work suggests that larval and adult Pacific Lamprey have some tolerance to hypoxia (Moser et al. 2023); however, higher temperatures result in respiratory stress and can deplete oxygen levels quickly (Carilli 2020), and actions that expose lamprey to high temperatures and low oxygen environments potentially cause sublethal impacts and should be avoided (Liedtke et al. 2023b). Juvenile lamprey outmigration has been correlated to increased turbidity (Baer et al. 2018), which may offer protection from predators. However, impacts of turbidity on more immobile life stages (i.e., eggs, prolarvae, larvae) have not been evaluated. Depending on the time of year and severity of events, high turbidity could suffocate eggs and prolarvae in nests or larvae burrowed in substrates. Impacts likely vary by life stage, size, and region, and could be exacerbated by climate change impacts to hydrologic patterns. More research is needed to understand how changes in water quality may impact Pacific Lamprey populations across their range.

***Harvest/Overutilization* —** The goal of the Agreement is to support traditional tribal cultural harvest and use of Pacific Lamprey. In some locations, historic non-tribal harvest for food or commercial purposes is still impacting recovery efforts to date (Clemens et al. 2023) and in others, current non-tribal harvest actions present a threat to local populations if these activities are concentrated on rivers with low population numbers. Harvest of lamprey can change population structure and alter distribution, thus reducing population numbers. It is currently illegal to sport-fish for or possess lamprey for bait in the states of Oregon, Washington, and Idaho. Legal harvest of adults and larvae occurs in California and Alaska. A non-tribal bag limit of five fish was imposed by California Department of Fish and Game for adult lamprey in 2010. These measures have restricted the harvest of Pacific Lamprey and helped reduce this threat.

Predation — Native and non-native fish, mammals, and birds prey on Pacific Lamprey throughout their life span (Semakula and Larkin 1968; Galbreath 1979; Beamish 1980; Roffe and Mate 1984; Wolf and Jones 1989; Close et al. 1995; Moyle 2002, Schultz et al. 2017, Clemens et al. 2019; Bingham et al. 2024) and may pose a threat to lamprey abundance, particularly in altered habitats. Native predators taking advantage of novel environments (i.e., reservoirs) or passage barriers that delay migration (such as culverts, fishways, and dams) can have significant impacts on migrating lamprey. These intensified predation events have been documented in many locations, including notably in recent years below Bonneville Dam in the Columbia River and Willamette Falls on the Willamette River due to the increased concentration of California sea lion *Zalophus californianus* and Stellar sea lions *Eumetopias jubatus*, but impacts to lamprey populations have not been extensively quantified (Tidwell et al. 2017; Edwards et al. 2022; Arakawa and Lampman 2020). Likewise, native Northern Pikeminnow *Ptychocheilus oregonensis* have thrived in reservoir habitats and predate on unquantified numbers of juvenile and larval lamprey (Shirley et al. 2023; Bingham et al. 2024). In marine waters, many fishes that Pacific Lamprey parasitize are capable of consuming Pacific Lamprey; such predation has been document but not quantified (Weitkamp et al. 2023). Non-native species, including Smallmouth Bass *Micropterus dolomieu*, have been documented preying on larval lampreys (see Bingham et al. 2024) and consumption rates on the Umpqua River were estimated (Schultz et al. 2017), but wide scale impacts across the Smallmouth Bass introduced range has not been documented or quantified. In many watersheds the pressure from both native predators taking advantage of novel environments (such as Northern Pikeminnow) and non-native predators is poorly studied but has been highlighted as an area of concern. A recent molecular study (using eDNA metabarcoding and targeted qPCR) in 2023 that examined predator fish species (primarily Northern Pikeminnow, Smallmouth Bass, Largemouth Bass, Walleye, and Channel Catfish) gut contents in the lower Yakima and Columbia rivers confirmed that a considerable portion of their prey was lamprey from these two rivers (Bingham et al. 2024). Aside from anecdotal observations, avian and mammalian predation risks have not been formally investigated to date.

Disease — Impacts of diseases on Pacific Lamprey populations is unknown and requires further study. Larval Pacific Lamprey on the Salmon River (Idaho) have been observed to have infections from digenetic trematode *Nanophyetus salmonicola*, but it is not known to what degree these parasites are having impacts on the larval lamprey, including growth, fitness, and survival (Cochnauer et al. 2006). The pathogen that causes furunculosis, *Aeromonas salmonicida,* has been detected in lamprey in the Columbia River Basin (Cummings et al. 2008; Clemens et al 2009; Ward et al. 2012; Jackson et al. 2019; Jolley and Lujan 2019) and western Oregon. The causative agent for bacterial kidney disease (BKD), *Renibacterium salmoninarum*, was also found in larval Pacific Lamprey sampled in the ponds at Entiat National Fish Hatchery in Washington (J. Evered, USFWS, personal communication). To assess possible risks associated with introducing wild lamprey into existing fish culture facilities, Kurath et al. (2013) tested larvae for susceptibility to infection and mortality caused by experimental exposures to the fish rhabdovirus pathogens infectious hematopoietic necrosis virus (IHNV) and viral haemorrhagic septicaemia virus (VHSV). There was no evidence of infection, replication, or persistence of the viruses, suggesting that larval Pacific Lamprey are highly unlikely to serve as hosts that maintain or transmit these viruses. There are still many data gaps in our understanding of disease impacts in both wild lamprey populations and in aquaculture settings. Further research is needed to address these questions.

Small Effective Population Size — The number of individuals that contribute offspring to the next generation is known as the effective population size (N_e) and is important for assessing conservation and the management of fishes (Rieman and Allendorf 2001). The loss of genetic diversity and the degree of inbreeding within a population is related to the rate of genetic drift that is measured by N_e (Wright 1969). As a result, maintaining populations large enough so that these effects are minimized has become an important goal for ESA-listed species (McElhaney et al. 2000). The various and commonly cited threats to Pacific Lamprey have the potential to lead to reductions in population size (Rieman and McIntyre 1993; Rieman et al. 1997) and therefore in N_e. A significant loss of genetic variation can influence population demographics, dynamics, and ultimately the persistence of populations via inbreeding depression, loss of phenotypic variation and plasticity, and loss of evolutionary potential. Although data on the effective population size is lacking for Pacific Lamprey, it is recognized as a critical data need (CRBLTWG 2005) for the conservation and enhancement of populations. In this Assessment, we use adult abundance (N) as a surrogate for N_e, because presently there are no studies that estimate the ratio of N_e:N for Pacific Lamprey.

Lack of Awareness — A lack of awareness and understanding of Pacific Lamprey can have negative and unintended impacts to conservation of the species (Clemens and Wang 2021). Information on their distribution, preferred habitat use, ecological role, and best management practices to protect and conserve lamprey are often inadvertently overlooked. Thus, in-channel activities, including those to restore habitat or passage for other species, can negatively impact lamprey. For example, dewatering a stream to replace a culvert may strand larvae and use of heavy equipment to dig out channels can remove larvae (Streif 2009; USFWS 2010).

To date, Pacific Lamprey have rarely been included in the analysis of impacts of land management activities, such as stream alteration or channel dredging, simply because their presence and distribution is not widely known. Until the early 2000s, Pacific Lamprey were not considered in hydropower operations, fish passage, and relicensing of hydropower dams. Lamprey passage criteria are not universally considered in passage prioritizations, replacements, or new projects and knowledge of these passage requirements varies greatly by region. Identifying and overcoming funding bias and barriers to lamprey-friendly salmon restoration work is needed, including incorporating lamprey needs from initial restoration design phases to in-water work salvage activities.

Publicity regarding the negative impacts of Sea Lamprey in their invasive range in the Great Lakes has given all lamprey species a bad reputation (Clemens and Wang 2021). We continue to gain a better understanding of the vital role Pacific Lamprey play in their native habitat as an important component of the ecosystem. To combat negative perceptions that many people have about lampreys, information on the ecological and cultural benefits of native lamprey needs to be disseminated.

Ocean Conditions— Pacific Lamprey spend up to seven years at sea (Hess et al. 2022), migrate long distances (Murauskas et al. 2019, Weitkamp et al. 2023), and gain most of their adult size prior to returning to freshwater to reproduce. Consequently, direct and indirect changes to the ocean environment may significantly influence all populations of Pacific Lamprey. Actions that greatly affect their host species or that alter the pelagic or substrate habitats to depths up to 500 meters may alter population demographics (Orlov et al. 2008, Murauskas et al. 2013; Wade and Beamish 2016; Clemens et al. 2019; Weitkamp et al. 2023). Predation, fisheries bycatch, host availability, and host contaminants load have been identified as marine limiting factors on lamprey abundance (Clemens et al 2019). However, few studies have focused on the ocean portion of their life cycle and most of what we do know is from incidental lamprey bycatch in research of fisheries targeting other species (Clemens et al. 2019; Weitkamp et al. 2023). Additional research, evaluation, and monitoring is needed to determine how actions and changes in the marine environment are reflected in lamprey populations.

Climate Change — Climate change may exacerbate the threats listed above, especially hydrologic patterns (i.e., run-off timing, peak flow, low flow), ocean conditions, water quality, diseases, and predation. Hydrologic changes caused by climate change such as hydrograph timing and stream temperature could affect Pacific Lamprey during all life stages (Sharma et al. 2016; Schaller et al. 2017; Baer et al. 2018; Wang et al. 2020; Clemens 2022). To inform a conservation strategy in the face of climate change, a climate change vulnerability assessment was recently conducted for Pacific Lamprey along the west coast of the U.S. (Schaller et al. 2017; Wang et al. 2020). Risk was evaluated under two different carbon emission scenarios and for two time periods (mid-century 2040 – 2069 and end of century 2070-2099) to compare climate change vulnerability risk for Pacific Lamprey across the 15 river basins from northern California to the Canadian border. Using downscaled temperature and hydrology projections, a modified NatureServe Climate Change Vulnerability Index consistently scored the vulnerability of Pacific Lamprey to future climate change (Schaller et al. 2017; Wang et al. 2020). Anthropogenic barriers and predicted relative variability in stream flow and temperatures were the two factors that contributed to identifying the most vulnerable watersheds. The findings revealed patterns of vulnerability for Pacific Lamprey across their U.S. range and could inform restoration activities. Since lampreys have persisted across immense timeframes and climatic changes and Pacific Lampreys have multiple life history expressions and a large distribution, there is hope they will be resilient to current climate change impacts (Wang et al. 2021).

Aquatic Invasive Species — Recent aquatic invasive species in the range of Pacific Lamprey (USGS 2024) include New Zealand mudsnails, quagga mussels, zebra mussels, Asian clams, Eurasion water milfoil, Didymo, water chestnut and others. These species may encroach on available habitat, compete for food sources or affect lamprey in ways not currently recognized.

For discussions of threats impacts on Pacific Lamprey at a regional and watershed scale, see the RIPs for each RMU: https://www.pacificlamprey.org/rmu/

3. METHODS

Pacific Lamprey Assessment

The Assessment uses a modification of the NatureServe ranking model (Master et al. 2009), which ranks a series of population demographic and threats factors to calculate the relative risk of extirpation of a species at a specific geographic scale. Pacific Lamprey demographic and threats ranking information was collected for discrete HUC 4 watersheds using an online questionnaire and/or virtual meetings. This information was summarized by larger Regional Management Unit (RMU) to assess overall patterns of risk. Assessment results are used to identify relative strongholds or weak areas for Pacific Lamprey and to guide the identification and prioritization of Pacific Lamprey conservation actions over the next five years. A detailed description of the Assessment development and NatureServe model selection process and approach can be found in the 2011 Assessment (Luzier et al. 2011).

2022 Assessment Revision

Spring 2022 was the third revision of the Assessment. The same NatureServe model version and conservation factors used in previous Assessments were used to re-evaluate the conservation risk of Pacific Lamprey in 2022. However, minor refinements were made to conservation factors and threats descriptions to promote consistency of interpretation among RMUs.

2022 NatureServe Conservation Factors

NatureServe and its member programs and collaborators use a suite of ten conservation factors to assess the extinction or extirpation (regional extinction) risk of plants, animals, and ecosystems (or "elements" of biodiversity). Conservation factors are grouped into three general categories including: Rarity, Trends and Threats. Ranking information for all ten conservation factors is not required to assign a conservation status rank (CSR). In 2022, we used a modified suite of seven factors to assess the relative risk of Pacific Lamprey by watershed throughout its range (Table 1). These factors were selected because we were able to collect the required information for most geographic populations.

Table 1. NatureServe definitions and source of information for the seven conservation factors used to assess the relative risk of Pacific Lamprey during the 2022 Assessment. A detailed description of these conservation factors can also be found in USFWS (2018).

	Conservation Factor	NatureServe Definition	Source of Information
Rarity Factor Group	**Range Extent**	Historical distribution	Historical range of Pacific Lamprey was determined using: historical tribal fisheries, museum records, early scientific papers, knowledge of elevational limits of Pacific Lamprey and geomorphic features (e.g., waterfalls). In OR, WA and ID RMUs, steelhead intrinsic potential (SIP) or coho distribution data was also used as a surrogate estimate of historical lamprey range extent in most areas where historical occupancy information was unavailable. In CA RMUs, range extent was calculated from the linear extent of the historical range of Pacific Lamprey.
	Area of Occupancy	Current distribution	Current distribution information was provided by RMU partners across the range of Pacific Lamprey. Sources of data include targeted field surveys, occupancy sampling, fish salvage efforts, spawning surveys, environmental DNA sampling (WA Coast and Puget Sound RMUs only) and incidental or anecdotal observations. A compilation of Pacific Lamprey occurrences obtained from RMU partners can be found at https://fws.maps.arcgis.com/apps/instant/basic/index.html?appid=3a85e0d266834a2aad815a9d2f18ddf5
	Population Size	Median number of adult (reproductive) Pacific Lamprey in the watershed over the last five years (i.e., 2017-2021).	Current abundance estimates were obtained from field experts during RMU meetings. Population size was estimated from Pacific Lamprey supplementation efforts, trapping information, dam counts or dam conversion counts, monitoring stations, spawning ground surveys and tagging studies. The objective was to estimate a range of values within which the adult population was likely to occur, based on available data or best professional judgement.
	Ratio of Area of Occupancy to Range Extent	The ratio of current to historical distribution	Ratio was added to the NatureServe ranking model in 2011 because of the uncertainty of historical distribution for Pacific Lamprey and our use of SIP and Coho Salmon distribution as surrogates. The addition of ratio lets us factor in the risk associated with rearing and spawning in less spatially diverse areas.

Trend Factor Group	**Short-term Trend**	The trend in population size over three lamprey generations (36 years). Generation time is defined as the average age of adults when they reproduce.	Trends were primarily assessed via professional opinion, augmented by available, albeit limited, long-term counts of adult Pacific Lamprey from fish ladders, counting stations, and other monitoring locations (e.g., FCRPS dams, Winchester Dam, Willamette Falls, etc.).
Threats Factor Group	**Threat Impact - Scope**	Threat scope: the proportion of a watershed affected by the threat.	Scope ranking values were based on the best professional judgement of RMU partners. Numeric ranking values from 0 to 4 (Unknown, Insignificant, Low, Moderate and High, respectively) were assigned to each scope factor for each assessed threat in the RMU (see Appendix B). The scope and severity values from the same and most influential threat category (i.e., highest ranking values) were input into the NatureServe rank calculator.
	Threat Impact - Severity	Threat severity: how badly or irreversibly a watershed is affected by the threat.	Severity ranking values were based on the best professional judgement of RMU partners. Numeric ranking values from 0 to 4 (Unknown, Insignificant, Low, Moderate and High, respectively) were assigned to each severity factor for each assessed threat in the RMU (see Appendix B). The scope and severity values from the same and most influential threat category (i.e., highest ranking values) were input into the NatureServe rank calculator.

2022 NatureServe Conservation Factor Modifications

All NatureServe modifications made during previous versions of the Assessment were retained in the 2022 Assessment and are described in USFWS (2018). The following modifications were made to NatureServe conservation factors in 2022 to enhance clarity and improve the quality of ranking information.

Population Size

In previous Assessment revisions, population size was defined as the estimated abundance of spawning adults currently present in a watershed. In this context 'current' was defined as the estimated abundance of adults in the year directly proceeding the Assessment revision (e.g., 2021). Regional Management Unit leads felt using a single year abundance estimate was too restrictive, did not account for fluctuations in population abundance each year and could unintentionally influence the model if the Assessment revision happened to fall after an abnormally high or low return year. As a result, current population size was redefined as the median value of adult spawner abundance in the five-year period prior to the Assessment revision (i.e., 2017-2021).

Short-term Trend

Short-term trend is defined as the degree of change in population size over three lamprey generations. During the first two Assessments, three lamprey generations was defined as approximately 27 years. In 2022, generation time was revised to 36 years based on (Hess et al. 2022) which estimated the median age of post spawn Snake River adults to be 12.9 years (range 9-20 years) based on genetic parentage and sibship analysis of adult Pacific Lamprey translocated into the upper Columbia and Snake River basins.

Threats

In 2022, RMUs ranked up to ten of the twelve original threat categories proposed in the 2011 Assessment (see Table 2). Specific threat categories were completely excluded from the 2022 Assessment due to a lack of information (i.e., disease) or absence of evidence for risk (i.e., translocation). Other threats were excluded on an individual RMU basis either due to lack of information (e.g., California RMUs did not rank climate change or lack of awareness) or because the threat was not applicable to an RMU. For example, small effective population size was only ranked in the Mid-Columbia, Upper Columbia and Snake RMUs and was not considered a threat in other RMUs. Similarly, harvest was only considered a threat in California RMUs and has never been ranked in Oregon, Washington or Idaho RMUs because non-tribal commercial harvest is prohibited. Finally, threat category descriptions were refined for two threats in 2022 (i.e., lack of awareness and climate change). Although core definitions of threat categories have remained the same since the 2011 Assessment, these minor revisions were intended to improve clarity and consistency of interpretation among RMUs and their partners.

Table 2. NatureServe definition and examples of the ten threat categories assessed within RMUs during the 2022 Pacific Lamprey Assessment. Note, not all threat categories are assessed within each RMU.

Threat	NatureServe Definition	Examples	RMUs affected	Citations
Tributary Passage	Natural or artificial barriers that impact distribution and abundance of Pacific Lamprey by impeding upstream migration of adult lamprey and downstream movement of larval and juvenile lamprey.	Dams, culverts, water diversions, tide gates, weirs, fish ladders, other barriers	All RMUs except Mainstem Columbia/Snake and North Pacific Ocean	Clemens et al. 2017a; USFWS 2018; PLCI 2021; Moser et al. 2021; LTWG 2020; LTWG 2022a; LTWG 2022b
Mainstem Passage	Disruption or delays to movement and migration due to dams on the mainstem Columbia River and Snake River.	Federal Columbia River Power System (FCRPS) Dams on mainstem Columbia and Snake Rivers	Mid-Columbia, Upper Columbia, Snake RMUs	Keefer et al. 2012; Storch et al. 2022
Dewatering and Flow Management	Rapid fluctuations in reservoir or stream water levels that isolate or dewater stream habitats, potentially stranding larval lamprey in the substrate or impeding adult migration.	Irrigation diversions, hydropower operations, instream restoration activities (e.g., channel reconstruction, barrier removals)	All RMUs except North Pacific Ocean	Lampman and Beals 2019; Harris et al. 2020; Liedtke et al. 2023b
Stream and Floodplain Degradation	Loss of stream habitat complexity and/or connectivity from current and legacy land use practices and habitat altering activities.	Dredging, mining, floodplain development, stream channelization, road construction, flood reduction, grazing, deforestation, agriculture	All RMUs except North Pacific Ocean	LTWG 2021; LTWG 2023
Water Quality	Excessive water temperature, low dissolved oxygen, pH extremes, heavy metals, sediment/turbidity and biological or chemical contaminants that can affect development, growth or survival of Pacific Lamprey.	Water temperature >20°C, presence of bacteria (e.g., fecal coliform), heavy metals (e.g., mercury), toxic pollutants (e.g., insecticides, PCBs)	All RMUs	Madenjian et al. 2021; Whitesel and Uh 2022; Clemens 2022; Smith et al. 2023

Harvest	Harvest (tribal or non-tribal) for food or commercial purposes can pose a threat to low abundance populations. Tribal harvest is greatly curtailed in OR, WA, and ID states due to low abundance.	Non-tribal harvest is illegal in OR, WA and ID. Legal harvest occurs in CA and AK. Illegal capture of lampreys for bait or consumption occur in many RMUs.	California & Alaska RMUs	https://www.dfw.state.or.us/fish/species/docs/lamprey/lamprey_as_bait_flyer.pdf; Almeida et al. 2021
Predation	Predation by native and nonnative fish, birds or mammals	Smallmouth bass, striped bass, walleyes, brown trout, Northern pike minnows, white sturgeon, sealions, seals, gulls, terns, cormorants, etc.	All RMUs	Schultz et al. 2017; Edwards et al. 2022; Bingham et al. 2024
Small Population Size	The number of adult individuals that contribute offspring to the next generation. Small population size can contribute to loss of genetic diversity or potential inbreeding.	Significant loss of genetic diversity can influence population demographics and persistence of populations	Mid-Columbia, Upper Columbia and Snake RMUs	Beamish and Northcote 1989; Hess et al. 2022, 2023
Lack of Awareness	Lack of awareness or understanding of Pacific Lamprey distribution, life history characteristics, habitat needs, ecological role, physiological limitations and best management practices to protect lampreys while conducting instream work.	Conducting instream activities (e.g., dredging, dewatering, channel restoration) without salvaging lamprey can kill thousands of larvae.	All RMUs	USFWS 2018; Clemens and Wang 2021
Climate Change	Thinking specifically for a watershed, and considering the current extent of occupied Pacific Lamprey habitat, will climate change have a minimal, moderate, or profound impact on Pacific Lamprey populations? Will the watershed be especially vulnerable or especially insulated from climate change?	Potential increase in summer maximum water temperature [1°-3°], alterations in precipitation patterns/intensity, diminished snowpack, timing shifts of snowmelt and peak flows, more extreme high/low flows, or an increase in the risk and extent of wildfires	All RMUs	Sharma et al. 2017; Wang et al. 2020, 2021; Clemens 2022

Designation of High Priority Threats

Numeric scope and severity ranking values for each threat category (e.g., water quality), were averaged across all HUC 4 watersheds in a RMU to obtain a single value that determined the overall magnitude of the threat (see Tables 3 and 4). Threat categories with an average cumulative score of ≥ 2.50 were designated a high priority threat in the RMU. Mean scope/severity values were not included as inputs into the NatureServe model, but used to identify research or conservation actions that can be implemented to address the priority threats.

Regional Meeting and NatureServe Ranking Process

Procedures for collecting the region-specific information on historical and current distribution, population abundance, population trends and identification of threats have evolved since the first Assessment due to the establishment and growth of RMU groups and other geographical or logistical challenges. A comprehensive description of the methods used to gather and compile NatureServe ranking information for past Assessments can be found in Luzier et al. (2011), Goodman and Reid (2012) and USFWS (2018).

In 2022, travel restrictions and COVID-19 concerns played a large role in prohibiting in-person meetings to collect NatureServe ranking information. As a result, RMU leads developed an Assessment questionnaire using Google Forms that was sent to RMU partners approximately one month prior to virtual meetings. The purpose of the Assessment questionnaire was to streamline the initial collection of NatureServe ranking information that could be used to guide group discussions during virtual RMU meetings. The questionnaire included each of the conservation factors used to populate the NatureServe model including a detailed description of conservation factors (Table 1). Regional Management Unit partners were also provided a NatureServe ranking key (Appendix B), a list of tributaries within each HUC 4 watershed and any notes or background information collected during the 2018 Assessment ranking meeting.

The process of 'ranking' each NatureServe conservation factor was analogous to a multiple-choice quiz. Each factor has a range of options or 'data bins' to choose from (see Appendix B). Partners were directed to select the data bin that best characterized current conditions within each HUC, based on quantitative information (if available) or best professional judgement. Partners had the option of selecting one or two data bins for a given conservation factor (Rarity and Trend factor groups only), though selecting two data bins tended to introduce uncertainty into the model (see Discussion). Many HUC 4 watersheds were still lacking quantitative information about population size and short-term population trend, so in addition to ranking the conservation factor, RMU partners also categorized the uncertainty of their ranking selection based on the following scale:

"0" = *No information available.*

"1" = *Best professional judgment based on expansion of data for other species (e.g., Steelhead).*

"2" = *Largely undocumented but based on extent of habitat, suspected barriers and/or anecdotal information.*

“3” = *Partial adult, juvenile, or nest survey data in one-half or less of the potential spawning and rearing habitat in the watershed.*

“4” = *Partial adult, juvenile, or nest survey data in more than one-half of the potential spawning and rearing habitat in the watershed with some estimate of error.*

“5” = *Comprehensive adult, juvenile, or nest survey data in more than 90% of the watershed incorporating some estimate of error*.

This secondary information was not included as an input within the NatureServe model, but rather, was intended to provide context for the ranking information during current and future Assessment revisions.

Many NatureServe conservation factors were ranked previously during the 2018 Assessment, so RMU partners were asked to review the 2018 NatureServe ranks for each HUC 4 watershed and only make revisions if new data or information supported a change in rank. Otherwise, the 2018 NatureServe rank was left unchanged. Partners were given approximately three weeks to fill out the Assessment questionnaire, at which time RMU leads compiled and summarized the responses in preparation for virtual meetings held February through April 2022. During virtual meetings, RMU leads reviewed NatureServe ranks for each HUC 4 watershed (derived from the Assessment questionnaire). Then RMU partners discussed any major changes, discrepancies and data gaps as a group. Based on their collective knowledge and consensus, the RMU partners decided on the final ranks to input into the NatureServe model.

In California, individual RMU meetings were not possible due to recent staffing changes within the California PLCI/RMU team. Revisions to 2018 NatureServe ranking information were made by California RMU leads based on ongoing conversations with stakeholders and local biologists, site visits, survey results, unpublished reports, recent peer-reviewed literature, information gained in development of RIPs and the experience of the California PLCI/RMU team.

NatureServe Rank Approach

NatureServe developed an automated rank calculator to compute and assign CSRs (NatureServe 2009; Master et al. 2012). Conservation factor ranking values collected during RMU meetings were entered into the automated rank calculator where they were assigned a scaled point value and weighted according to influence on risk. Scores for the individual factors were pooled according to category (i.e., Rarity, Threats, and Trends) and assigned a second weighting value. The resulting three summary scores were combined to yield an overall numeric score, which was translated into a final CSR for each HUC 4 watershed (see Appendix C). A more detailed description of how CSRs were calculated with the 2009 version of the rank calculator can be found in NatureServe (2009). The following are the definitions for interpreting the NatureServe CSRs at the subnational (S-rank) level (Master et al. 2009).

> ***SX Presumed Extirpated —*** Species or ecosystem is believed to be extirpated from the jurisdiction (i.e., nation, or state/province). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered. (= “Regionally Extinct” in IUCN Red List terminology).

SH Possibly Extirpated — Known from only historical records but still some hope of rediscovery. There is evidence that the species or ecosystem may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include: (1) that a species has not been documented in approximately 20–40 years despite some searching or some evidence of significant habitat loss or degradation; or (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.

SU Unrankable — Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.

S1 Critically Imperiled — Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction.

S2 Imperiled — Imperiled in the jurisdiction because of rarity due to very restricted range, very few occurrences, steep declines, or other factors making it very vulnerable to extirpation from the jurisdiction.

S3 Vulnerable — Vulnerable in the jurisdiction due to a restricted range, relatively few occurrences, recent and widespread declines, or other factors making it vulnerable to extirpation.

S4 Apparently Secure — Uncommon but not rare; some cause for long-term concern due to declines or other factors.

S5 Secure — Common, widespread, and abundant in the jurisdiction.

Please note, NatureServe defines CSRs that span two ranks (e.g., S1S2) as Range Status Ranks. This occurs if one or more of the conservation factors (e.g., population size) has information that is less precise than required by the rating scale (i.e., selecting two data bins rather than one). Using the example above, a Range Status Rank of S1S2 has a roughly equal chance of being either an S1 or S2, but further information is needed to resolve the uncertainty. The rank will eventually change to an S1 or S2 with more refined information.

For this application, calculated CSRs are not used to assess conservation status of Pacific Lamprey, but rather to guide our understanding of the relative level of risk by watershed and region. For example, a HUC with an overall ranking of secure (S5) would have the lowest relative risk, while a rank of presumed extirpated (SX) would be associated with the highest relative risk. The purpose of this Assessment was to re-evaluate patterns of risk amongst geographic population groupings using current population attributes and threats information to identify changes that have occurred over the last five years. Results of this Assessment will be used to guide and prioritize potential conservation measures within a watershed and geographic region. A summary of results and maps depicting the spatial arrangement of final NatureServe CSRs and individual conservation factor ranks can be found in Chapters 4, 5 and Appendices D and

4. RANGE WIDE ASSESSMENT RESULTS

Every five years, local stakeholder knowledge and expertise are used to evaluate Pacific Lamprey distribution, population demographics and threats at the HUC 4 watershed level to revise the Pacific Lamprey Assessment. Information gathered is used to inform NatureServe, a diagnostic tool that characterizes the conservation risk of Pacific Lamprey across their historical range. In 2022, information about current Pacific Lamprey distribution, population size, trends, and watershed threats were collected from stakeholders in 15 RMUs through an online Assessment questionnaire and/or virtual meeting. This Assessment was not conducted in Alaska, the Mainstem Columbia/Snake or North Pacific Ocean RMUs; however, we provide an update on available information within these RMUs in chapter 5. The following is a brief overview of range wide results for the 2022 Assessment.

2022 General Assessment Results (CA, OR, WA & ID)

We were able to complete the Assessment in 210 HUC 4 watersheds in 2022. A total of 95 HUCs were assessed in California, whereas 115 HUCs were assessed throughout Oregon, Washington and Idaho (Figure 2). This total includes 21 HUCs that were evaluated for the first time in Puget Sound/Strait of Juan de Fuca, Washington Coast, Mid-Columbia and Upper Columbia. NatureServe CSRs ranged from Presumed Extirpated (SX) to Vulnerable (S3), with the highest proportion of watersheds falling in the Critically Imperiled (S1; 41%) and Imperiled categories (S2; 27%). Overall, CSRs changed in 29 HUCs (14%) from the 2018 to 2022 Assessment, improving in 11 HUCs and worsening in 18 HUCs. Watersheds with improved CSRs were attributable to natural increases in population abundance or distribution (e.g., Mid-Columbia, Snake and Puget Sound RMUs), passage improvements (California North Coast RMU), natural recolonization of Pacific Lamprey into historical habitat (California South Coast RMU) or areas where human-assisted efforts such as adult translocations past barriers have occurred (e.g., Snake and Upper Columbia RMUs). The worsening of CSRs was due to the absence of lamprey in a HUC (Lower Salmon in the Snake RMU), ranking uncertainty (e.g., partners were unable to rank short-term trend in 52% and population size in 30% of HUCs), the uncertainty in the NatureServe model created by selecting two data bins resulting in a Range Status Rank (i.e., S1S2; see Discussion), or a worsening of threats. For example, climate change scope and/or severity values changed from a ranking of "Unknown" in 2018 to a ranking of "High" in 28 HUCs in 2022, lowering CSRs in at least 6 HUCs in the Oregon Coast and lower Columbia RMUs.

The overall pattern of risk is unchanged in the 2022 Assessment. Pacific Lamprey populations at highest relative risk are those in the Upper Columbia, Snake and Mid-Columbia River RMUs (Figure 2). All 53 HUCs in these areas were ranked Presumed Extirpated (13%), Possibly Extirpated (21%) or Critically Imperiled (62%) except two HUCs in the Mid-Columbia RMU that were ranked Imperiled. Watersheds downstream of major mainstem passage barriers, such as parts of the Willamette RMU and several HUCs along the coast of California, Oregon, and Washington, had lower risk but were still primarily ranked Critically Imperiled or Imperiled. Three HUCs currently ranked at lowest risk in 2022 (Vulnerable), include the Clackamas River (Willamette RMU), Smith River (California North Coast RMU) and San Francisco Coastal South (California South Central Coast RMU).

Population Demographics

Historical and Current Distribution

NatureServe rankings for historical distribution remained unchanged from the 2018 Assessment. Ranking of current distribution remained stable or expanded in many RMUs in 2022 (Figure 3). Information on Pacific Lamprey distribution continues to improve in all RMUs. Area of occupancy (current distribution) expanded in 24 HUCs in 2022. This was attributable to: adult translocation efforts (e.g., Snake & Upper Columbia RMUs); new data collected about Pacific Lamprey often while monitoring for other species (e.g., Lower Columbia, Puget Sound/Strait of Juan de Fuca, Washington Coast RMUs); increased sampling effort for Pacific Lamprey, such as targeted spawning ground surveys, environmental DNA (eDNA) sampling, occupancy sampling or fish salvages (e.g., Oregon Coast, Washington Coast, Puget Sound/Strait of Juan de Fuca, Mid-Columbia RMUs); passage improvements (Smith River in California North Coast RMU); or the discovery of a new reproducing population of Pacific Lamprey (Santa Margarita River in California South Coast RMU).

Population Abundance

Our ability to estimate Pacific Lamprey population abundance has improved in many RMUs over the last 5 years (Figure 5). We have quantitative estimates of adult abundance in many watersheds along the Oregon Coast and Lower Columbia RMUs from Pacific Lamprey nest counts conducted by Oregon and Washington State agencies during winter steelhead spawning ground surveys (see Clemens et al. 2021). Pacific Lamprey abundance was updated in the Willamette RMU using counts of returning adults at Willamette falls, and annual passage counts at mainstem Columbia and Snake River dams provided a foundation for estimating Pacific Lamprey population size within select Mid-Columbia, Upper Columbia and Snake RMU HUCs. Outside of these locations, there is still high uncertainty regarding adult abundance. Even when Pacific Lamprey are known to be present in a watershed, without targeted surveys and consistent data collection, it is difficult to estimate population sizes.

Short-term Population Trend

Many HUCs still lack adequate information to evaluate short-term trend. Short-term population trend, which is defined as the degree of change in population size over three lamprey generations (~36 years), was ranked “Unknown” in 110 watersheds (28 HUCs in California RMUs, 82 HUCs in Oregon, Washington and Idaho RMUs) due to the lack of continuous, long-term adult count data (Figure 6). Of the 100 watersheds that ranked short-term trend, populations in 10 watersheds are believed to be stable or increasing (one HUC in California, 9 HUCs in Oregon, Washington and Idaho), while populations in 90 watersheds are believed to be declining (66 HUCs in California, 24 HUCs in Oregon, Washington and Idaho). There is consensus that lamprey populations have declined substantially from levels documented 50-60 years ago at Willamette Falls, Bonneville Dam and Winchester Dam on the south Oregon Coast. Recently, however passage counts at dams and abundance indices for Pacific Lamprey in western Oregon indicate modest increases in adult abundance over the last several years (Clemens et al. 2021). Additionally, adult translocation programs led by the Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe and Yakama Nation have boosted lamprey abundance and distribution in Mid- and Upper Columbia and Snake RMUs, though these datasets are not long enough to infer population trend.

Threats (OR, WA & ID)

High priority threats to Pacific Lamprey have remained consistent with those identified in the 2018 Assessment. Some changes in threat scope/severity values since the last Assessment were the result of true changes in conditions. Others were caused by new information gained or a better understanding of Pacific Lamprey needs (e.g., passage), rather than a true change in the magnitude of the threat.

For the 94 currently occupied HUCs in Oregon, Washington and Idaho (82% of HUCs assessed), 69 are ranked Critically Imperiled, 15 are ranked Imperiled, nine are ranked Critically Imperiled/Imperiled and a single HUC is ranked Vulnerable (Appendix D). Of those ranked Critically Imperiled, 33 (48%) may be attributable to dams on the mainstem Columbia River and Snake River. Mainstem passage is still the most serious threat impacting Pacific Lamprey in the Mid-Columbia, Upper Columbia and Snake RMUs (Table 3). Lamprey in the upper most reaches of the Columbia River must pass up to eight hydroelectric dams migrating upstream as adults and downstream as juveniles. Though efforts to improve passage are ongoing, the physical and hydraulic conditions in and around the various fishways may delay or impede passage of migrating lamprey or cause mortality directly or indirectly. The combined impact of mainstem and tributary passage impediments has led to fewer adult Pacific Lamprey reaching Mid-Columbia, Upper Columbia and Snake River watersheds, increasing the severity of small effective population size as a threat in these RMUs.

Excluding mainstem passage, climate change was the highest-ranked threat in 2022 (68 HUCs; Table 3). This was a major shift from the 2018 Assessment in which climate change was not ranked (due to a lack of information) or ranked as “Unknown” in 39 HUCs (41% of watersheds assessed). The negative impacts of climate change are happening faster and more intensely than anticipated. The combined effects of climate change (e.g., changes in distribution or abundance of marine prey-base, rising water temperatures, increased aridity, shifts in precipitation and streamflow patterns) and predicted rise in human population will likely exacerbate other threats within RMUs, affecting all Pacific Lamprey life stages. Climate change is a critical threat across the range of Pacific Lamprey, but the feasibility of making tangible changes will be challenging and require large-scale institutional changes.

Stream and floodplain degradation, lack of awareness and water quality were also high-ranking threats in RMUs below Bonneville Dam and especially outside of the Columbia Basin (Table 3). Human settlement and land development have significantly altered river ecosystems. Floodplain development, stream channelization, road building (e.g., channel confinement, simplification, habitat fragmentation), flood reduction (e.g., channel straightening, levees), dredging, mining, and vegetation removal (e.g., grazing, deforestation, agriculture) contribute to Pacific Lamprey habitat degradation. Partners continue to work hard to implement restoration projects aimed at addressing habitat degradation and impaired floodplain function throughout the range of Pacific Lamprey. However, as human populations and associated land use continues to rise, habitat degradation may outpace restoration efforts in some areas.

Lack of awareness has improved in many RMUs since the 2018 Assessment, but there are still HUCs where information about Pacific Lamprey presence, biology, habitat and passage requirements are not widely known or considered. Tribes, state and federal agencies, watershed councils and others have played significant roles in improving awareness of Pacific Lamprey through targeted outreach, education events, and informational campaigns. Nevertheless, there is still a need for more awareness regarding the life cycle, species identification, habitat requirements and inclusion of Pacific Lamprey in the design and implementation of fish passage, dredging, screening and habitat restoration projects. Educating biologists, biological managers, permit reviewers, funding agencies, and the general public about the cultural and ecological importance of Pacific Lamprey will continue to be an essential component of Pacific Lamprey conservation and recovery efforts.

Degraded water quality remains a Moderate to High threat across much of the range of Pacific Lamprey (Tables 3 and 4). Elevated water temperature and contaminants were the primary water quality concerns identified during the 2022 Assessment. Factors contributing to high water temperatures include increased air temperature, loss of floodplain connectivity, reduced instream flows associated with water withdrawals and lack of riparian cover attributable to timber harvest, land clearing activities and recent wildfires. Prolonged elevated water temperatures can impact Pacific Lamprey embryonic development, physiology, adult migrations, and survival (Clemens et al. 2016; Clemens 2022). Industrial discharge and surface water runoff from farms, roads and urban areas were cited as potential sources of contaminants entering waterbodies. Toxic contaminants such as dichlorodiphenyldichloroethylene (DDE), PCBs, flame retardants and heavy metals may be a particular concern for Pacific Lamprey because direct exposure in water, sediment, or through dietary intake can result in high concentrations of contaminants accumulating in fatty tissues that may compromise development, reproduction and survival (Nilsen et al. 2015; Clemens et al. 2017a; Madenjian et al. 2021). More monitoring and research are needed to better understand the magnitude of water quality impacts on Pacific Lamprey and how climate change may influence or exacerbate current water quality conditions.

Threats (CA)

For the 59 currently occupied HUCs in California (62% of HUCs assessed), 16 are ranked as Critically Imperiled, 41 as Imperiled and two as Vulnerable. Of those ranked Critically Imperiled, ten have limited Pacific Lamprey distribution caused by impassable dams or smaller passage barriers and the other six have water quality or entrainment issues.

The principal constraint on the current distribution of Pacific Lamprey in California is the presence of over 59 large, impassable dams that collectively block 8,954 km (48%) of historical habitat in 4th order or higher streams (Table 4). All but three of these dams have been in place since prior to 1968. Not only have impassable dams severely constrained the current range, but numerous smaller barriers block or impede the upstream migration of lampreys. The barriers include smaller dams and weirs, as well as fishways that do not incorporate lamprey passage needs. Fortunately, there has been considerable progress on understanding the design features necessary to facilitate lamprey passage, identification of potential barriers, increasing awareness of lampreys, and their incorporation into passage projects (e.g., LTWG 2022a). In Fall 2023, Hemphill Dam in Auburn Ravine (a tributary of the Feather River near Sacramento) was removed and replaced with a roughened rock ramp to improve passage for salmonids. During dewatering to remove the dam, adult lamprey were observed and we would expect them to navigate upstream and increase their distribution during the migration season of 2024. Improvement of passage has been a major focus of implementation planning and projects since 2012. Passage improvement for Pacific Lamprey is expected to continue as lampreys are incorporated into passage assessments (Reid and Goodman 2016, 2017). Dam removals could also increase distribution. For example, removal of four dams on the Klamath River is scheduled to begin in 2023 and removal of two dams on the Eel River seems likely within the next five to ten years.

Downstream passage of outmigrating juveniles is also recognized as a major threat, both for success of local populations and as a drain on the regional metapopulation (Goodman et al. 2015; Moser et al. 2015; Goodman et al. 2017). There are two major areas of concern, entrainment and stranding. Large numbers of juveniles in the lower Sacramento and San Joaquin are entrained annually by the two major pumping projects in the delta (California Aqueduct and Delta Mendota canals), both of which lack screening suitable for lampreys. Secondly, outmigrating juveniles are periodically stranded with mass mortalities in dry lower mainstem reaches of the Carmel, Salinas and middle reaches of the San Joaquin rivers caused by the periodic inability of freshet flows to reach the ocean (Goodman et al. 2015; Goodman and Reid 2017).

Dewatering and flow management presented the most influential threats throughout the region, after passage (Table 4). All Eel, Russian River and San Francisco Bay HUCs were impacted by numerous water withdrawals impacting mainstem flow. The Eel was also affected by substantial diversion of flow from the upper mainstem into the Russian River, however, we expect this impact to be reduced if dam removal moves forward. Dewatering and flow management were also ranked moderate to high in severity throughout most currently unoccupied drainages south of San Luis Obispo, which occur in arid regions further exacerbated by urbanization, agricultural withdrawals and recent drought conditions. Flow management by large mainstem dams also impact migration cues for outmigrating juveniles and spawning of adult lamprey. Manipulation of flow in the lower Sacramento and San Joaquin by the two major pumping projects in the delta may also have substantial effects on migrating lampreys (both adults and juveniles).

Three HUCs north of San Luis Obispo (Carmel, Salinas, and San Joaquin-middle) are substantially impacted by total desiccation of their lower reaches, resulting in lack of access for in-migrating adults and periodic stranding of outmigrating juveniles. The inability of freshet flows to reach the ocean in the Carmel, Salinas and middle reaches of the San Joaquin rivers periodically cause mass emigration mortalities and is now recognized as a substantial threat, both for success of local populations and as a drain on the regional metapopulation. Carmel is currently in the process of shifting their water source away from groundwater pumping. Construction has begun on a recycled water pipeline project and installation of a large desalinization plant, as well as changes in flow management to ensure channel continuity to the ocean. There is also a major restoration project underway on the San Joaquin River to improve flow and downstream passage success in the mainstem. However, currently, all three rivers are still subject to periodic mass mortalities due to outmigration strandings.

Water quality was generally considered to be a widespread but low severity issue for Pacific Lamprey in California. Principal exceptions where severity rose to Moderate or High were: 1) highly urbanized reaches of the San Francisco and Southern Coastal RMUs (4 HUCs); 2) highly agricultural areas where there is substantial runoff into streams (3 HUCs); 3) the Klamath River, where mainstem dams, low flows and extensive upstream agricultural inputs impair water quality in the mainstem downstream of Iron Gate Dam, though we expect this to be partially mitigated by future dam removal operations and 4) the Eel Drainage and Mattole (5 HUCs) where unregulated marijuana cultivation reduces summer flows, raises temperatures, and inputs contaminants and nutrients into the mainstems, promoting algal blooms.

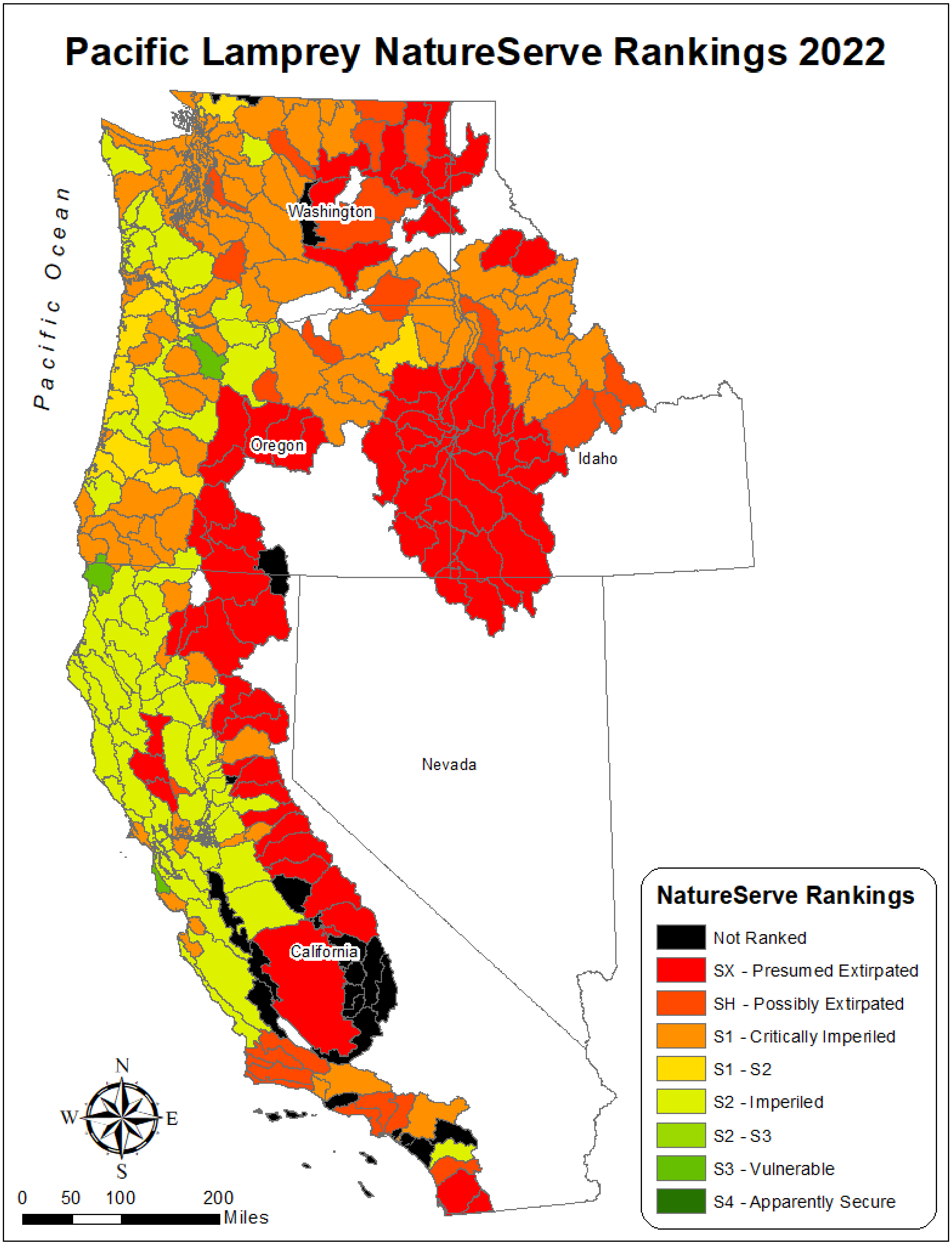

Figure 2. Calculated NatureServe conservation status ranks for Pacific Lamprey, 2022.

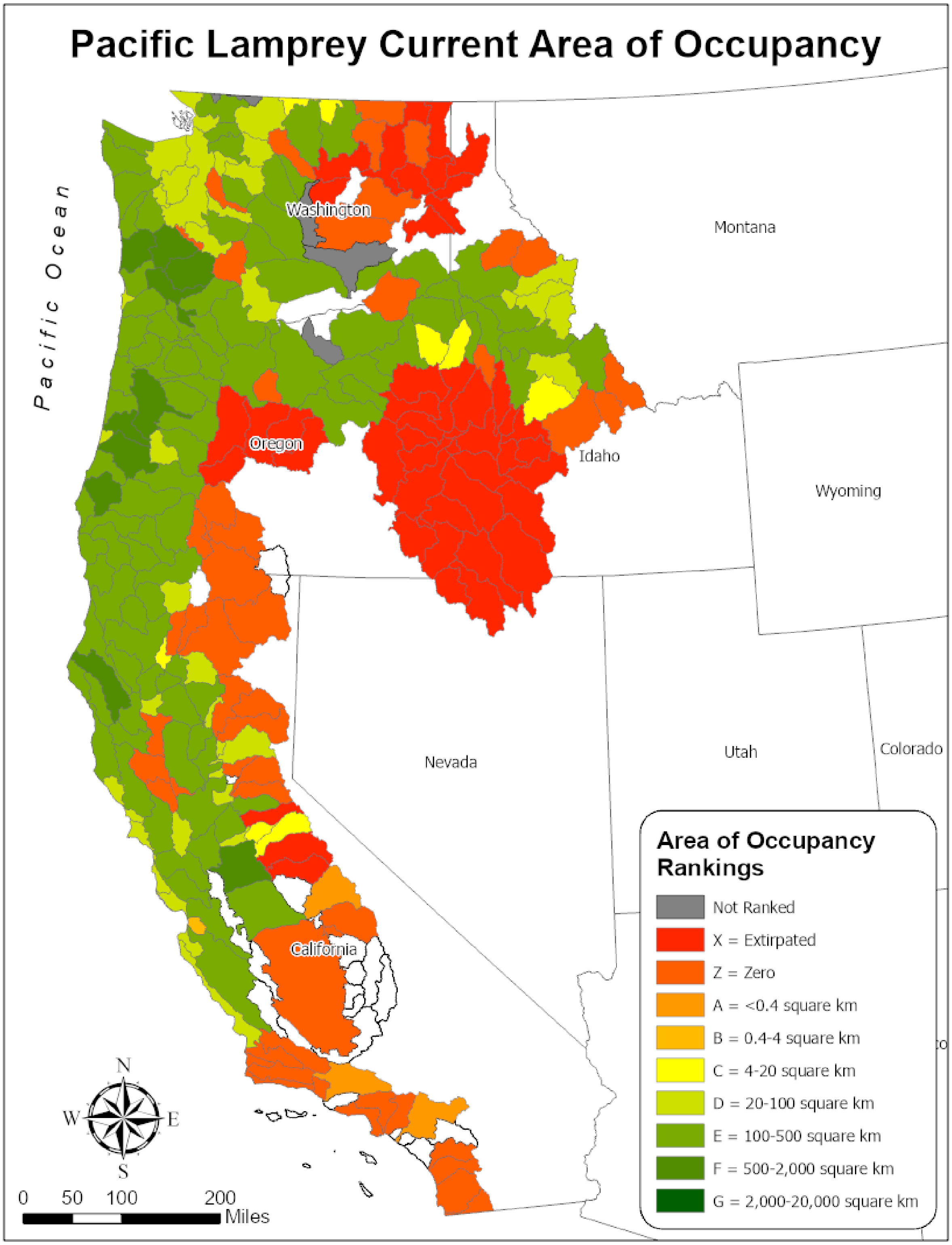

Figure 3. Current Area of Occupancy for Pacific Lamprey, 2022.

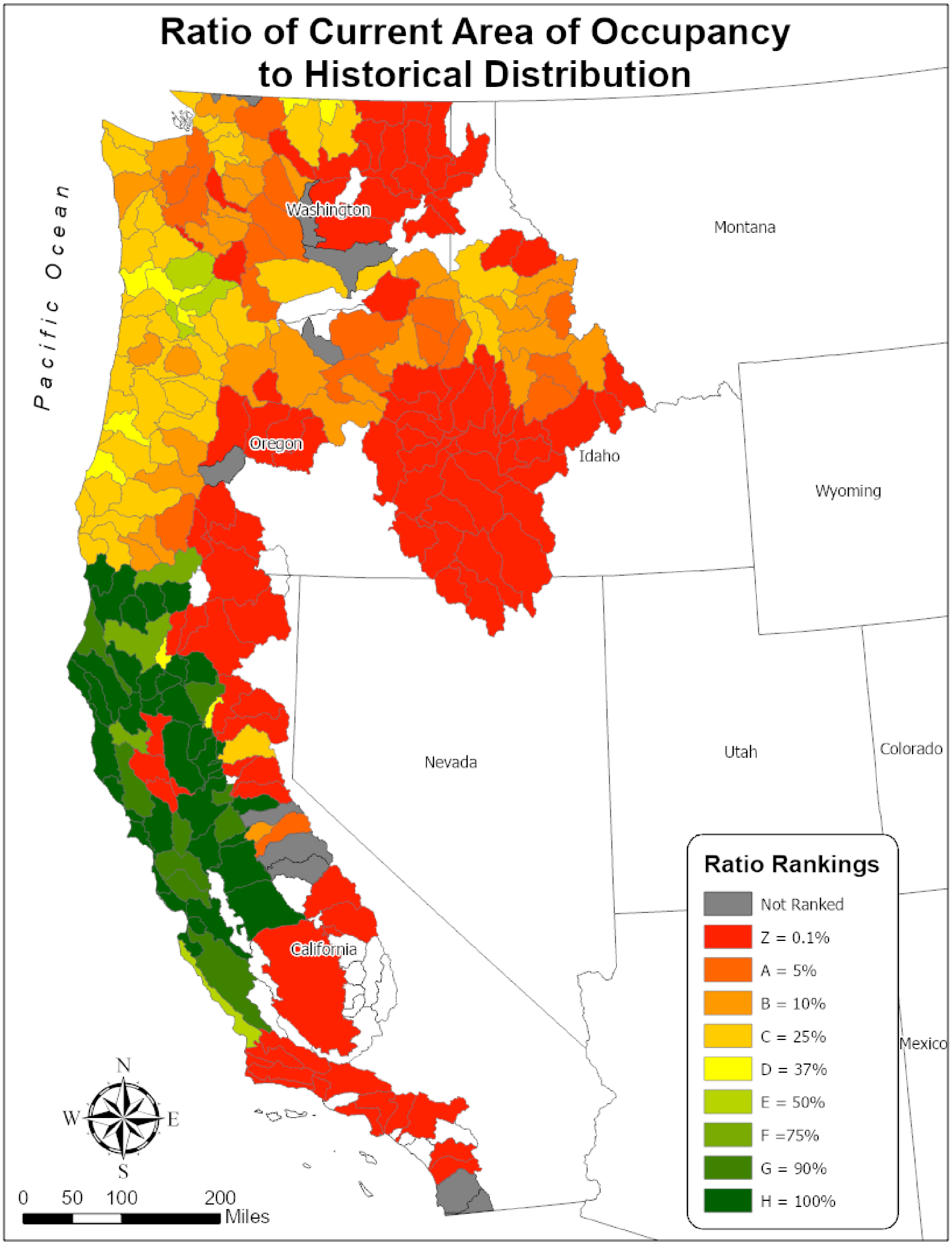

Figure 4. Ratio of current Area of Occupancy to Historical Range Extent for Pacific Lamprey, 2022.

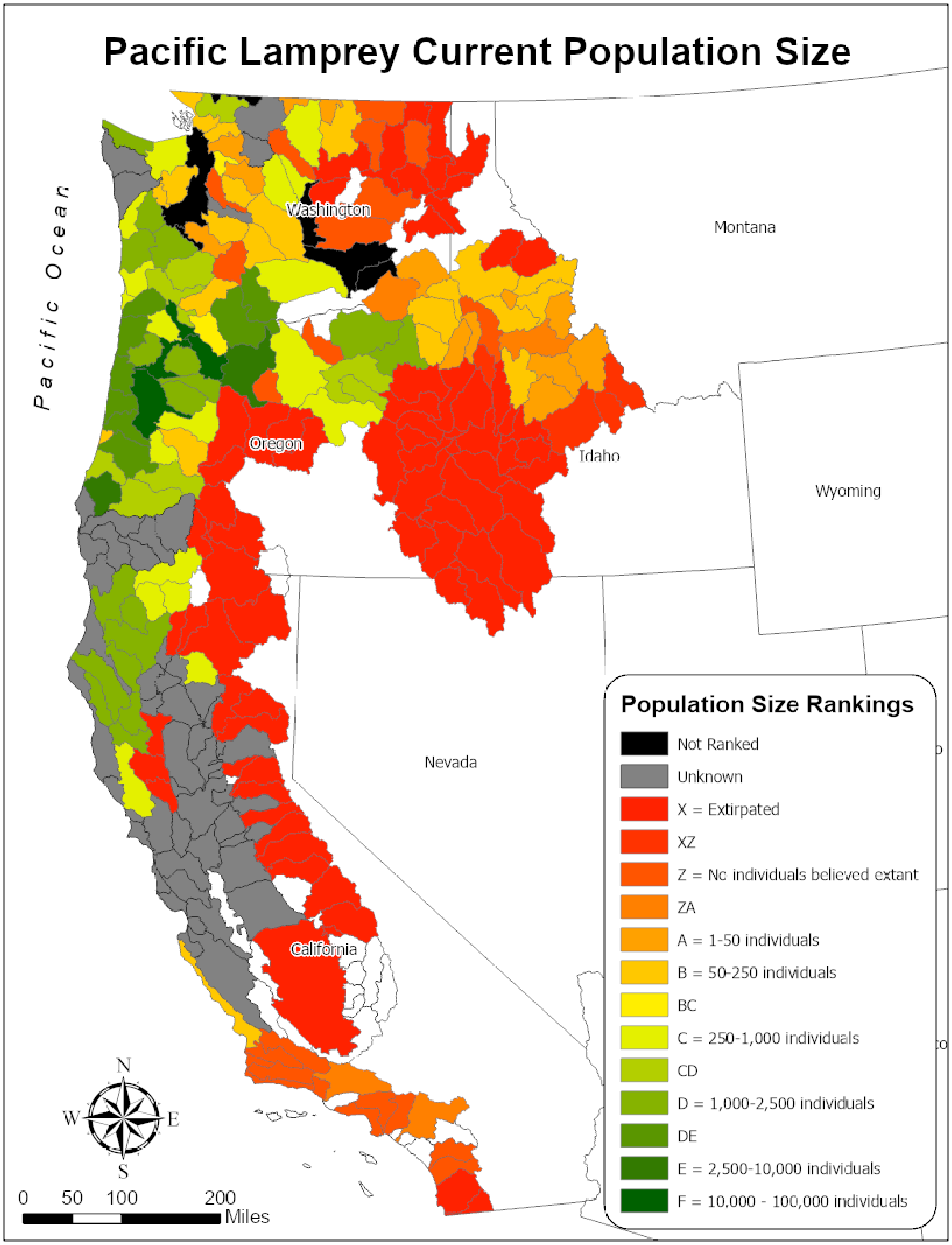

Figure 5. Current Population Size for Pacific Lamprey, 2022.

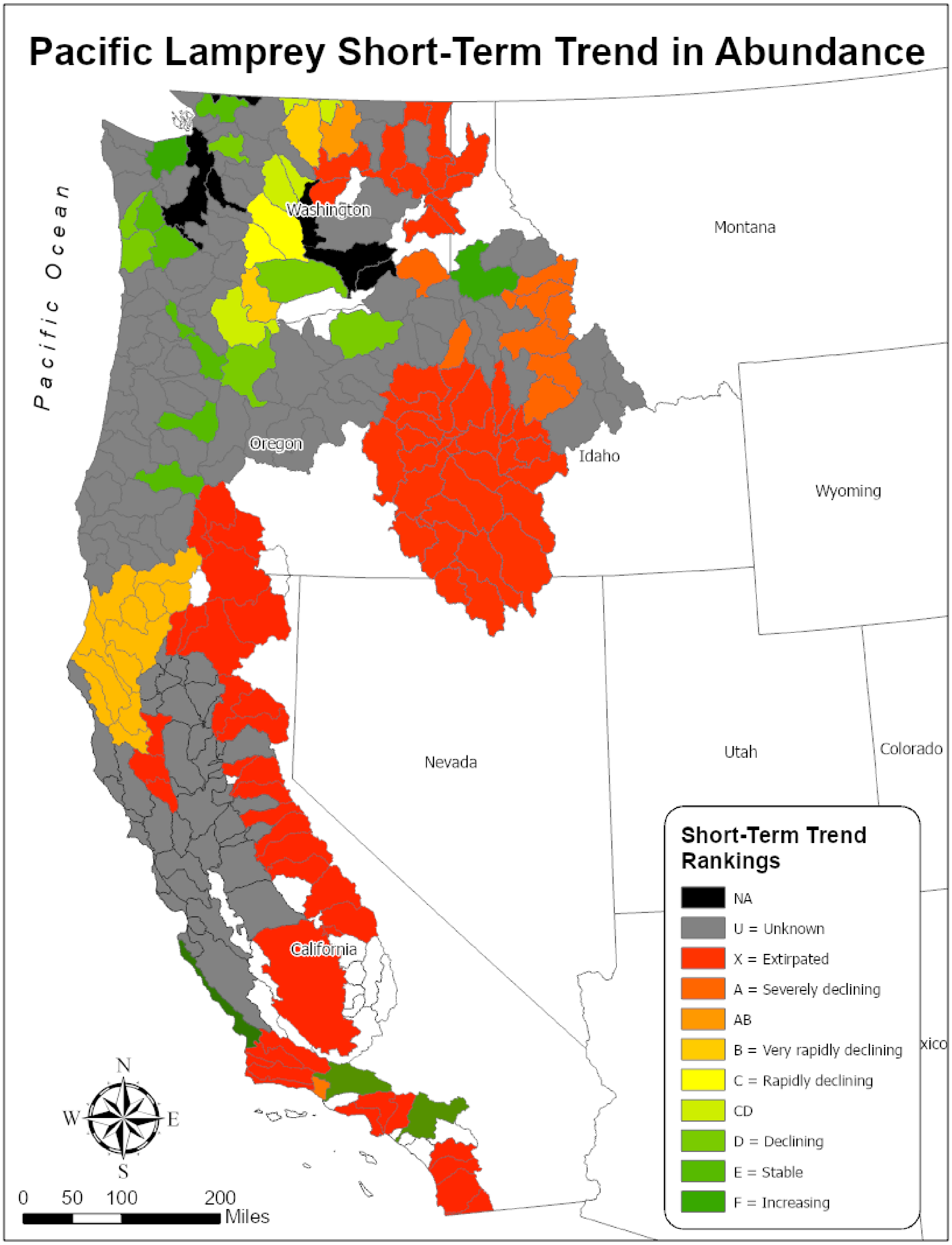

Figure 6. Short-term Trend in abundance for Pacific Lamprey, 2022.

Table 3. Threats to Pacific Lamprey as ranked by participants at regional meetings in 2022 (OR, WA, ID RMUs). Numeric scope and severity ranking values for each threat category were averaged across all HUC 4 watersheds in a RMU to obtain a single value that determined the overall magnitude of the threat. Threat categories with an average cumulative score ≥ 2.50 were designated a high priority threat in the RMU. Insignificant threat = green (mean scope/severity 0-1.49), Low threat = yellow (mean scope/severity score 1.5-2.49), Moderate threat = orange (mean scope/severity score 2.5-3.49), High threat = red (mean scope/severity score 3.5-4.0), Unknown = grey, NA (not assessed) = no color (see Appendix B).

Regional Management Unit	Mainstem Passage	Tributary Passage	Dewatering & Flow Management	Stream & Floodplain Degradation	Water Quality	Predation	Small Population Size	Lack of Awareness	Climate Change	Harvest
South Oregon Coast Sub-region	NA	Low	Moderate	Moderate	Moderate	Unknown	NA	Moderate	High	NA
North Oregon Coast Sub-region	NA	Moderate	Low	High	Moderate	Unknown	NA	Moderate	High	NA
Willamette	NA	Moderate	High	High	High	Moderate	NA	Low	High	NA
Lower Columbia	NA	Moderate	Moderate	Moderate	Moderate	Unknown	NA	High	High	NA
Mid-Columbia	High	Moderate	Moderate	Moderate	High	Low	Moderate	Moderate	High	NA
Snake	High	Low	Low	Low	Low	Low	High	Moderate	Moderate	NA
Upper Columbia	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High	NA
Washington Coast	NA	Low	Low	Moderate	Low	Low	NA	Low	Moderate	NA
Puget Sound/Strait of Juan de Fuca	NA	Moderate	Low	Moderate	Low	Insignificant	NA	Moderate	Moderate	NA

Table 4. Threats to Pacific Lamprey as ranked by participants at regional meetings in 2022 (CA RMUs). Numeric scope and severity ranking values for each threat category were averaged across all HUC 4 watersheds in a RMU to obtain a single value that determined the overall magnitude of the threat. Threat categories with an average cumulative score ≥ 2.50 were designated a high priority threat in the RMU. Insignificant threat = green (mean scope/severity 0-1.49), Low threat = yellow (mean scope/severity score 1.5-2.49), Moderate threat = orange (mean scope/severity score 2.5-3.49), High threat = red (mean scope/severity score 3.5-4.0), Unknown = grey, NA (not assessed) = no color (see Appendix B).

Regional Management Unit	Mainstem Passage	Tributary Passage	Dewatering & Flow Management	Stream & Floodplain Degradation	Water Quality	Predation	Small Population Size	Lack of Awareness	Climate Change	Harvest
California South Coast	Moderate	Moderate	Moderate	Low	Moderate	Low	Unknown	NA	Unknown	Insignificant
San Joaquin	High	High	Moderate	Moderate	Moderate	Moderate	Unknown	NA	Unknown	Insignificant
California South Central Coast	Moderate	Moderate	Moderate	Low	Moderate	Low	Unknown	NA	Unknown	Insignificant
San Francisco Bay	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Unknown	NA	Unknown	Low
California North Central Coast	Moderate	Moderate	Low	Low	Moderate	Low	Unknown	NA	Unknown	Insignificant
Sacramento	Moderate	Moderate	Moderate	Low	Moderate	Low	Unknown	NA	Unknown	Insignificant
California North Coast	Low	Low	Moderate	Low	Moderate	Low	Unknown	NA	Unknown	Insignificant

5. ASSESSMENT RESULTS BY REGIONAL MANAGEMENT UNIT

Overview

Pacific Lamprey distribution has been organized into 18 RMUs spanning the U.S. range of Pacific Lamprey from Alaska to California, including the Pacific Ocean (Figure 7). This division facilitates a finer level of resolution for description of populations, distribution, and their habitats. It also provides a more optimal structure for partner collaboration on conservation and restoration activities.

The 2022 Assessment revision was conducted within 15 of the 18 RMUs in Oregon, Washington, Idaho and California. In this chapter we present a high-level summary of Assessment results at the RMU level, including major changes to CSRs, population demographics and threat factors since the last Assessment revision in 2018. A more detailed summary of Assessment results can be found in the corresponding RIP for each RMU on the PLCI webpage (https://www.pacificlamprey.org/rmu/). Maps depicting historical and current Pacific Lamprey distribution can also be found in the RIPs and Pacific Lamprey Distribution and Observations web map (https://fws.maps.arcgis.com/apps/instant/basic/index.html?appid=3a85e0d266834a2aad815a9d2f18ddf5). Pacific Lamprey population demographic and threats ranking information input into the NatureServe model for each RMU can be found in Appendices D and E. Although the Assessment was not conducted in Alaska, the Mainstem Columbia/Snake and North Pacific Ocean, we provide a brief overview of threats and data gaps within these RMUs.

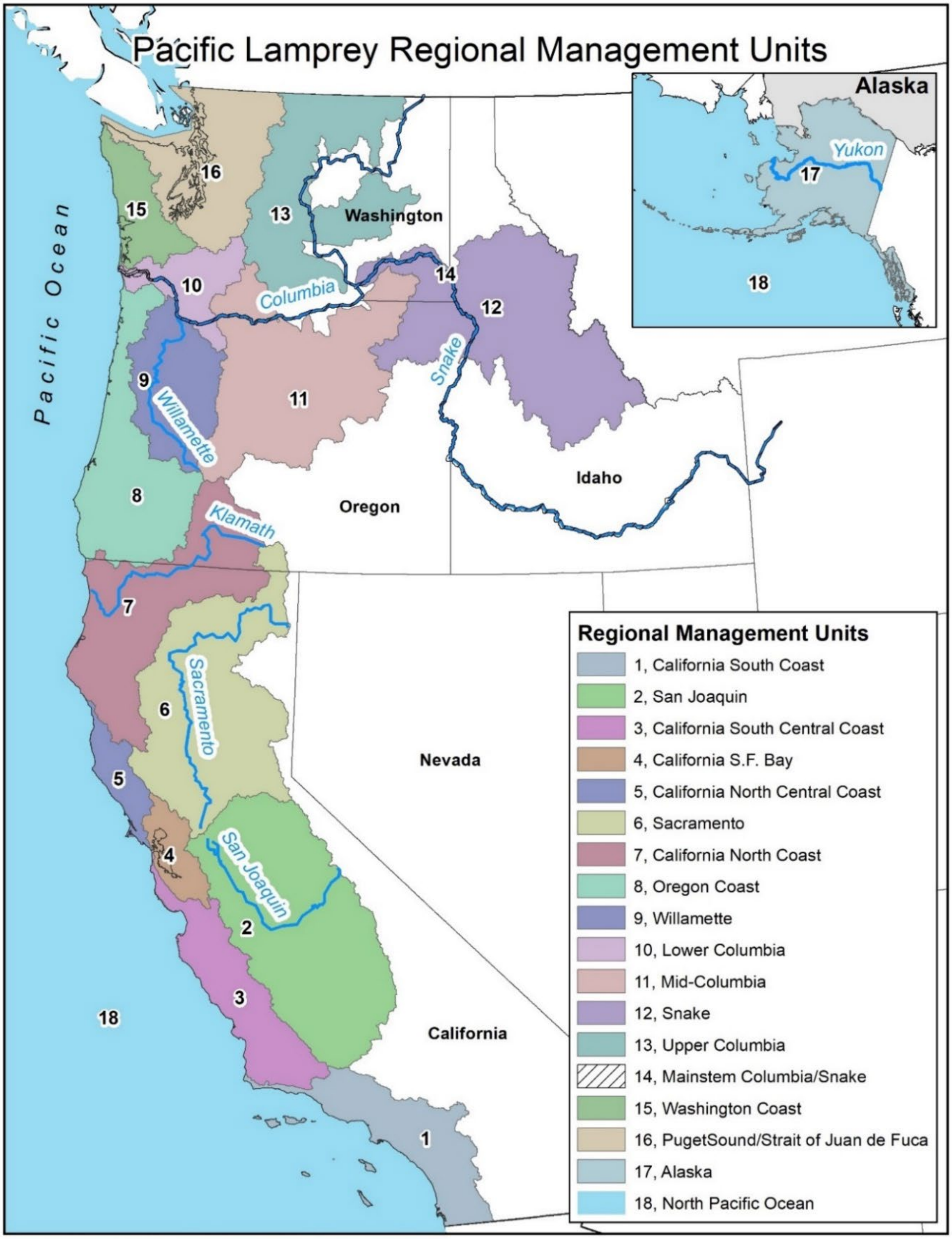

Figure 7. Map of 18 Regional Management Units within the historical range of Pacific Lamprey.

CALIFORNIA SOUTH COAST

The California South Coast RMU includes all coastal drainages from Point Conception south to the Mexican border, including the Ventura-San Gabriel, Santa Ana and Laguna-San Diego coastal USGS accounting units. It includes 15 4^{th} field HUCS, ranging in size from 233 - 4,403 km^2 (Figure 8; Appendix E). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs changed in four of fifteen HUCs since 2018 based on continuing monitoring of southern drainages.
- The CSR improved from Possibly Extirpated (SH) to Imperiled (S2) in the Santa Margarita River. Larvae of multiple size classes were found in the Santa Margarita in 2018-2019, adding additional support to the potential for Pacific Lamprey to naturally recolonize drainages from which they have been absent, suggesting that fluctuations in the extent of the southern range may be subject to environmental conditions as well as opportunity for passage (Reid and Goodman 2020).
- Conservation status ranks also improved from Possibly Extirpated (SH) to Critically Imperiled (SI) in Ventura, Santa Clara and Santa Ana HUCs. A small number of Pacific Lamprey adults were observed in 2017 (i.e., 2-3 fish). However, subsequent surveys in 2018-2019 did not find larvae to confirm successful reproduction. Continued monitoring is planned.
- All other HUCs continue to be categorized as Possibly Extirpated (SH), based on the absence of larvae or adult observations (Swift and Howard 2009, Reid and Goodman 2016, 2020, 2021; unpublished data).
- Although Pacific Lamprey were not documented in many South Coastal drainages from 2006-2022. The observations of migrating adults in three rivers and successful recolonization of the Santa Margarita River demonstrate that management for Pacific Lamprey even in currently unoccupied historical range should still aim to provide suitable habitat and passage.
- Both passage and channel desiccation remain principal distributional constraints on lamprey populations in the South Coastal RMU.
- The primary threats in the South Coast RMU are associated with dessication of lower reaches by diversions and groundwater withdrawals. Dry reaches block adults migrating in from the ocean, as well as creating a sink for outmigrating juveniles. The periodic inability of freshet flows used by outmigrating juveniles to reach the ocean can cause mass emigration mortalities and is now recognized as a substantial threat, both for success of local populations and as a drain on the regional metapopulation. Channel degradation and water quality are also a concern in highly urbanized reaches.

A detailed summary of 2022 Assessment results for the California South Coast RMU can be found in the South Coast RMU Regional Implementation Plan (Boyce et al. 2022) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

California South Coast RMU Nature Serve Rankings

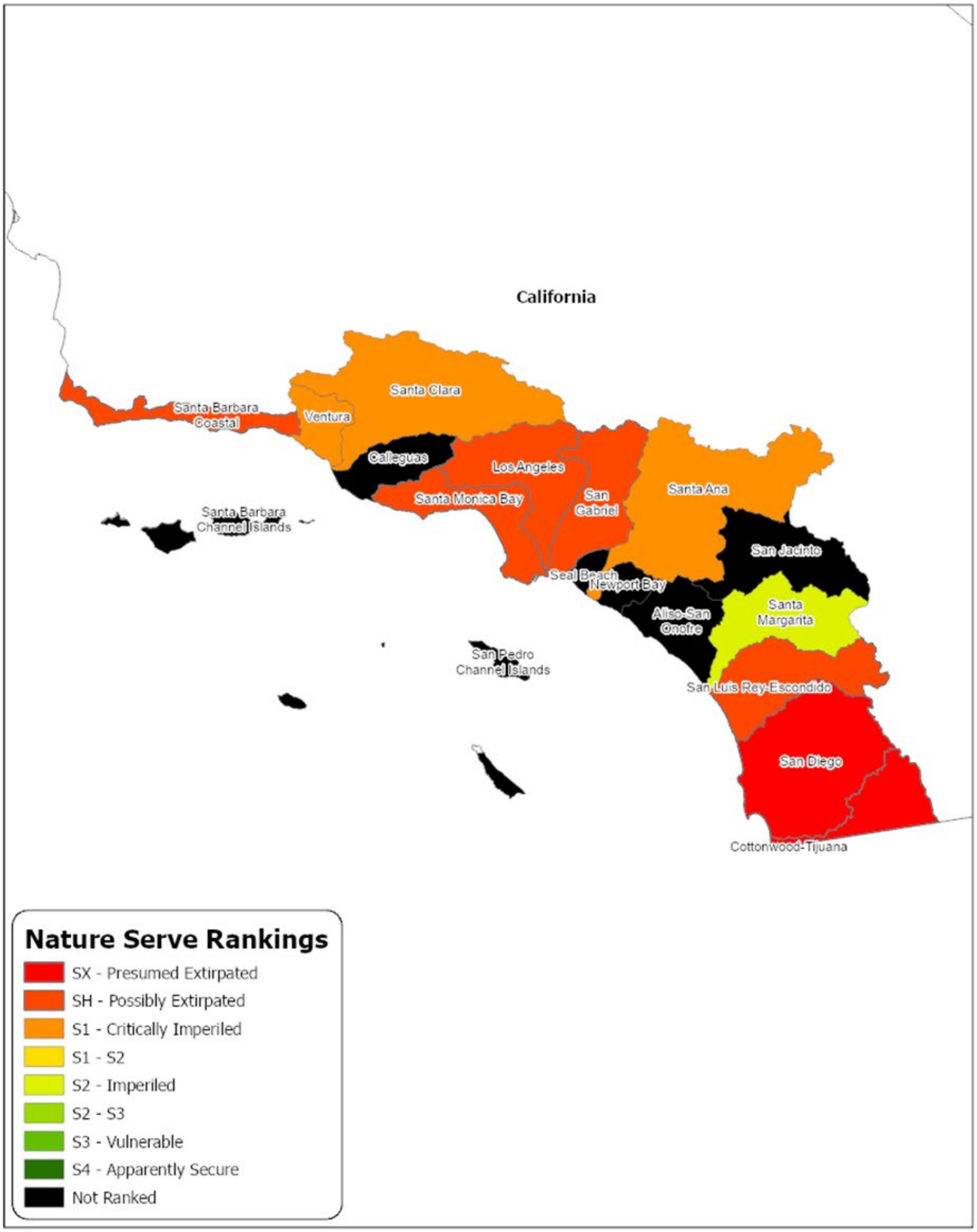

Figure 8. NatureServe conservation status ranks for the California South Coast RMU, 2022.

SAN JOAQUIN

The California San Joaquin RMU includes all drainages in the southern Central California Valley, including the San Joaquin and Tulare sub-basins, downstream (north) to the delta and confluence with the Sacramento, including the San Joaquin and Tulare USGS subregions and accounting units. Due to subregional differences in hydrology and historical use we have generally separated the San Joaquin and Tulare sub-basins within the broader San Joaquin RMU. All anadromous access to the Tulare sub-basin was lost by the 1870's due to diversion of its inflows and drainage of the lakebed for agricultural purposes, and the Tulare Basin was not analyzed further in the Assessment, with the exception of the Kings drainage (and tributary Mill Creek) that connects northwards to the San Joaquin. The San Joaquin sub-basin includes 15 4^{th} field HUCS, ranging in size from 629 - 6,921 km^2 (Figure 9; Appendix E). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs remained stable when analyzed with similar methods between 2018-2022. Most currently occupied HUCs below dams were categorized as Imperiled (S2).
- Current Pacific Lamprey distribution has remained the same in all HUCs since the 2018 Assessment.
- Population abundance of Pacific Lamprey in the California San Joaquin RMU is thought to be largely unchanged since the 2012 Assessment.
- Although no long-term count of Pacific Lamprey exists in the San Joaquin RMU, unobstructed populations are believed to have declined considerably since the 1970's and by 50-70% since 1990, based on range-wide trends and anecdotal reports from local residents (Goodman and Reid 2012).
- Passage remains the principal distributional constraint on lamprey populations in the San Joaquin RMU. However, the middle reaches of the mainstem San Joaquin River have large dry gaps that are currently under restoration.
- The primary threats in the San Joaquin RMU were entrainment by the two large diversions in the Delta and dewatering in the middle reaches of the San Joaquin mainstem. Additional concerns were dewatering and water quality in the middle reaches of the San Joaquin, as well as potential predation in the upper Cosumnes and lower San Joaquin.

A detailed summary of 2022 Assessment results for the California San Joaquin RMU can be found in the San Joaquin RMU Regional Implementation Plan (Boyce et al. 2022) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

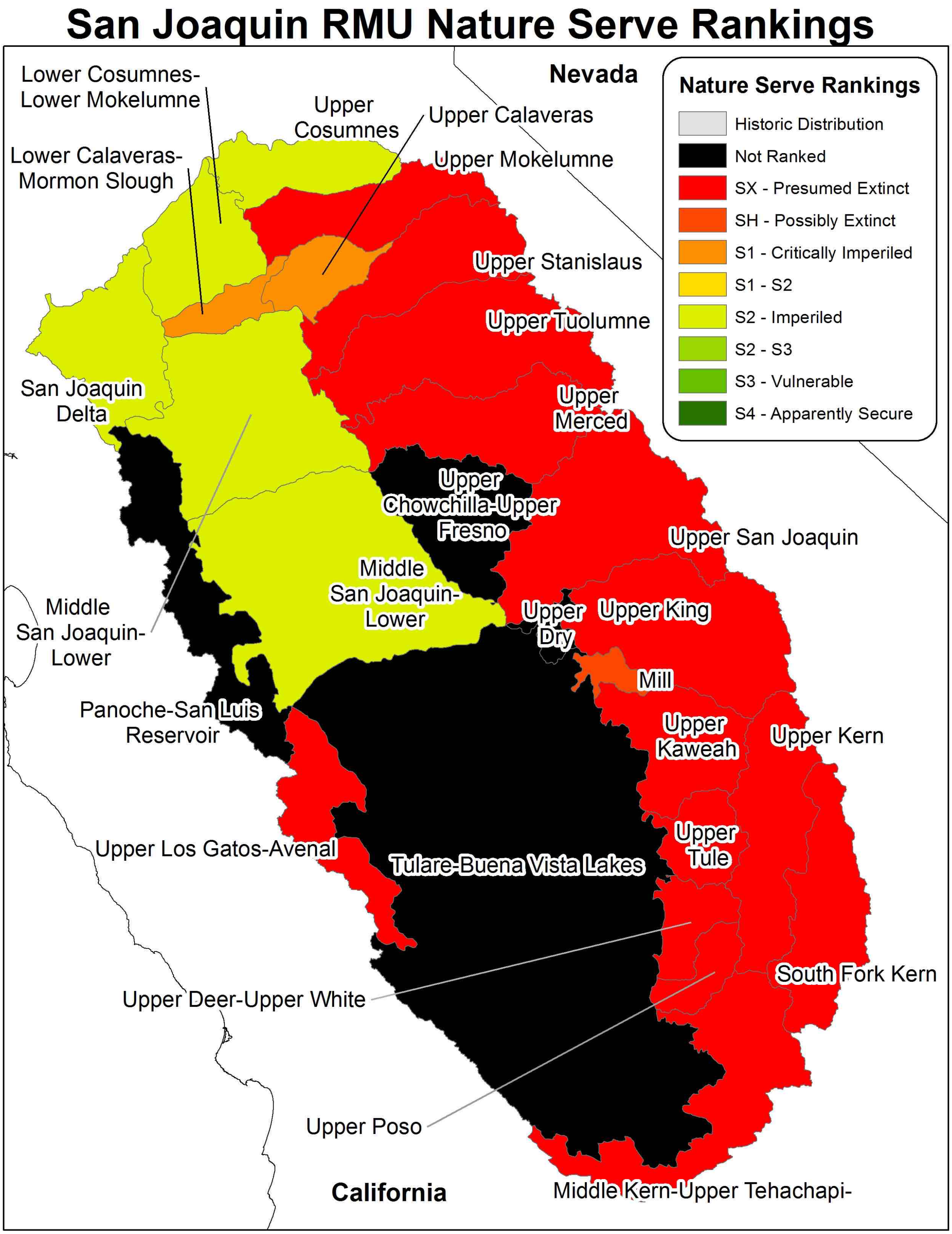

Figure 9. NatureServe conservation status ranks for the San Joaquin RMU, 2022.

CALIFORNIA SOUTH CENTRAL COAST

The California South Central Coast RMU includes all coastal drainages from the Golden Gate Bridge to Point Conception, including the coastal portion of the San Francisco Bay and most of the Central California Coastal USGS accounting units. It includes 12 4th field HUCS, ranging in size from 574 - 8,519 km^2 (Figure 10; Appendix E). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs remained stable when analyzed with similar methods between 2018-2022.
- HUCs from the Central Coast north were categorized as Critically Imperiled (S1) to Vulnerable (S3). The southernmost HUCs apparently remain unoccupied (ranked SH – Possibly Extirpated) as of 2022.
- In 2017 Pacific Lamprey re-extended their range 160 km to the south in the Central Coastal HUC and have spawned in San Luis Obispo Creek annually through 2022. Otherwise, Pacific Lamprey distribution remained essentially the same.
- Population abundance of Pacific Lamprey in the California South Central Coast RMU is thought to be largely unchanged since the 2012 Assessment.
- No long-term count of Pacific Lamprey exists in the California South Central Coast RMU. Unobstructed populations are believed to have declined considerably since the 1970's and by 50-70% since 1990, based on range-wide trends and anecdotal reports from local residents.
- Both passage and channel desiccation remain principal distributional constraints on lamprey populations. However, a major dam was removed on the Carmel River in 2015 (San Clemente Dam, RKM 30) opening an additional 10 km of additional habitat, and a lamprey passage modification on San Luis Obispo Creek in 2013 (Marre Weir) has allowed Pacific Lamprey to recolonize this drainage, extending the southern distribution by 160 km along the coast.
- The primary threats in the South Central Coast RMU are associated with desiccation of lower reaches by diversions and groundwater withdrawals. Dry reaches block adults migrating in from the ocean, as well as creating a sink for outmigrating juveniles. The periodic inability of freshet flows used by outmigrating juveniles to reach the ocean in both the Salinas and Carmel rivers can cause mass emigration mortalities and is now recognized as a substantial threat, both for success of local populations and as a drain on the regional metapopulation.

A detailed summary of 2022 Assessment results for the California South Central Coast RMU can be found in the South Central Coast Regional Implementation Plan (Boyce et al. 2022) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

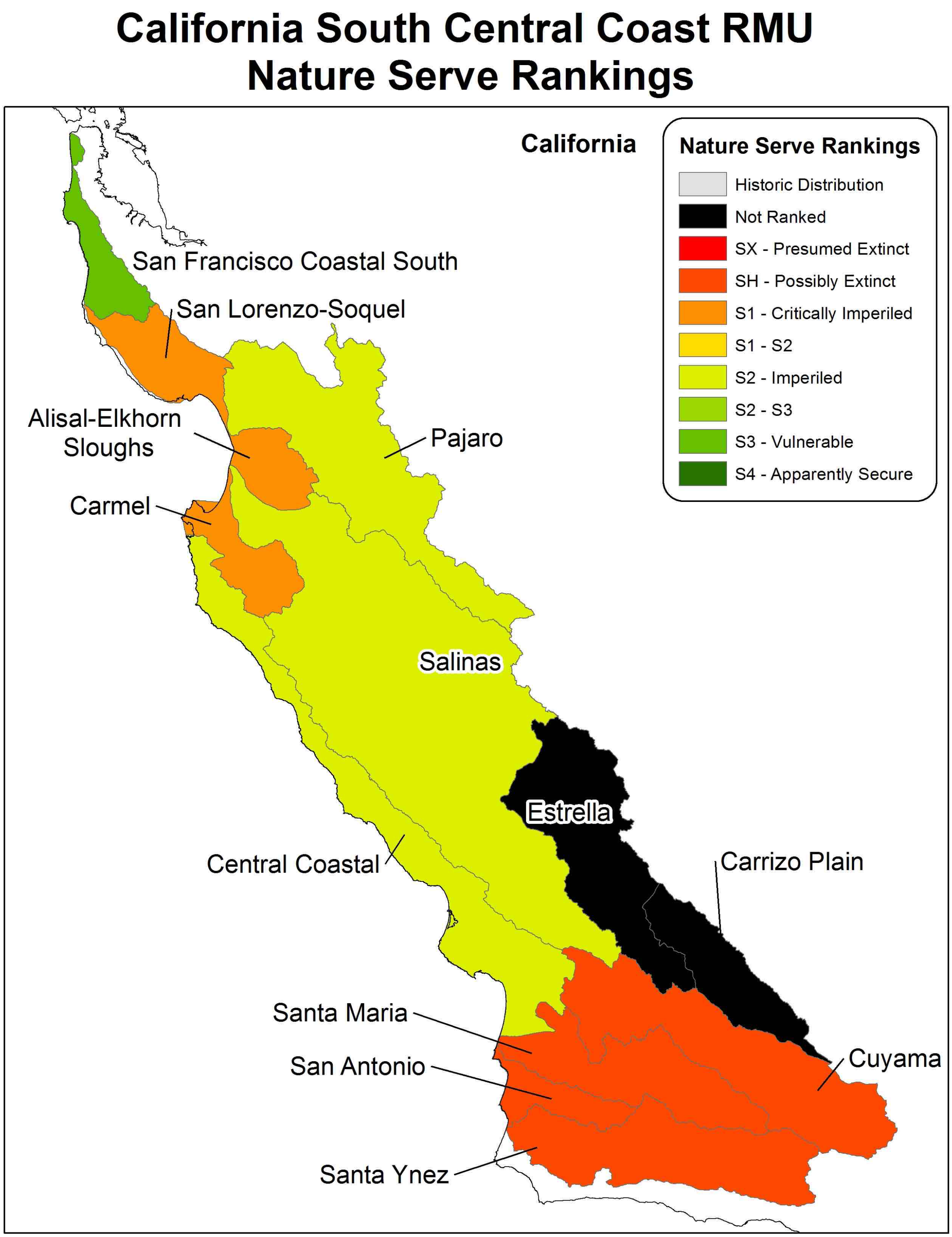

Figure 10. NatureServe conservation status ranks for the California South Central RMU, 2022.

SAN FRANCISCO BAY

The California San Francisco Bay RMU includes all drainages that enter San Francisco and its component bays from the confluence of the Sacramento and San Joaquin rivers to the Golden Gate, including the San Francisco Bay USGS accounting unit, without the outer coastal HUCs that are included in the central coastal RMUs. It includes four 4^{th} field HUCS, ranging in size from 1,695−3,171 km^2 (Figure 11; Appendix E). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs remained stable when analyzed with similar methods between 2018-2022. Three HUCs are currently categorized as Imperiled (S2) and one as Critically Imperiled (S1).
- Current Pacific Lamprey distribution remained generally the same in all HUCs, with a slight increase in the Napa River, following removal of a large culvert barrier.
- Population abundance of Pacific Lamprey in the California San Francisco Bay RMU is thought to be largely unchanged since the 2012 Assessment.
- No long-term count of Pacific Lamprey exists in California San Francisco Bay RMU. Unobstructed populations are believed to have declined considerably since the 1970's and by 50-70% since 1990, based on range-wide trends and anecdotal reports from local residents (Goodman and Reid 2012).
- Passage remains the principal distributional constraint on lamprey populations in the San Francisco Bay RMU. However, considerable effort has gone into better understanding passage needs of lamprey. Passage projects are proposed under implementation plans and a number of projects are underway in the Alameda and Coyote drainages.
- Stakeholder discussions and site visits identified a potential threat from illegal subsistence fishing by homeless population in highly urbanized streams of the Bay Area.

A detailed summary of 2022 Assessment results for the California San Francisco Bay RMU can be found in the San Francisco Bay RMU Regional Implementation Plan (Boyce et al. 2022) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

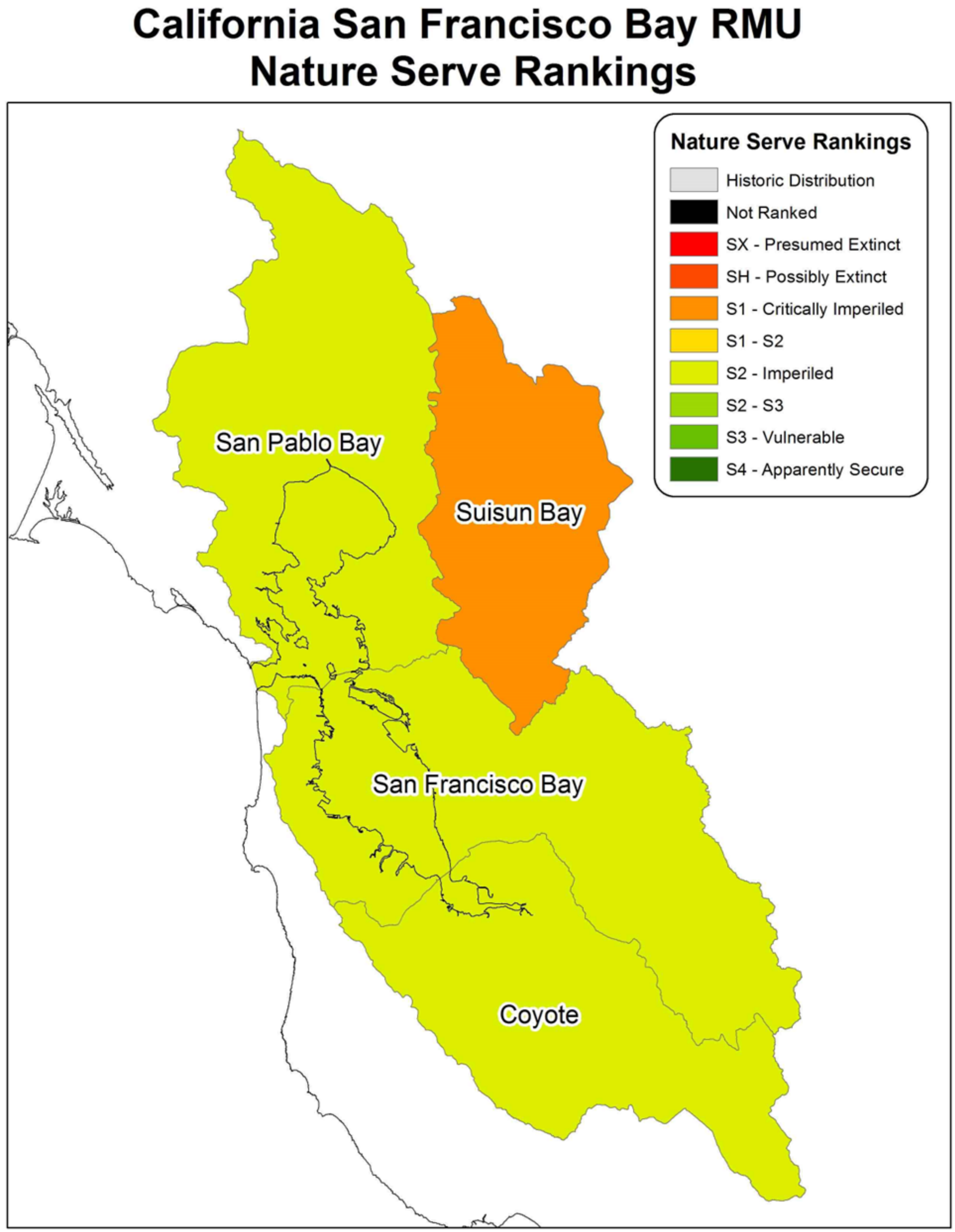

Figure 11. NatureServe conservation status ranks for the San Francisco Bay RMU, 2022.

CALIFORNIA NORTH CENTRAL COAST

The California North Central Coast RMU includes all coastal drainages from Punta Gorda (Mattole River) in the north to the Golden Gate in the south, including the southern half of the Northern California Coast (01) and the outer coast portion of the San Francisco Bay USGS accounting units. It includes five 4th field HUCS, ranging in size from 402 - 3,849 km^2 (Figure 12; Appendix E). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs remained stable when analyzed with similar methods between 2018-2022. Four HUCs were categorized as Imperiled (S2) and one (Tomales Bay) was categorized as Critically Imperiled (S1) due to impassable dams and limited distribution.
- Current Pacific Lamprey distribution remained the same in all HUCs.
- Population abundance of Pacific Lamprey in the California North Central Coast RMU is thought to be largely unchanged since the 2012 Assessment.
- No long-term count of Pacific Lamprey exists in the California North Central Coast RMU. However, some monitoring is now occurring on the Russian River. Unobstructed populations are believed to have declined considerably since the 1970's and by 50-70% since 1990, based on range-wide trends and anecdotal reports from local residents.
- Passage remains the principal distributional constraint on lamprey populations in the North Central Coast RMU. However, considerable effort has gone into better understanding passage needs of lamprey. The impact of seasonal dams was reviewed on the Russian River and passage improvements made at the Veterans Park Weir.
- The primary threats in the North Central Coast RMU were dewatering and the impacts of seasonal dams (passage and water quality) on the mainstem Russian River. Most threats were ranked as low in Severity, with no severe threats in any HUCs.

A detailed summary of 2022 Assessment results for the California North Central Coast RMU can be found in the North Central Coast RMU Regional Implementation Plan (Boyce et al. 2022) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

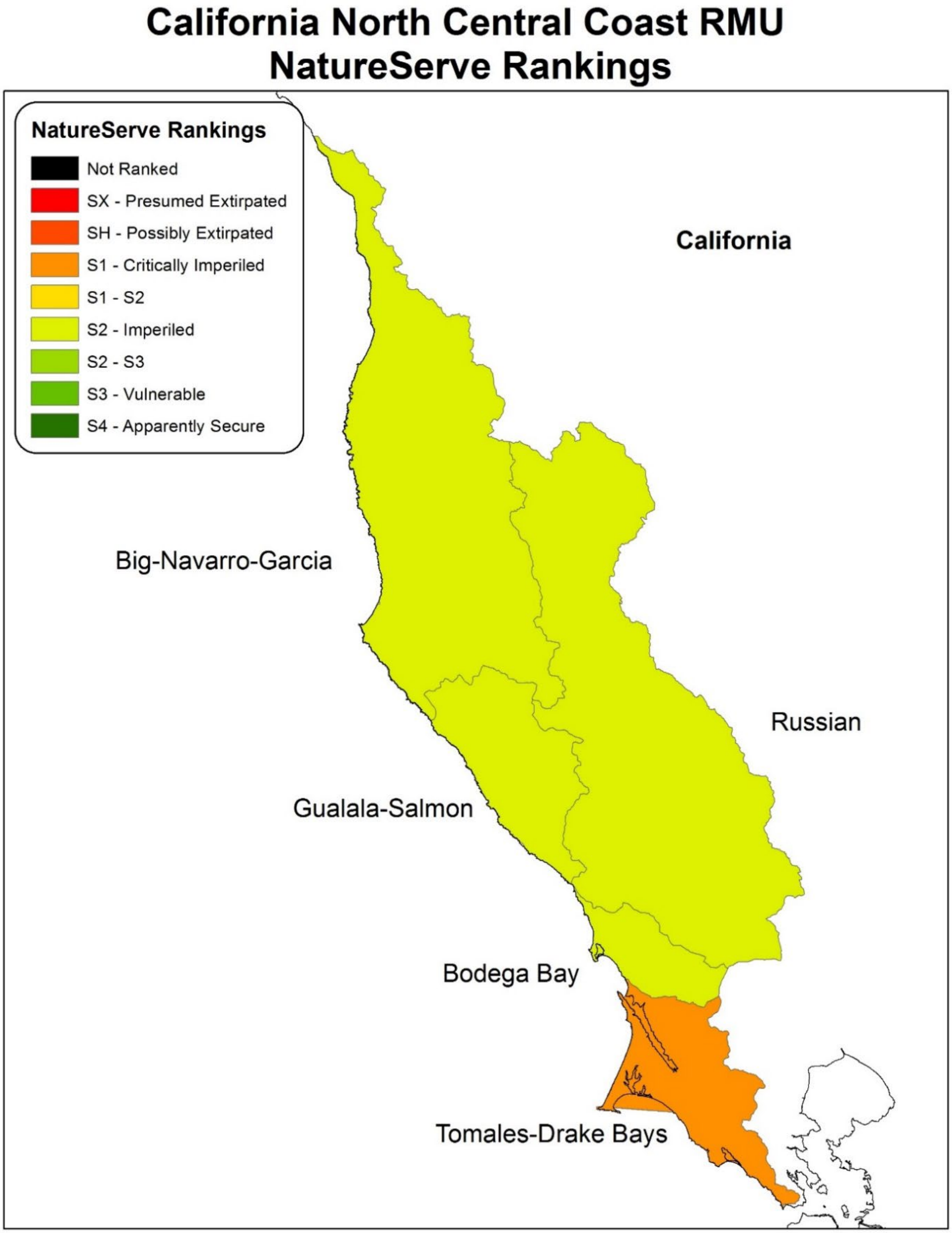

Figure 12. NatureServe conservation status ranks for the San Joaquin RMU, 2022.

SACRAMENTO

The California Sacramento RMU includes the mainstem Sacramento River and all of its tributaries downstream to the confluence with the San Joaquin River, including the Upper and Lower Sacramento USGS accounting units. It includes 34 4th field HUCS, ranging in size from 96−7,041 km^2 (Figure 13; Appendix E). The RMU extends from the San Francisco Bay inland through California's Central Valley, east into the Sierra Nevada Mountains, northwards to Mount Shasta, and inland to the arid Goose Lake Basin (currently endorheic and not shown in tables) and western slope of the Warner Mountains. Due to differences in hydrology, habitat and threats, we have grouped the HUCs within the RMU into three sub-groupings: Upper Sacramento, East Foothills and Sierras, West Valley and Coast Range. The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs remained stable in all HUCs when analyzed with similar methods between 2018-2022.
- Current Pacific Lamprey distribution remained the same in all HUCs.
- Population abundance of Pacific Lamprey in the CA Sacramento RMU is thought to be largely unchanged since the 2012 Assessment.
- Although no long-term count of Pacific Lamprey exists in CA Sacramento RMU, unobstructed populations are believed to have declined considerably since the 1970's and by 50-70% since 1990, based on range-wide trends and anecdotal reports from local residents (Goodman and Reid 2012).
- Passage remains the principal distributional constraint on lamprey populations in the Sacramento RMU. There is a need to further assess and resolve, if necessary, small passage barriers throughout the RMU. A major review of passage barriers throughout the Sacramento Drainage was carried out in 2019-2021 (Reid 2022).
- Recognition of relatively high current and projected water temperatures in the Central Valley has prompted assessment of temperature tolerances in native lampreys (Reid and Goodman, in review).

A detailed summary of 2022 Assessment results for the California Sacramento RMU can be found in the Sacramento RMU Regional Implementation Plan (Boyce et al. 2022) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

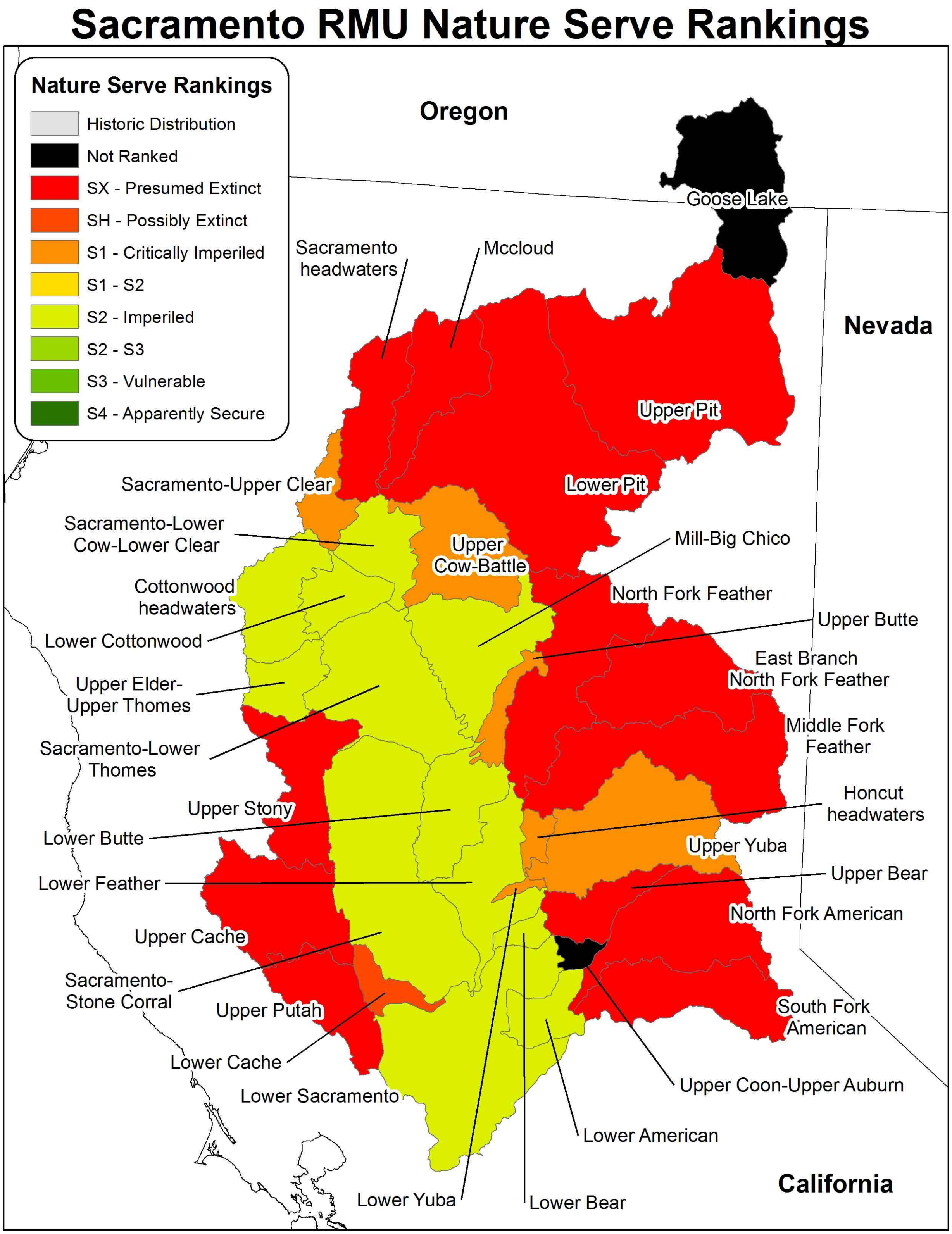

Figure 13. NatureServe conservation status ranks for the Sacramento RMU, 2022.

CALIFORNIA NORTH COAST

The California North Coast RMU includes all coastal drainages from Punta Gorda (Mattole River) north to the Oregon border, including the northern half of the Northern California Coastal (01) and the entire Klamath (02) USGS accounting units. It includes 19 4th field HUCS, ranging in size from 1,292 - 7,759 km^2 (Figure 14; Appendix E). The RMU extends from the coast inland, cutting through the Klamath and Cascade Mountain ranges into the interior and occupies the Coast Range, Klamath Mountains, Cascade, and Eastern Cascade, slopes and foothills ecoregions. Due to subregional differences in hydrology, habitat and threats, we have grouped the HUCs into three sub-groupings: Klamath Basin, Eel Basin and Coastal. The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs remained stable in all HUCs with the exception of the Smith River which changed from Imperiled (S2) to Vulnerable (S3), where passage issues were resolved at the fish ladder on Rowdy Creek. The majority of currently occupied HUCs were categorized as Imperiled (S2).
- Current Pacific Lamprey distribution remained the same in all HUCs.
- Population abundance of Pacific Lamprey in the California North Coast RMU is thought to be largely unchanged since the 2012 Assessment. However, in 2017 over 11,480 lampreys were documented passing through the new lamprey passage corridor on Van Arsdale Dam (Eel River) and tribal fishermen on the Klamath River reported relatively higher catches, though this may have been an exceptional year. In 2021 fewer than 100 lampreys passed the dam, demonstrating considerable interannual variability due to unknown drivers.
- Although no long-term count of Pacific Lamprey exists in the California North Coast RMU, unobstructed populations are believed to have declined considerably since the 1970's and by 50-70% since 1990, based on anecdotal reports from local residents and the impressions of tribal fishermen. A monitoring station has been installed on the upper Eel River at Van Arsdale.
- Passage remains the principal distributional constraint on lamprey populations in the North Coast RMU. However, considerable effort has gone into better understanding passage needs of lamprey and experimental modification at Van Arsdale Dam (Eel River) has resulted in effective passage over the 19 m dam. There is also considerable progress being made on removal of mainstem dams in the Klamath River, with an expected start to removals of the four mainstem dams in 2023. Relicensing discussions and assessment proposals are also underway for dams on the upper Eel.
- Dewatering and eutrophication due to small-scale unregulated agricultural uses which reduce flow, raise summer temperatures, add nutrients and promote algal blooms in the mainstems are considered major concerns in the Eel, Mattole, and S.F. Trinity drainages. Legalization of Marijuana in California and improved regulation may influence this threat in the future. However, that still remains to be seen.

A detailed summary of 2022 Assessment results in the California North Coast RMU can be found in the California North Coast RMU Regional Implementation Plan (Boyce et al. 2022) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

California North Coast RMU Nature Serve Rankings

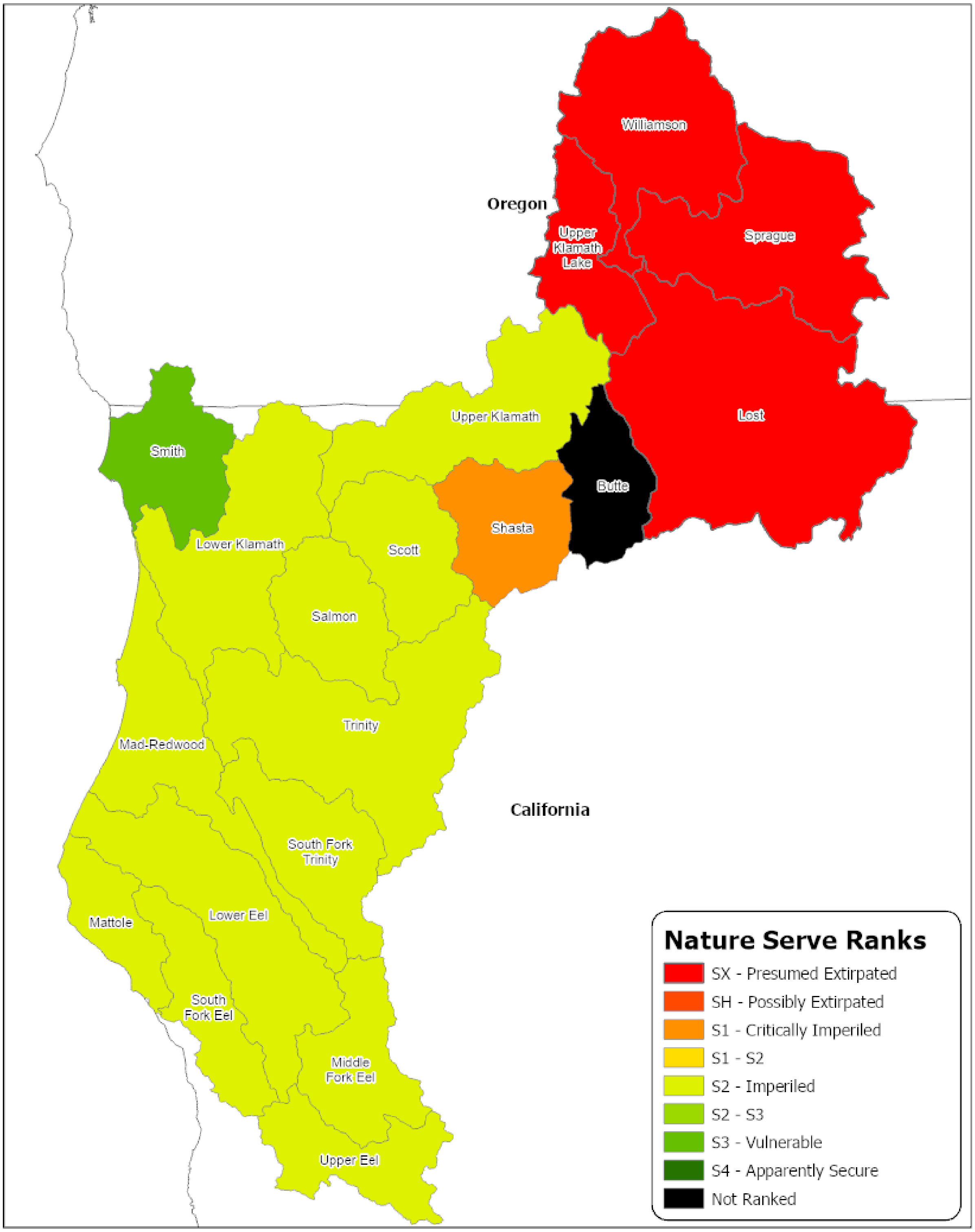

Figure 14. NatureServe conservation status ranks for the California North Coast RMU, 2022.

OREGON NORTH COAST

The Oregon Coast RMU is separated into two sub-units equivalent to the USGS hydrologic unit accounting units 171002 (Northern Oregon Coastal) and 171003 (Southern Oregon Coastal).

The Oregon North Coast sub-unit includes all rivers that drain into the Pacific Ocean from the Columbia River Basin boundary in the north to the Umpqua River boundary in the south. It is comprised of seven 4th field HUCs ranging in size from 338 to 2,498 km^2 (Figure 15; Appendix D). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs changed in five of seven HUCs in 2022.
- Status ranks worsened from Imperiled (S2) to Critically Imperiled (S1) in the Necanicum due the increase in the threat ranking of Climate Change from Unknown in 2018 to High in 2022.
- Ranks changed from Imperiled (S2) to Critically Imperiled/Imperiled (S1S2) in the Nehalem, Wilson-Trask-Nestucca, Siletz-Yaquina, and Alsea, due to uncertainty in the model associated with our population size ranking (see Discussion).
- Current Pacific Lamprey distribution expanded in the Siuslaw (+82km^2) but has remained the same in other North Coast watersheds since the completion of the 2018 Assessment.
- The ratio of current to historical distribution was estimated to be small in the majority of watersheds ranging from 20% (Necanicum, Nehalem, Wilson-Trask-Nestucca) to 29% (Siuslaw) in areas with known Pacific Lamprey occupancy.
- Pacific Lamprey population abundance in North Coast watersheds was estimated using consolidated data from nest count surveys conducted in coastal watersheds by Oregon Department of Fish and Wildlife (ODFW) personnel.
- Estimated population abundance in the North Coast sub-unit has ranged from ≈ 323 – 20,051 lamprey per year between 2007 and 2021 (Clemens et al. 2021).
- Short-term population trend was ranked as Unknown in all North Coast watersheds in 2022 because there is a lack of continuous long-term population trend data in the region.
- Climate change and stream and floodplain degradation were ranked a High threat in the North Coast sub-unit, while passage, water quality and lack of awareness were ranked a Moderate threat in 2022.
- Climate Change and Passage were new priority threats in 2022.
- Threat scores for climate change, stream and floodplain degradation, water quality and passage worsened in 2022; while the threat score for lack of awareness improved in 2022.
- Changes in threat scores generally reflect a better understanding of habitat conditions and lamprey passage needs within the watersheds rather than true changes on the ground for lamprey. For example, the increase in Passage from a Low to Moderate threat in 2022 was a result of new information gained from barrier assessments and/or a better understanding of Pacific Lamprey passage needs rather than a true increase in the number of barriers in North Coast watersheds.

A detailed summary of 2022 Assessment results for the Oregon North Coast sub-unit can be found in the North Coast sub-unit Regional Implementation Plan (Gray and Poirier 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

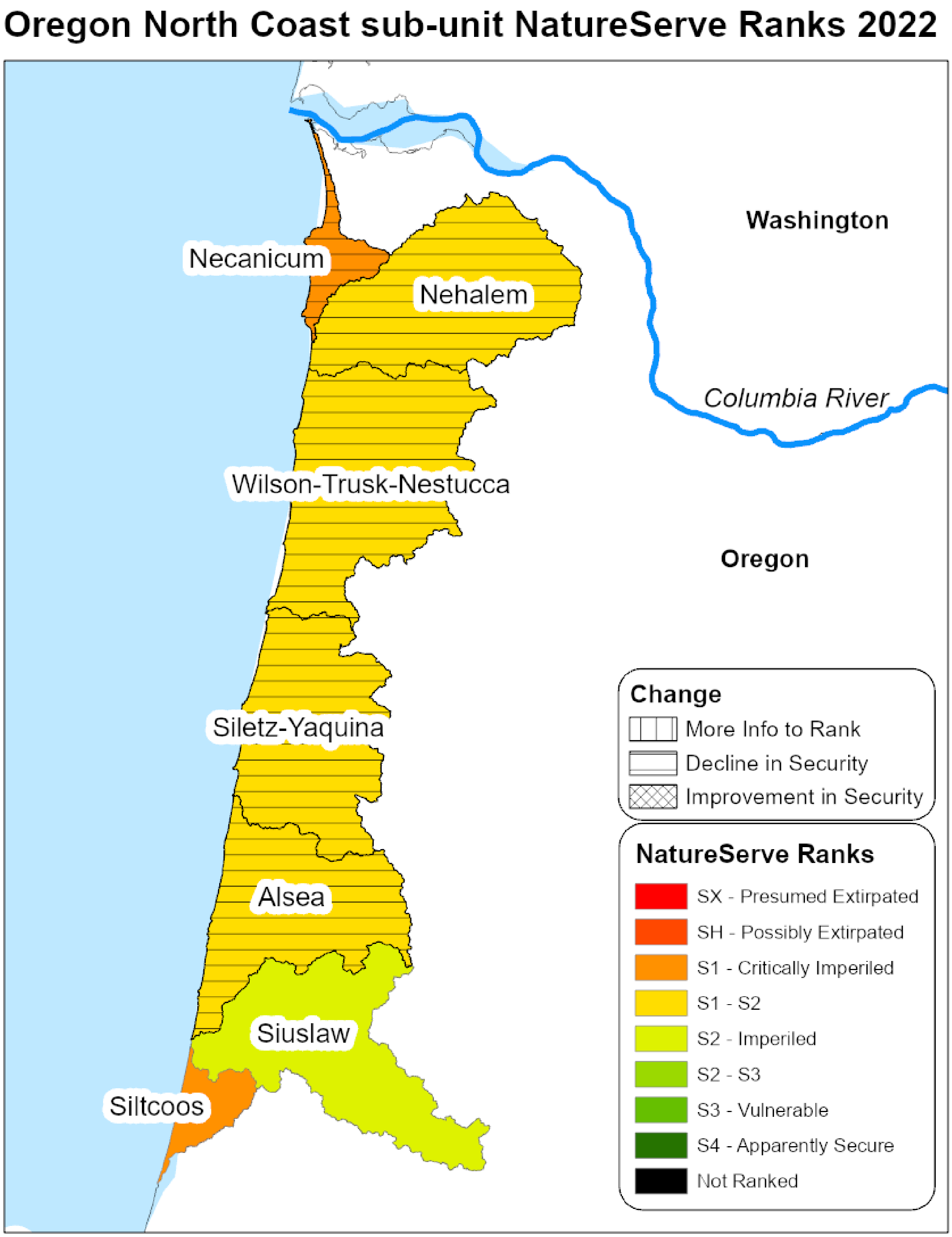

Figure 15. NatureServe conservation status ranks for the Oregon North Coast sub-unit, 2022.

OREGON SOUTH COAST

The Oregon South Coast sub-unit includes all rivers that drain into the Pacific Ocean from the Umpqua River basin south to the Smith River boundary in California. It is comprised of twelve 4^{th} field HUCs ranging in size from 1,216 to 4,662 km^2 (Figure 16; Appendix D). The following are key outcomes of the 2022 Assessment

- NatureServe CSRs changed in eight of twelve HUCs in 2022.
- Status ranks worsened from Imperiled (S2) to Critically Imperiled (S1) in the Sixes, Middle Rogue, Applegate, Lower Rogue, and Chetco. Change in these watersheds was due to a combination of our inability to rank population size and an increase in the threat ranking of climate change to High in 2022.
- Conservation status ranks also changed from Imperiled (S2) to Imperiled/Critically Imperiled (S1S2) in the North Umpqua, Umpqua and Coos. This change was a result of uncertainty within the NatureServe model associated with the population size ranking in these watersheds versus a true increase in risk level (see Discussion).
- Current distribution of Pacific Lamprey has remained the same in many watersheds since the completion of the 2018 Assessment, though distribution expanded modestly in the Coos (+96 km^2), Illinois (+66 km^2) and Chetco (+75 km^2) watersheds due to increased sampling effort.
- Distribution information is still limited in the Upper Rogue and Applegate watersheds.
- Pacific Lamprey population abundance was revised in the North Umpqua, South Umpqua, Umpqua, Coos and Coquille watersheds using consolidated data from nest count surveys conducted in coastal watersheds by ODFW personnel.
- Adult Pacific Lamprey abundance is currently unknown in the Sixes, Upper Rogue, Middle Rogue, Applegate, Lower Rogue, Illinois, and Chetco Rivers.
- Short-term Trend was ranked Unknown in all South Coast watersheds with the exception of the North Umpqua River, which was ranked as Stable. Winchester Dam has maintained a continuous count of adult Pacific Lamprey on the North Umpqua River since 1965. Overall, counts of Pacific Lamprey at Winchester Dam have declined since the early 1970s. More recently however, the number of adults passing Winchester Dam has shown a slight increase following the installation of a lamprey passage structure in 2013.
- Oregon Department of Fish and Wildlife abundance indices in the Mid-South Coast and Umpqua geographic management areas also indicate a possible increase in adult abundance over the last several years (Clemens et al. 2021), but this dataset is not long enough to infer population trend.
- Climate change was the highest-ranking threat in the South Coast sub-unit followed by water quality, lack of awareness, stream & floodplain degradation and dewatering and flow management.
- Threat ranking scores worsened for climate change, water quality & lack of awareness, and improved for dewatering. Scoring for Stream and floodplain degradation stayed the same in 2022.

A detailed summary of 2022 Assessment results for the Oregon South Coast sub-unit can be found in the South Coast sub-unit Regional Implementation Plan (Poirier and Coates 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

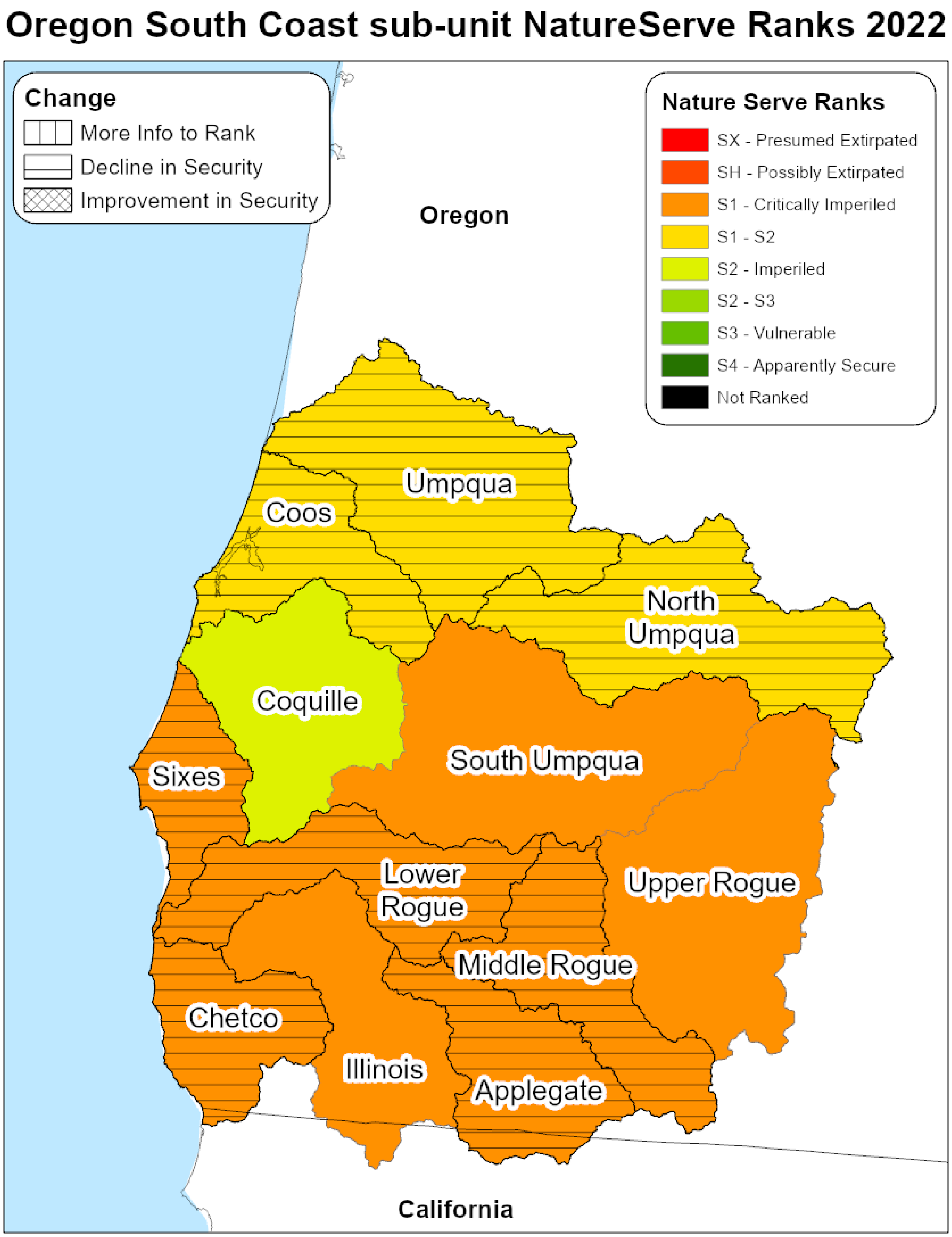

Figure 16. NatureServe conservation status ranks for the Oregon South Coast sub-unit, 2022.

WILLAMETTE RIVER

The Willamette River Sub-unit within the Lower Columbia River/Willamette RMU includes the entire Willamette River Basin, which is all within Oregon. The Willamette River flows north and enters the Columbia River at RKM 163, near Portland, Oregon. It is comprised of twelve 4th field HUCs ranging in size from 1,668−4,850 km^2 (Figure 17; Appendix D). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs did not change between 2018 and 2022.
- Status ranks varied from Critically Imperiled to Imperiled (S1-S2) in all HUCs with the exception of the Clackamas, which retained a ranking of Vulnerable (S3).
- Overall, understanding of Pacific Lamprey distribution and abundance has expanded in Oregon State tributaries.
- Pacific Lamprey abundance was updated, based on information on numbers of returning adults at Willamette Falls (e.g., Baker and McVay 2018). Population size for each HUC upstream of Willamette Falls was based on the percentage of radio tagged fish for each HUC (Clemens et al. 2017b). The number of lamprey that did not pass Willamette Falls was split equally between the Clackamas and the Lower Willamette, which includes the mainstem and a few small tributaries (e.g., Abernathy Creek), to determine abundance below Willamette Falls.
- Ranking of short-term population trend was changed to Unknown in 9 HUCs in the Willamette River sub-unit, as there was insufficient information to assess trends over the past 27-36 years for these Willamette tributaries. Three HUCs were changed to Stable: McKenzie, Clackamas, and Lower Willamette, based on limited available information and professional opinion. Over the longer term, populations have declined substantially from levels documented in the 1940s at Willamette Falls.
- The highest priority threat to Pacific Lamprey in the Willamette River sub-unit was climate change, followed by stream and floodplain degradation, water quality, dewatering and flow management, and fish passage. Climate Change was the only new priority threat in 2022. Because climate change influenced an increase of several other threat scores, it was omitted from the NatureServe analysis; this omission did not significantly change the results of the NatureServe model vulnerability analysis.

A detailed summary of 2022 Assessment results for the Willamette sub-unit can be found in the 2022/2023 [Willamette sub-unit Regional Implementation Plan](https://www.pacificlamprey.org/rmu/) (Poirier, Gray and Clemens 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

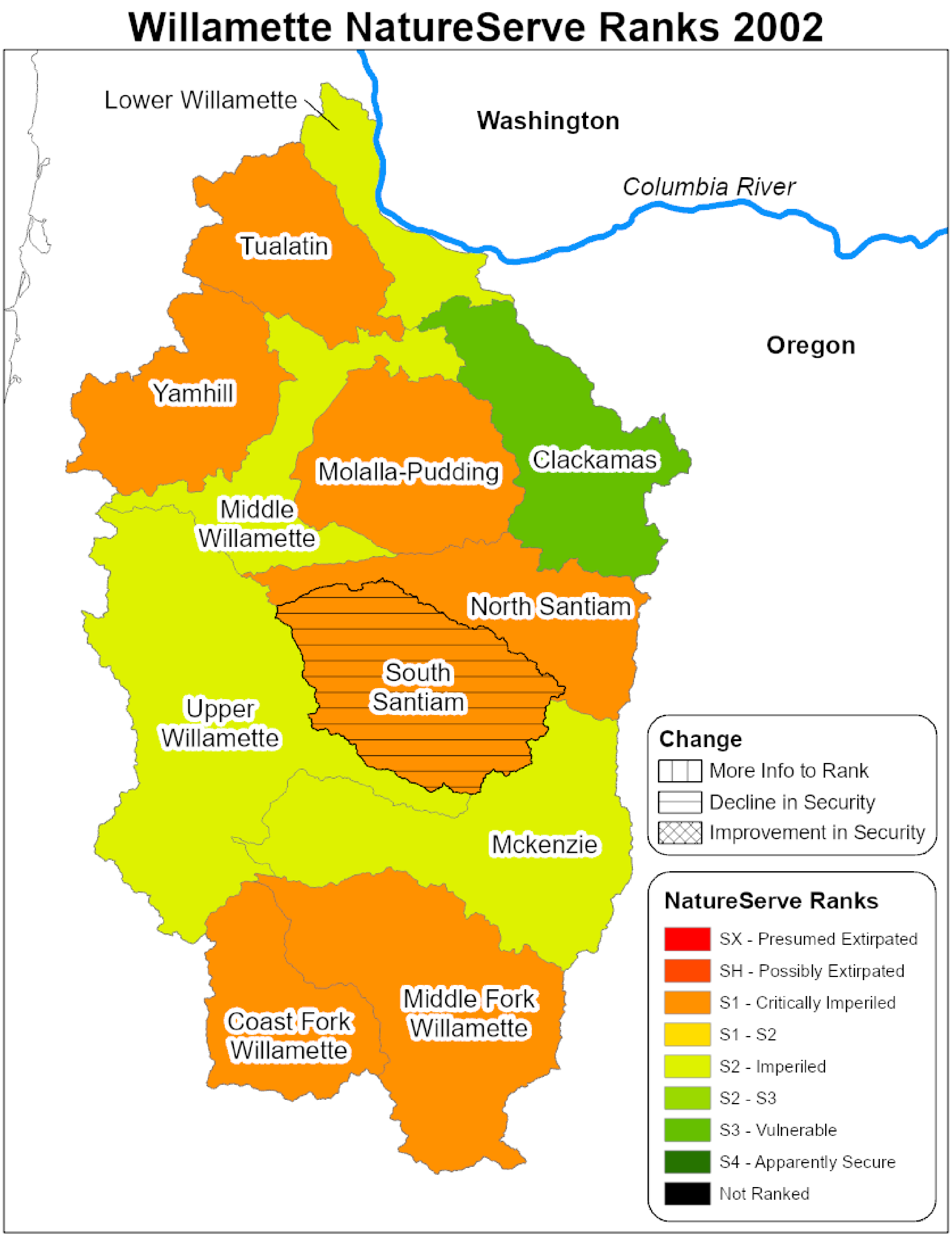

Figure 17. NatureServe conservation status ranks for the Willamette sub-unit, 2022.

LOWER COLUMBIA

The Lower Columbia Sub-unit within the Lower Columbia River/Willamette RMU includes watersheds that drain into the Columbia River mainstem from Bonneville Dam at Rkm 235, west to confluence of the Columbia River with the Pacific Ocean. It is comprised of six 4th field HUCs ranging in size from 1,753−3,756 km^2 (Figure 18; Appendix D). The following are key outcomes of the 2022 Assessment.

- Conservation Status Ranks changed in two of six HUCs in 2022.
- Status ranks worsened from Imperiled (S2) to Critically Imperiled (S1) in the Lower Columbia-Sandy and Lower Columbia HUCs. Changes in these areas are attributable to an increase in the threat ranking of Climate Change from Unknown in 2017 to High in 2022.
- Assessment ranking of current occupancy increased in all HUCs except the Upper Cowlitz.
- Distribution expanded in the Clatskanie, (+35km^2), Lewis (+99km^2), lower Columbia (+49km^2), lower Cowlitz (+127km^2) and Sandy (+47km^2).
- Understanding of Pacific Lamprey distribution has expanded considerably in both Oregon and Washington State tributaries due to increased awareness and sampling effort (e.g., smolt trapping, nest count surveys, occupancy sampling, fish salvages).
- Pacific Lamprey population abundance was estimated in five HUCs using consolidated data from nest count surveys conducted by ODFW and WDFW personnel.
- Median abundance of adult Pacific Lamprey for years 2017-2021 ranged from 42-288 fish in the Sandy Basin, 24-161 fish in the Lewis, 155-1048 fish in the Lower Cowlitz, 149-1034 fish in the Clatskanie River, and 31-209 fish in the Grays River.
- Pacific Lamprey are still believed to be extirpated from the Upper Cowlitz River. The Cowlitz Salmon Hatchery Barrier Dam and Mayfield Dam effectively block access to the upper portion of the Lower Cowlitz River (above RM 49.6) and upper Cowlitz basin.
- Short-term population trend was ranked as unknown in all Lower Columbia watersheds in 2022, due to a lack of continuous long-term population trend data in the region.
- Climate change and lack of awareness were the highest-ranking threats in the Lower Columbia sub-unit. NatureServe threat severity ranks increased from Unknown to High in all watersheds in 2022.
- Other priority threats remained the same in 2022, though ranking scores worsened for stream & floodplain degradation and water quality and improved for tributary passage.
- Climate change and lack of awareness were new priority threats in 2022.

A detailed summary of 2022 Assessment results for the Lower Columbia sub-unit can be found in the Lower Columbia sub-unit Regional Implementation Plan (Poirier and Gray 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

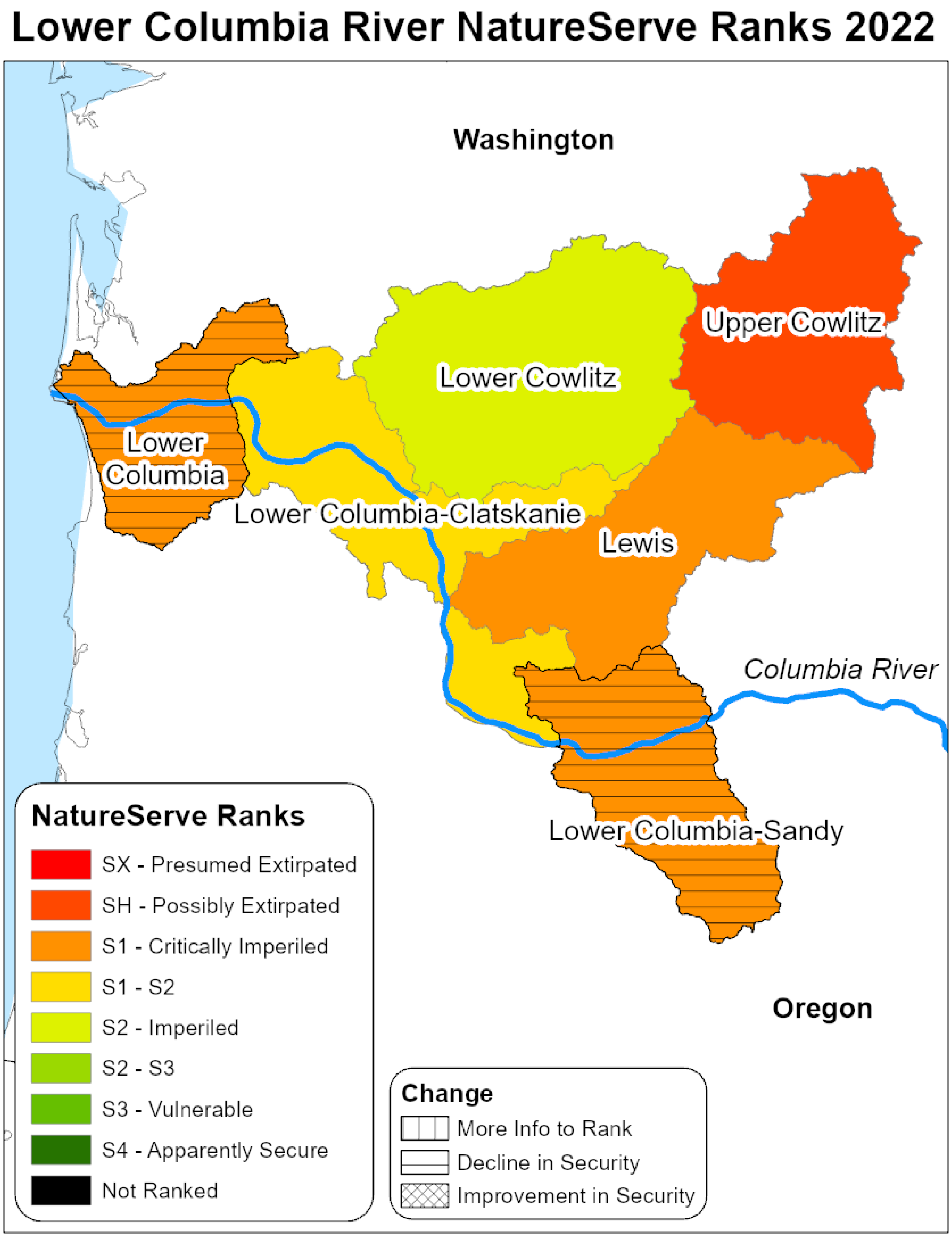

Figure 18. NatureServe conservation status ranks for the Lower Columbia sub-unit, 2022.

MID-COLUMBIA

The Mid-Columbia RMU includes watersheds that drain into the Columbia River mainstem from the Walla Walla River at Rkm 507, west to Bonneville Dam at Rkm 235. It is comprised of sixteen 4th field HUCs ranging in size from 1,793−8,158 km^2 (Figure 19; Appendix D). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs changed in two of 16 HUCs in 2022.
- Status ranks improved from Critically Imperiled (S1) to Imperiled (S2) in the Mid-Columbia-Hood and Lower Deschutes. Changes in these areas are attributable to an expansion in current occupancy (Mid-Columbia-Hood) and high estimated population abundance (Lower Deschutes).
- Conservation status ranks in Willow changed from Unknown (SU) to Possibly Extirpated (SH). The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) recently conducted environmental DNA sampling within the subbasin and had no detections for Pacific Lamprey, though they did detect *Lampetra*.
- Pacific Lamprey are still believed to be extirpated in the Walla Walla and Trout Creek. Environmental DNA sampling was conducted throughout the Walla Walla River (2021) and lower Trout Creek in 2020 and 2021, but no Pacific Lamprey were detected in either watershed.
- Five HUCs are still ranked as Presumed Extirpated (SX). These watersheds are located above the Pelton Round-Butte dam which is currently impassable to lamprey and translocation is not occurring.
- Area of occupancy expanded in both the Klickitat (+17 km^2) and Mid-Columbia-Hood (+81 km^2).
- Pacific Lamprey abundance was estimated in seven watersheds using annual passage counts at the three lowest mainstem Columbia River dams and the publication by Noyes et al. (2015) which estimated adult lamprey entrance in mid-Columbia tributaries from multiple years of acoustic telemetry and PIT tagging information.
- Short-term trend was ranked as Unknown in all but four mid-Columbia watersheds. Given the decline in adult counts at Bonneville Dam, mark-recapture information and Traditional Ecological Knowledge from CTUIR tribal members, Pacific Lamprey populations are estimated to be declined by 10-30% in the Umatilla and lower Deschutes, 10-50% in the Mid-Columbia Hood, and 50-70% in the Klickitat over the last 36 years.
- High priority threats remained the same in the 2022 Assessment.
- Mainstem passage, climate change and water quality were ranked a High threat in the Mid-Columbia, while stream and floodplain degradation, dewatering and flow management, tributary passage, lack of awareness and small population size were ranked a Moderate threat in 2022.
- The threat scores of Climate Change, Water Quality and Dewatering & Flood Management worsened in 2022 while the scores of tributary passage, lack of awareness and small population size improved slightly in 2022.

A detailed summary of 2022 Assessment results for the Mid-Columbia RMU can be found in the Mid-Columbia RMU Regional Implementation Plan (Poirier and Jackson 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

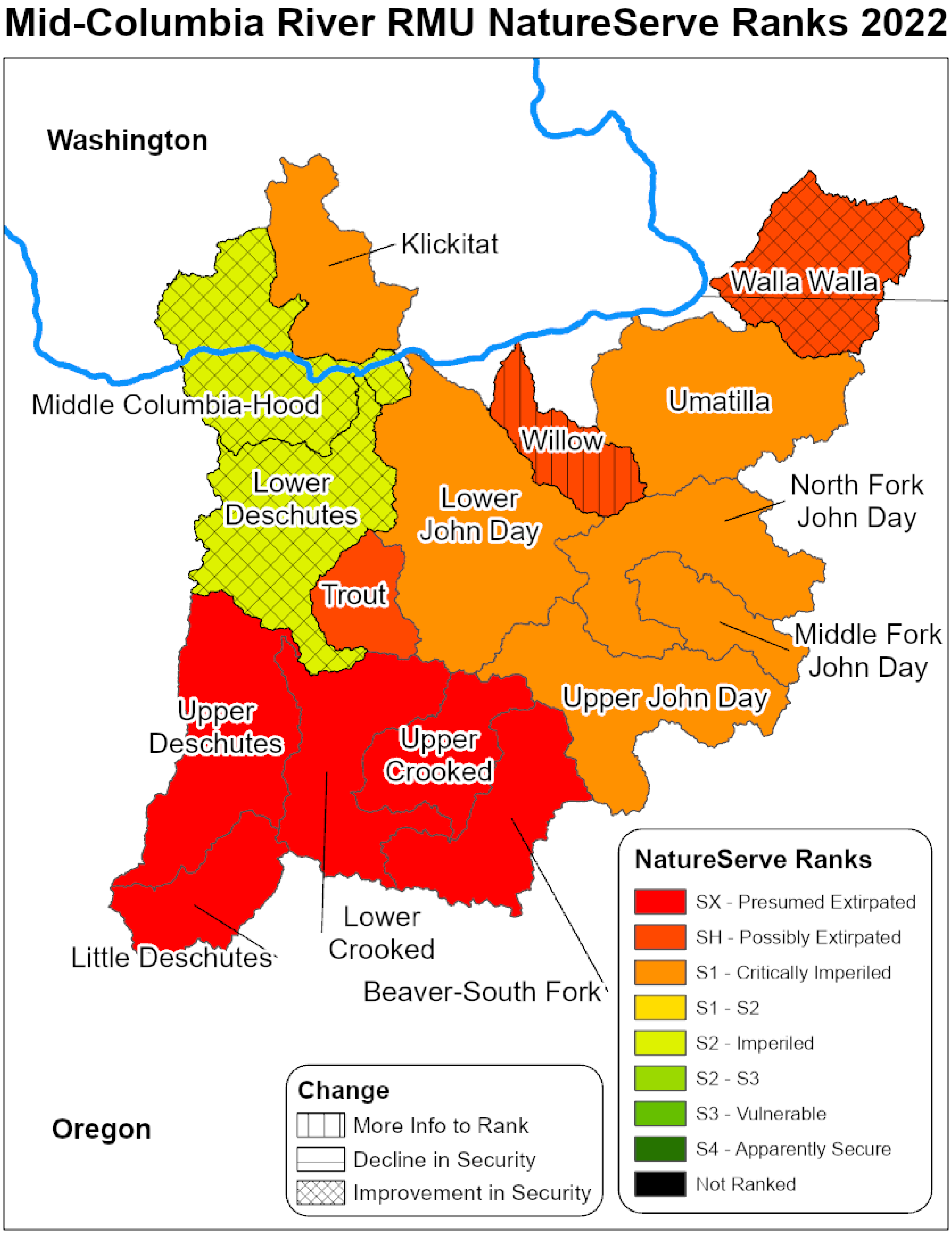

Figure 19. NatureServe conservation status ranks for the Mid-Columbia RMU, 2022.

SNAKE RIVER

The Snake River region includes the Snake River and all waters draining into it downstream of Hells Canyon Dam (river km 397) to its confluence with the Columbia River. There are three RMUs: the Lower Snake Basin, the Clearwater River Basin, and the Salmon River Basin with five major tributaries: Imnaha, Salmon, Grande Ronde, Clearwater, and Tucannon rivers. Several historically occupied areas are not included in this assessment as they are blocked by impassable dams. These include the Snake River from Hells Canyon Dam Complex upstream to Shoshone Falls and its major tributaries, and the North Fork Clearwater River, now blocked by Dworshak Dam. The Palouse River historically had Pacific Lamprey from the mouth upstream 9.7 km to Palouse Falls but current status has not been reviewed. Within the RMUs there are 22 Hydrologic Unit Code (HUC) watersheds that are still accessible to Pacific Lamprey and assessed every five years. These watersheds range in size from 552-6,242 km^2 (Figure 20; Appendix D). The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs changed in two of 22 Snake River HUCs in 2022. Ranks varied from Critically Imperiled (S1) to Possibly Extirpated (SH) in all HUCs.
- Ranks improved from Possibly Extirpated (SH) to Critically Imperiled (S1) in the Upper Middle Fork Salmon as recent electrofishing data from Idaho Department of Fish and Game (IDFG) show Pacific Lamprey are present in the most downstream areas within the HUC.
- Ranks in the Lower Salmon changed from Critically Imperiled (S1) to Possibly Extirpated (SH) because it is believed adult spawning occurs upstream and no lamprey have been documented in any tributaries of the Lower Salmon HUC. However, larval lamprey, downstream migrants, or upstream migrating adults may be present within the Lower Salmon.
- Population demographic information was revised in most categories with population sizes changing due to increased efforts by the Nez Perce Tribe (NPT) and Confederated Tribes of the Umatilla Reservation (CTUIR) in supplementing HUCs through the adult Pacific Lamprey Translocation Program. CTUIR also began larval supplementation in the Tucannon River in 2001.
- An index of Pacific Lamprey abundance for the Snake River region was estimated by using 24-hour passage count data at Lower Granite Dam collected by the Army Corps of Engineers (ACOE). The median count of Pacific Lamprey from 2016-2021 was only 976. Radio telemetry studies (Mcllraith et al. 2015, USFWS unpublished data), recent PIT tag detection data from translocated adult lamprey released into mainstem rivers (Nez Perce Tribe unpublished data), recent effective population size estimates in the Lochsa River (USFWS and CRITFC unpublished data), and professional judgement based on larval electrofishing were used to estimate distribution of the fish throughout the HUCs. Abundance in all occupied HUCs (18 HUCs) were estimated to have the lowest abundance ranking (1-50 adults) except for two. The Lower Selway River and the South Fork Clearwater River were estimated to have 50-250 adults. It is unknown, however, how close the count data at Lower Granite is to actual abundance. The NPT and CTUIR adult translocation programs have been boosting and maintaining adult abundances since 2007 (Hess et al. 2022). Adding the median translocation numbers (2016-2021) to each HUC increased the abundance ranking in nine of the HUCs.

- Assessment rankings of current distribution remained the same as the 2018 assessment in all HUCs except for two. There was an increase in the South Fork Salmon and the Middle Salmon-Panther HUCs. The South Fork Salmon likely increased due to expanded translocation efforts and the Middle Salmon-Panther HUC increased because of electrofishing data from IDFG.
- Understanding of the abundance and distribution of non-translocated fish remains limited.
- Short-term population trend information also changed to Unknown in many HUCs. Populations are believed to be declined (from historical levels), but adequate information does not exist to estimate the magnitude of the decline over the last 36 years (3 lifespans).
- Short-term trend has changed to increasing in some HUCs where the Translocation Program has been expanding since 2007.
- The highest priority threats to Pacific Lamprey in the Snake River Sub-Unit remains to be mainstem passage and small population size. These threats remain a high priority for all HUCs in all three RMUs. Additional high priority threats in the Lower Snake RMU are lack of awareness and climate change.

A detailed summary of 2022 Assessment results for the Snake River region can be found in the Regional Implementation Plan (Erhardt et al. 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

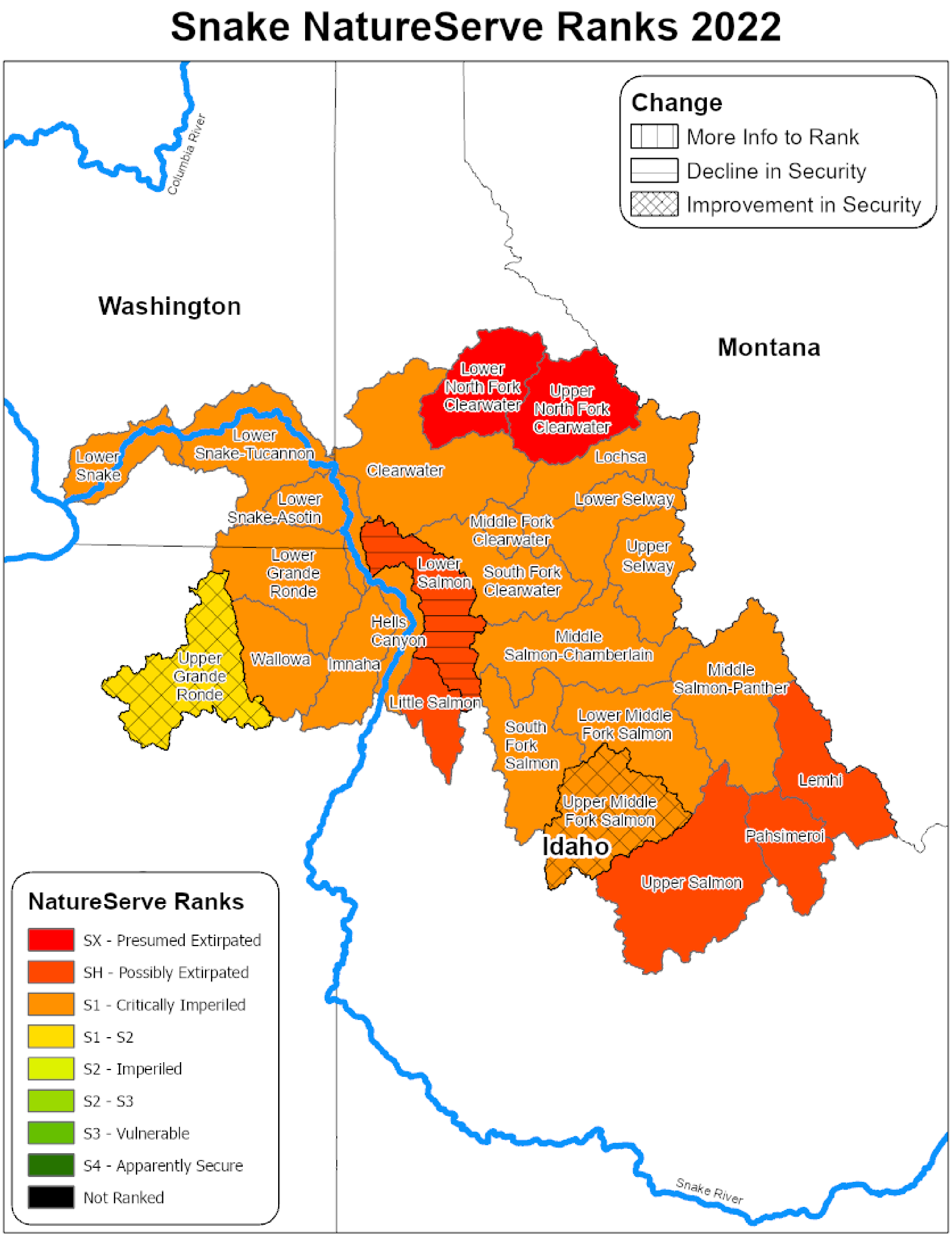

Figure 20. NatureServe conservation status ranks for the Snake River region, 2022.

UPPER COLUMBIA

The Upper Columbia RMU includes watersheds that drain into the Columbia River mainstem from the Snake River confluence at Rkm 516 to the Kettle River at Rkm 1133. It is comprised of 14 4th Field Hydrologic Unit Codes (HUCs) and several smaller tributaries to the Columbia River (Figure 21; Appendix D). This Assessment section focuses on 11 of these HUCs: Upper and Lower Yakima, Naches, Upper and Lower Crab Creek, Wenatchee, Entiat, Lake Chelan, Methow, Okanogan, and Similkameen, in addition to the group of smaller tributaries on the Colockum Plateau and Foster Creek. Although the Okanogan and Similkameen subbasins extend into Canada, only the U.S. portion of these systems is included in our analysis. The Sanpoil, Colville, and Kettle HUCs are likewise excluded from consideration at this time due to existing anadromous passage barriers at Chief Joseph and Grand Coulee dams. In future assessments, we recommend the inclusion of habitat consideration within these areas as well as in Canadian territories to help shed light on historic distribution and habitat within the full extent of the Upper Columbia River Basin.

The following are key outcomes of the 2023 Assessment.

- NatureServe CSRs changed in two of six HUCs in 2022 compared with 2018. Status ranks varied from Possibly Extirpated to Critically Imperiled (SH-S1).
- Ranks improved from Presumed Extirpated (SH) to Critically Imperiled (S1) in the Okanogan and Similkameen largely due to translocation increases in both Population Size and Area of Occupancy in both systems.
- Population demographic information was revised in most categories owing to new information on current Population Size and Area of Occupancy from translocation activities and field surveys.
- Overall, understanding of Pacific Lamprey status in much of the Upper Columbia RMU is robust, although more information on lamprey presence and numbers is needed in several of the less-studied HUCs (Lake Chelan, Upper and Lower Crab Creek, Smaller Tributaries).
- Adult translocation has been a major driver of change in the Upper Columbia. Between 2018 – 2022 a total of 6,262 translocated adult Pacific Lamprey were released into Upper Columbia RMU HUCs (Upper and Lower Yakima, Naches, Wenatchee, Methow, Okanogan, and Similkameen) with an additional 1,572 released into the mainstem Upper Columbia River. Over this time, translocation releases averaged 1,566 adults annually across the RMU.
- To assess the impacts of translocation, we calculated 2022 demographic metrics both with and without translocation. This comparison was done for HUCs with active translocation activities. Translocation increased both the population size and the area of occupancy in these systems.
- Area of occupancy was revised using electrofishing, eDNA and adults release data. The area of occupancy ranking either improved (Wenatchee, Okanogan, Similkameen, Naches, and Upper Yakima) or stayed constant (Lower Yakima) once translocation was included. Area of occupancy remained the same in HUCs without translocation (Upper and Lower Crab Creek, Entiat, Lake Chelan, Smaller Tributaries). Differences in distribution scores with and without translocation highlight that many distribution gains occur upstream of dams with limited or no lamprey passage.

- Pacific Lamprey population size was revised using a combination of mainstem Columbia River dam counts and known translocation release numbers. When translocated adults were included, population rankings either increased (Methow, Okanogan, Similkameen, Upper Yakima, Naches) or stayed constant (Wenatchee, Lower Yakima). Population rankings in non-translocation HUCs stayed the same (Upper and Lower Crab Creek, Entiat, Lake Chelan, Smaller Tributaries).
- Ranking the short-term population trend was discussed extensively by RMU members given the lack of comprehensive data over the 36-year timeframe to complete this metric; the primary information available during this period is via tribal elder interviews. Lamprey are declining throughout the RMU in this timeframe, but adequate information is lacking to more than estimate the magnitude of the decline. While translocation efforts are improving lamprey numbers and distribution, additional conservation actions that directly address the threats causing reduced populations and occupancy will be needed to reverse this trend.
- The highest priority threats to Pacific Lamprey in the Upper Columbia RMU are mainstem passage, climate change, and small population size. Other priority threats are tributary passage, water quality, dewatering and flow management, stream and floodplain degradation, and predation. Lack of awareness was scored for the first time in 2022, but was not ranked as a priority threat.

A detailed summary of 2022 Assessment results can be found in the Regional Implementation Plan for the Upper Columbia Regional Management (https://www.pacificlamprey.org/rmu/).

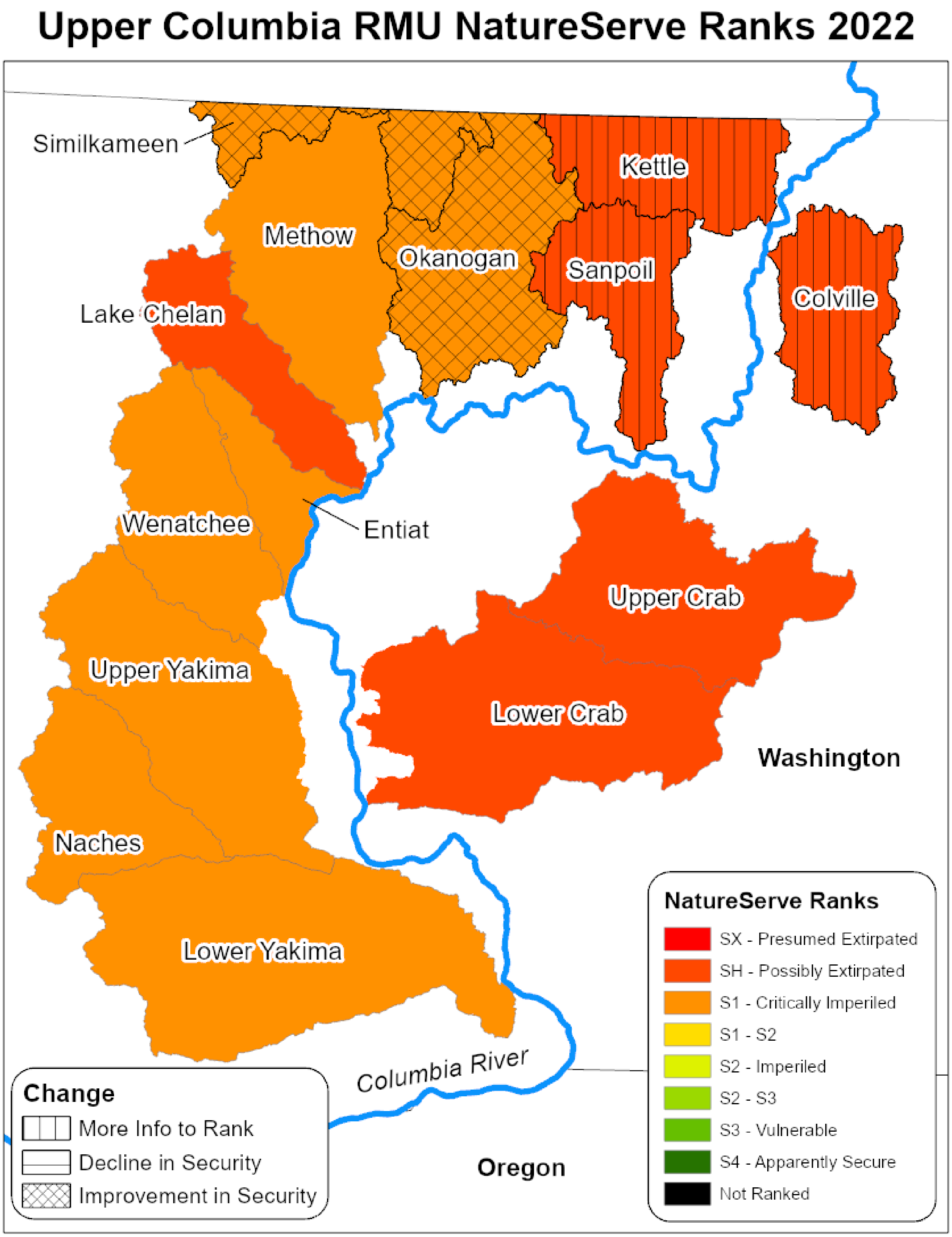

Figure 21. NatureServe conservation status ranks for the Upper Columbia RMU, 2022.

MAINSTEM COLUMBIA RIVER AND SNAKE RIVER REGION

The Mainstem Columbia/Snake River RMU (Mainstem RMU) includes mainstem habitat upstream from Bonneville Dam to the extent of migration in the Columbia and Snake Rivers. Historically, the range of Pacific Lamprey extended into tributaries high up into the Columbia and Snake River drainages. As part of completing their anadromous life history, adults and juveniles need to migrate through these mainstem corridors and the Federal Columbia River Power System and 5 Public Utility District dams (Figure 22) to complete their anadromous lifecycle. The purpose of the Mainstem RMU is to assess threats in this migratory corridor.

The mainstem RMU was originally developed to assess the impacts of the configuration and continued operation of the hydroelectric dams on Pacific Lamprey migrating through the system. The group has since expanded the focus to include potential impacts on rearing lamprey such as dredging and water level fluctuations due to observations on juvenile lamprey rearing in mainstem habitats. The group also serves as a forum for providing updates and discussion on activities, planning taking place through other processes, and identifying research needs.

Unlike other RMUs, Pacific Lamprey in the mainstem RMU are not seen as distinct populations, therefore population status was not ranked. Although, evidence of rearing in the mainstem and some overwintering of larvae and juveniles exits (Jolley et al. 2012), it is unknown whether spawning occurs in mainstem habitats.

Threats were assessed for the Mainstem to assess the risk for the various population groupings during their seaward migration as juveniles and the adult migration to the spawning grounds through the hydro system. We divided the mainstem areas into three sub-regions above Bonneville Dam, the most downstream facility in the Columbia River: Mid-Columbia - mainstem Columbia from Bonneville Dam to the Confluence with the Snake River, Upper Columbia – Mainstem Columbia above confluence with the Snake River, Snake Basin – Snake River above confluence with the Columbia. The following are key outcomes of the 2022 Mainstem RMU threats assessment (Table 5).

- The priority threats have remained consistent over time. Passage, Water Quality (Temperature), and Predation, continued to rank as priority threats. Not surprisingly passage has consistently been identified as the most important among the suite of threats.

- The way Climate Change has been dealt with as a threat has changed over time. Initially it was seen as a constant factor that compounds the other threats. While still true, it is now (2018 and 2022) broken out as a separate threat that has increased since 2018 from 2.9 to a 4.0 and added to the list of priority threats.

- Dewatering and flow Management increased slightly from 2.75 to 3.0, Water Quality increased slightly from 3.58 to 4.0, and Stream and Floodplain Degradation increased slightly from 3.17 to 3.5. These increases were partly attributed impacts climate change exacerbating these threats.

- RMU participants acknowledged the efforts to improve conditions including passage improvements, flow management, and floodplain restoration projects, however they did not feel the degree of progress warrants a change in risk status.

Figure 22. Map of Mainstem Columbia/Snake RMU.

Significant developments in RMU

- The most significant development for Pacific Lamprey in the Mainstem RMU is the 2018 extension of the Columbia Basin Fish Accords and allocation of $20 million to the USACE in FY 2020 to continue adult and juvenile Pacific Lamprey passage actions and research, monitoring and evaluation. The USACE continues to implement this program and has expressed additional capability to continue lamprey passage efforts in FY25. The Accords were further extended in 2020 and 2023.

- Pacific Northwest National Laboratory (PNNL) developed a new acoustic micro transmitter specifically designed for use in juvenile eels and lampreys, called the lamprey/eel tag. Prior to this development, existing acoustic tags were too large to be effectively implanted into the body cavities of juvenile lampreys and would result in a tag burden that exceeds accepted standards. This new technology will allow for improved research into juvenile lamprey migration and movement. The USACE began funding initial juvenile and larval lamprey passage studies at lower Snake River and lower Columbia River dams in 2022 and these studies are expected to continue (pending funding) through 2025.

- We have seen improvements in adult passage through alternative passage systems, modifications to fish ladders, and translocation efforts, but distribution to upper parts of the basin is still highly limited.

Identified Key Data Needs

- The presence of pathogens and observations of disease have been observed on adult lamprey, but little is known on the degree of impact of disease on individuals and at the population level.

- Migration behavior and fate of adult lamprey that do not pass dams (particularly Bonneville and The Dalles dams). Similarly, what is the fate of adult lamprey that overwinter in the mainstem. Do these overwintering adult lamprey eventually move on to successfully migrate and spawn.

- Adult lamprey guidance within lower velocity/lower turbulence fishway sections of hydropower facilities (typically in lower portions of fishways) like collection channels, junction pools, etc. Why don't adult lamprey successfully pass these fishway sections at Bonneville Dam and elsewhere?

- Juvenile lamprey passage and survival (route use, at dam survival, system survival) and the effects of juvenile salmonid spill regimes on passage behavior and success of adult, juvenile, and larval lamprey.

Table 5. Threats to Pacific Lamprey and their habitats within the Mainstem Columbia River and Snake River Region from May 23, 2022 meeting.

Drainage/HUC	Passage		Dewatering and Flow Management		Stream and Floodplain Degradation		Water Quality	
	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Snake Basin	4	4	3	3	3.5	3.5	4	3.5
Upper Columbia – Above Priest	4 (3.5)	4 (3.5)	3	2.5	3	3	4	3
Mid-Columbia – Bonneville to Priest	4	4	3	3.5	3.5	3.5	4	3.5
Mean	4	4	3	3	3.5	3.5	4	3.5
Rank[a]	H	H	M	M	M/H	M/H	H	M/H
Mean Scope and Severity	4		3		3.5		4	
Drainage Rank	H		M		M/H		H	

H (High) = 4, M/H (Moderate/High) = 3.5, M (Moderate) =3, L/M (Low/Moderate) = 2.5, L (Low) = 2, I (Insignificant) = 1, U = No value

Drainage/HUC	Predation		Dredging (Direct Take)		Climate Change		Disease	
	Scope	Severity	Scope	Severity	Scope	Severity	Scope	Severity
Snake Basin	4	4	1	0	4	4	1	1 or 0
Upper Columbia – Above Priest	4	4	1	0	4	3	1	0
Mid-Columbia – Bonneville to Priest	4	4	1	0	4	4	1	2
Mean	4	4	1	0	4	4	1	1
Rank[a]	H	H	L	L	H	H	L	L
Mean Scope and Severity	4		1		4		1	
Drainage Rank	H		L		H		L	

WASHINGTON COAST

The Washington Coast RMU is comprised of all the Washington State watersheds that discharge directly into the Pacific Ocean. It is comprised of six 4th field HUCs ranging in size from 1,471 to 3393 km^2 (Figure 23; Appendix D).

The 2022 Assessment was the first attempt to rank four out of the six HUCs in this RMU. Previously in 2017, the Lower Chehalis was ranked as an intermediate between Imperiled and vulnerable (S2S3) and the Upper Chehalis was ranked as Imperiled (S2). In 2022, both Chehalis HUCs along with Willapa Bay, Grays Harbor, and the Hoh-Quillayute were all ranked Imperiled (S2). The worsening of the Lower Chehalis is likely due to the more explicit incorporation of threats analysis in this watershed and not reflective of changes in Pacific Lamprey populations between assessments as their populations are regarded as stable. The Queets-Quinault HUC was the only HUC ranked Critically Imperiled (S1). This ranking is potentially partially due to the limited demographic information in this watershed and increased data collection could improve the resolution of this HUCs status. Spawning data from multiple partners was invaluable for distribution data for many watersheds. Additionally, several watersheds leveraged eDNA data to expand distributions. The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs for this RMU are based on consistently collected and reliable demographic data as well as informed threat evaluations.
- Distribution data was greatly expanded in this RMU. From 2017 to 2021, known distribution increased by 42% from 1352 sq/km to 1926 sq/km. Especially significant gains in collating distribution data were made in Grays Harbor and the Hoh-Quillayute. Even with these gains, known distributions likely underestimate current distributions across the RMU.
- Four out of six HUCs have had consistent spawning data collection since 2006 and represent the most accurate abundance estimates in western Washington. Expanding existing spawning surveys to encompass the entire Pacific Lamprey spawning season would further increase the accuracy of these estimates. The Hoh-Quillayute and Queets-Quinault watersheds had limited data, and abundance was not estimated.
- There are no HUCs in this RMU where adequate information exists to estimate the magnitude of the decline over the last 36 years. However, current estimates of short-term trends are based on expert opinion and over a decade and a half of consistent data collection in four of the HUCs. In both the Upper and Lower Chehalis watersheds, Pacific Lamprey populations are considered stable, while in Grays Harbor and Willapa Bay populations are declining. Populations are also believed to be possibly declining in the Queets-Quinault, though there is a need for more data to evaluate the degree of decline. The Hoh-Quillayute did not have enough data to estimate population trends.
- The highest priority threat to Pacific Lamprey in this RMU was climate change, followed by stream and floodplain degradation. Water quality was also considered a widespread threat though it was of lower significance. Lack of awareness, passage, dewatering and flow management, and predation, were additional threats that were identified within certain watersheds but were not considered key threats at the RMU scale. This was the first-time threats were evaluated within this RMU and further refining these threats to reflect lamprey specific impacts will be a valuable for the next assessment.
- Lack of awareness about Pacific Lamprey is a lower threat in this RMU but there is still a need to expand inclusions of Pacific Lamprey into existing conservation efforts.

Incorporation of Pacific Lamprey's habitat requirements and salvage measures into restoration has begun in a few locations but needs to be more widespread. Smaller scale passage barriers exist in every watershed and evaluating and prioritizing barriers improvements based on lamprey specific characteristics is a necessary component of recovery for this species across the RMU.

A detailed summary of 2022 Assessment results for the Washington Coast RMU can be found in the Washington Coast RMU Regional Implementation Plan (Blanchard 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

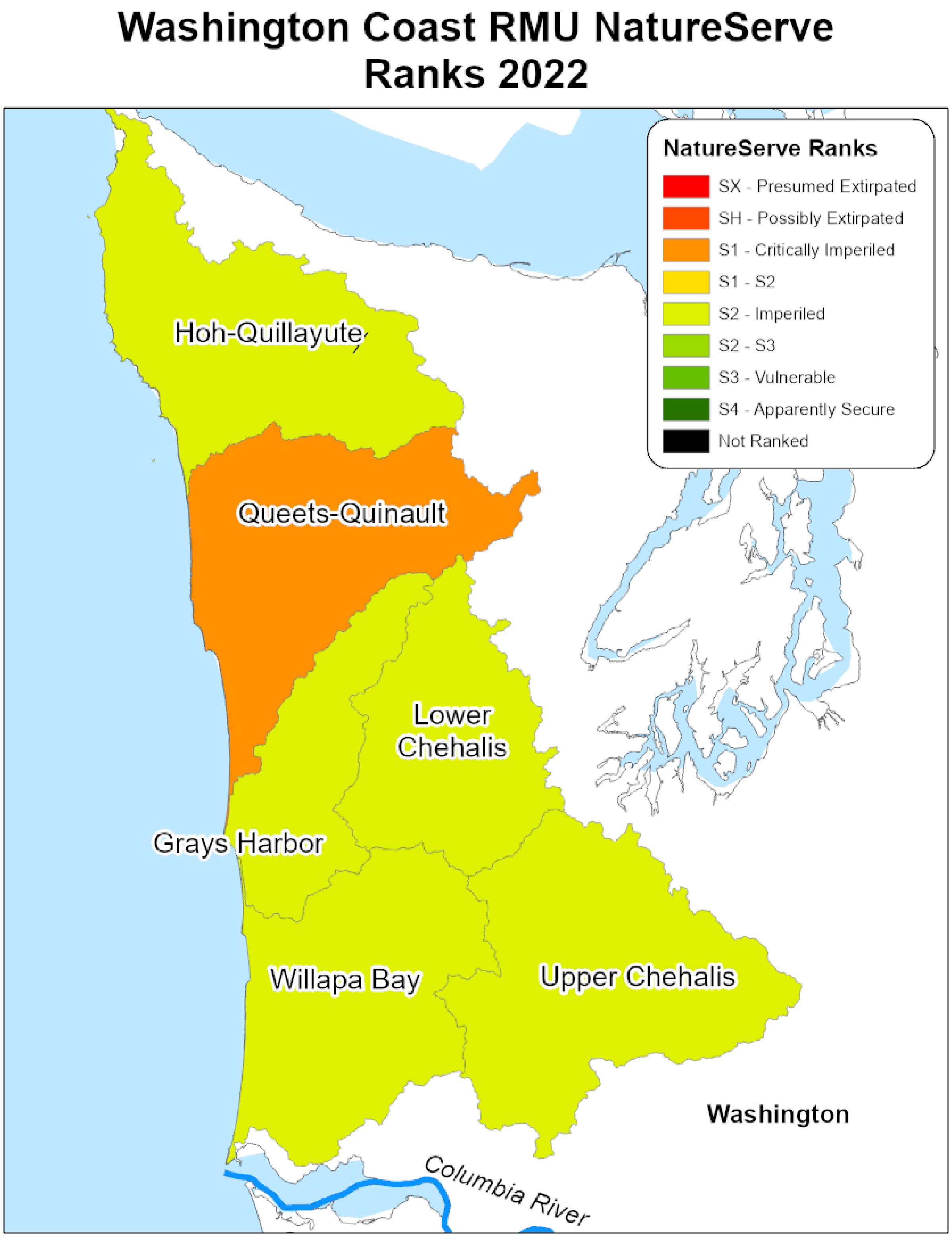

Figure 23. NatureServe conservation status ranks for the Washington Coast RMU, 2022

PUGET SOUND/STRAIT OF JUAN DE FUCA

The Puget Sound/Strait of Juan de Fuca RMU includes watersheds that drain into the Salish Sea. It is comprised of 21 4^{th} field HUCs ranging in size from 435−6,604 km^2 (Figure 24; Appendix D).

The 2022 NatureServe Assessment was the first attempt to rank most of the HUCs in this RMU. Previously only three HUCs were evaluated, the Crescent-Hoko, Dungeness-Elwha, and the Nooksack, and all were estimated to be Critically Imperiled (S1). In 2022 an additional 16 HUCs were ranked for the first time. The majority of HUCs within this RMU were ranked Critically Imperiled (S1). Two HUCs, the Deschutes and Lake Washington, were ranked Possibly Extirpated (SH), due to recent surveys having been conducted where Pacific Lamprey were not detected. Two HUCs, the San Juan Islands and the Fraser, were not ranked as there has been no effort to date to collect data in either HUC. The Nooksack HUC had an intermediate rank between Critically Imperiled and Imperiled (S1S2), and the Sauk River HUC is the only watershed to be ranked Imperiled (S1). This ranking is driven by lower threat values in this watershed, though there is very limited population demographic information. In all watersheds that were ranked, an increase in demographic information and more detailed threat evaluations were made in 2022. Spawning data from the Washington Department of Fish and Wildlife was invaluable for distribution data for many watersheds. Additionally, several watersheds leveraged eDNA data to expand distributions. However, every watershed is still deficient in distribution, abundance, and trend data. The following are key outcomes of the 2022 Assessment.

- NatureServe CSRs for most watersheds in the RMU were Critically Imperiled (S1). This highlights the need to expand and implement conservation measures in this RMU immediately.
- Distribution data was greatly expanded in this RMU. From 2017 to 2021, known distribution of Pacific Lamprey almost doubled from 819 sq/km to 1521 sq/km (45% increase). However, broadly the known distributions are still underestimates of current distributions and more targeted lamprey surveys are needed to more accurately capture Pacific Lamprey presence within the RMU.
- Abundance data is greatly lacking throughout this RMU. Prioritizing lamprey data collection, consistent documentation, and expanded timeframes for spawning surveys would improve abundance estimates. Current estimates are primarily based on expert opinion and insufficient nest counts.
- There are no HUCs in this RMU where adequate information exists to estimate the magnitude of the decline over the last 36 years. Current estimates of short-term trends are based on expert opinion and depict variations at the HUC scale. The Nooksack is considered stable over the short term while the Stillaguamish is declining. The Elwha-Dungeness HUC is increasing, notably due to the removal of the two Elwha River dams and the resultant increased access to quality freshwater habitat. Improvements in data collection and Pacific Lamprey documentation are needed to be able to evaluate trend information in the future.
- The highest priority threat to Pacific Lamprey in this RMU was climate change, followed by lack of awareness, stream and floodplain degradation, and passage. Impacts from these four threats were considerable across the RMU. Water quality, dewatering and flow management, and predation, were additional threats that were identified within certain watersheds but were

not considered key threats at the RMU scale. This was the first-time threats were evaluated within this RMU. Further refining these threats to reflect lamprey specific impacts and filling in unknown threats will be a valuable for the next assessment.

- Addressing the lack of awareness about Pacific Lamprey in this RMU is needed to expand inclusion of Pacific Lamprey into existing conservation efforts. Incorporation of Pacific Lamprey's habitat requirements and salvage measures into restoration has begun in a few locations but needs to be more widespread. Several large-scale passage impediments have been identified and many smaller-scale road crossing barriers exist in every watershed. Facilitating Pacific Lamprey passage to blocked portions of these watersheds will be a necessary component of recovery for this species across the RMU.

A detailed summary of 2022 Assessment results for the Puget Sound/Strait of Juan de Fuca RMU can be found in the Puget Sound/Strait of Juan de Fuca Regional Implementation Plan (Blanchard 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

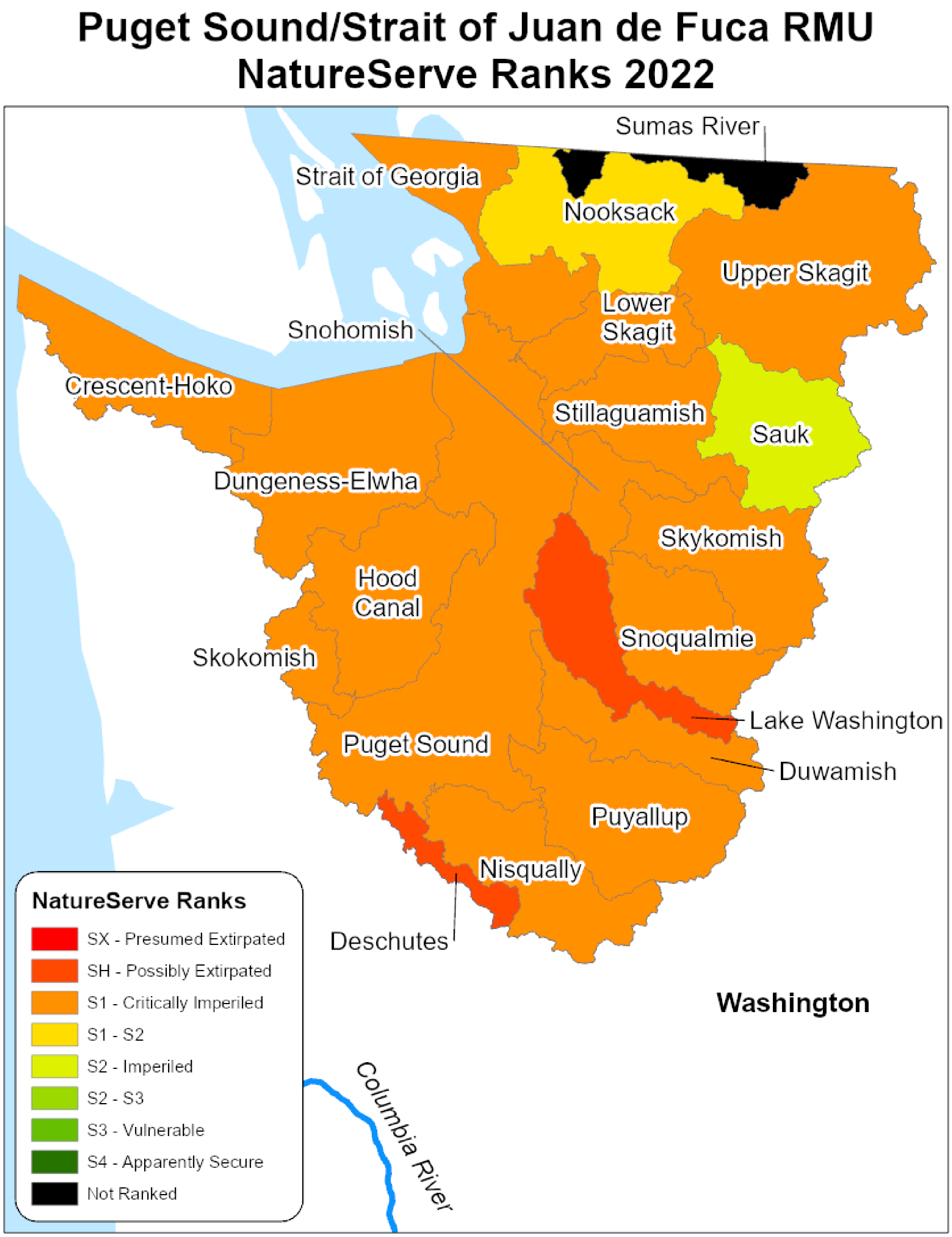

Figure 24. NatureServe conservation status ranks for the Puget Sound/Strait of Juan de Fuca RMU, 2022.

ALASKA

The Alaska RMU encompasses the entire state of Alaska, an area of approximately 632,000 square miles (USGS 2019). The Alaska region is divided into six subregions which are further subdivided into hydrologic units (HUCs): southeast (4 HUCs), southcentral (7 HUCs), southwest (5 HUCs), Yukon (8 HUCs), northwest (4 HUCs), and Arctic (5 HUCs; USGS 2019). Major Alaskan rivers within these subregions includes, the Yukon River (3,185 km), Kuskokwim River (1,130 km), Stikine River (610 km), Susitna River (504 km), Copper River (470 km), and Kobuk River (451 km). Alaska's rivers drain into the Beaufort, Chukchi, and Bering seas as well as the Gulf of Alaska (Figure 25).

Five species of lamprey are known to occur in the Alaska RMU: Arctic lamprey *Lethenteron camtschaticum*, Pacific Lamprey *Entosphenus tridentatus*, Western river lamprey *Lampetra ayresii*, Western brook lamprey *Lampetra richardsoni*, and Alaskan brook lamprey *Lethenteron alaskense*. Previous research efforts within the Alaska RMU have primarily focused on Arctic lamprey because of their value as a subsistence and commercial resource; however, understanding of their basic biology (e.g., time spent at sea, migration timing, abundance, etc.) remains limited. Unfortunately, even less is known about the four remaining lamprey species within the Alaska RMU.

2022 was the first attempt at performing the NatureServe Assessment in the Alaska RMU. Though level of interest was high, the Alaska RMU is severely data-deficient for Pacific Lamprey with only minimal information available in the Susitna River watershed. There has been little research or sample collections conducted on this species to date in this drainage. Consequently, only three respondents participated in the NatureServe ranking survey. The consensus was that the current population status of Pacific Lamprey in the Susitna River drainage is unknown.

- Population demographic and threats remain largely unknown in the Susitna River drainage and throughout the Alaska RMU. Due to the absence of both subsistence and commercial fisheries for Pacific Lamprey, this species has not been a management priority for state or federal agencies. Conducting research in Alaska is also logistically challenging and expensive which makes funding lamprey projects difficult. As a result, monitoring and survey efforts have only recently (June 2019) been initiated on Susitna River tributaries.
- Overall, the distribution of Pacific Lamprey in the Alaska RMU is poorly understood. Specimens have been documented near Nome and St. Matthew Island, but are thought to be rare north of the Alaska Peninsula (Mecklenburg et al. 2002). Pacific Lamprey have been observed in the Gulf of Alaska (e.g., Copper River) and drainages in southeast (e.g., Stikine, Unuk, Chilkat, and Naha rivers) and southcentral (e.g., Copper, Susitna, Kasilof, and Kenai rivers) Alaska. To date, no comprehensive larval or adult Pacific Lamprey surveys have been conducted in the Alaska RMU.
- There have been several years of observations of spawning Pacific Lamprey in the Gulkana River between Paxson Lake and Sourdough Campground and in the Susitna River drainage in 2022. There have also been annual captures of adult Pacific Lamprey by subsistence and personal use fishers using fish wheels in the mainstem Copper River near Chitina, Alaska as well as adult and larval Pacific Lamprey captured by Cook Inlet Aquaculture in 2022 and 2023 from the Kasilof River and Shell Creek (a tributary of the Susitna River).

- While there is little to no data on the threats impacting Pacific Lamprey in the Susitna River drainage, the following threats were listed as potential concerns that could impact Pacific Lamprey: culvert passage (particularly if the West Susitna Access Road goes forward) and any associated dewatering due to blocked culverts, predation (particularly from invasive northern pike *Esox lucius*), and climate change/warming.
- Lack of awareness of Pacific Lamprey, lack of baseline information and lack of dedicated research were identified as priority threats/information gaps in the Susitna River drainage and the Alaska RMU.
- Alaska has had two dedicated RMU leads since 2019. Though there are only a few people in the state focused on lamprey, efforts have been made to inform others (e.g., members of the public, non-profit organizations and agency biologists) and increase awareness of Pacific Lamprey in the Alaska RMU. However, given the large size of the RMU, much more work is needed to build communication networks and collaborations across the state.
- Targeted outreach efforts have yielded an increase in RMU participation, but additional work is needed to develop/expand baseline datasets for Pacific Lamprey populations across Alaska, educate biologists and members of the public on how to identify and report Pacific Lamprey observations and find ways to leverage existing salmon assessment projects to improve knowledge of Pacific Lamprey and other native lamprey species in Alaska.
- 2023 began the first targeted efforts by ADF&G to sample Pacific Lamprey in the state. Effort relied on a paired sampling design using eDNA and electrofishing. Outreach efforts identified project partners from nonprofit organizations, other agencies, tribal entities, and members of the public or fishing communities. Work focused on the Copper River basin as well as the upper Cook Inlet watersheds. Sampling resulted in eDNA detections, nominations to the Anadromous Waters Catalog, and genetic verification of the identities of larval and juvenile lampreys.
- RMU leads have identified salmon sonar stations as being able to count lamprey, with decades worth of data in some instances, from major streams such as the Kenai River, Kasilof River, and Klutina River. Further investigation into using this technology will be assessed and more data gathered in 2024.

A synthesis of available information for Arctic Lamprey and Pacific Lamprey in the Alaska RMU can be found in the Alaska RMU Regional Implementation Plan (Sutton, Garcia, Cathcart and Shink 2023) on the PLCI webpage (https://www.pacificlamprey.org/rmu/).

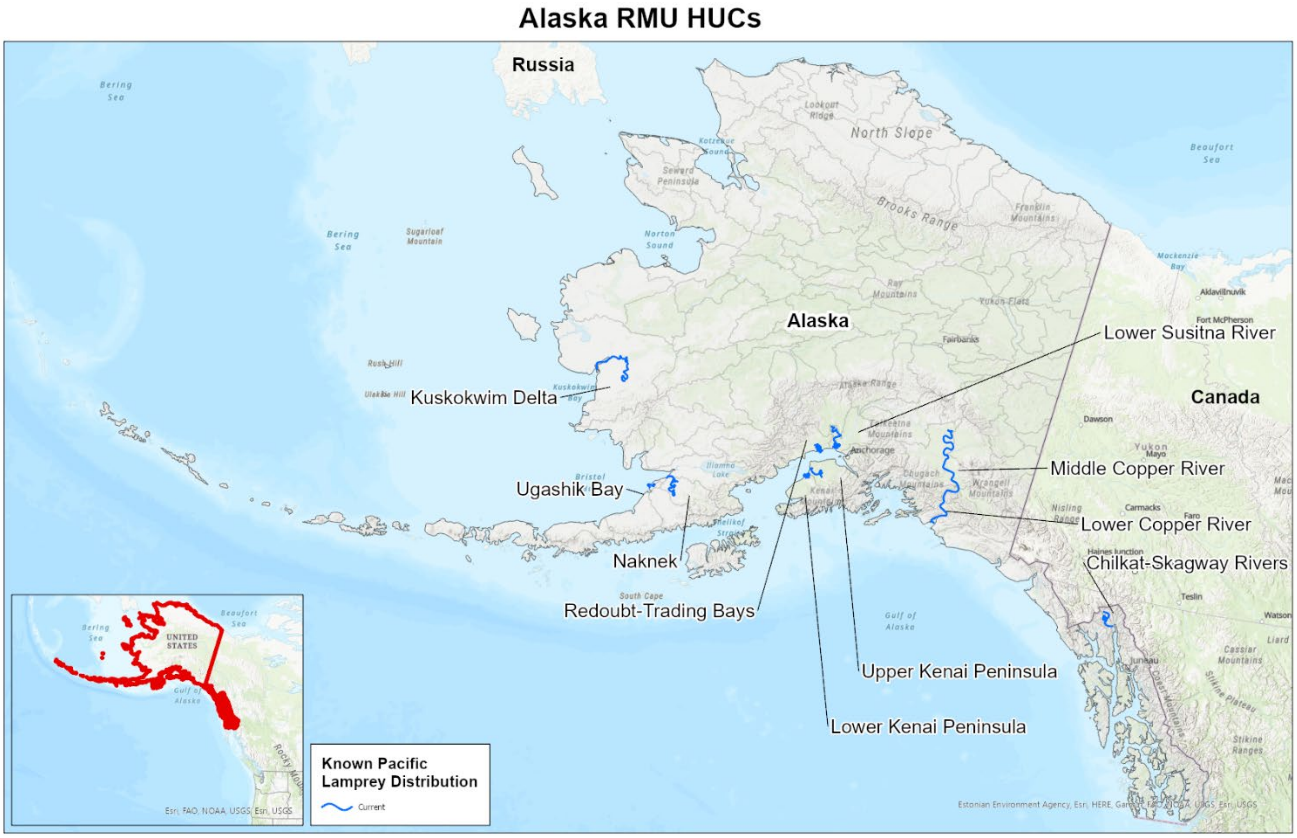

Figure 25. Map of current known Pacific Lamprey distribution and location of 4th field HUCs in the Alaska RMU, 2022

NORTH PACIFIC OCEAN

The North Pacific Ocean RMU is vast, encompassing Pacific Lamprey originating from rivers across all RMUs (USFWS 2018) and other international areas, from Baja, Mexico north to the Bering and Chukchi seas off Alaska and Russia (Renaud 2008, 2011; Orlov et al. 2009), and south to Hokkaido and Honshu Islands, Japan (Yamazaki et al. 2005; Figure 26).

Population Status of Pacific Lamprey

The status of Pacific Lamprey was not ranked during the 2022 Assessment because there is no distinct separation of lamprey populations in the North Pacific Ocean. 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 as or even more important than the freshwater life stages for population recruitment (Murauskas et al. 2013).

Distribution and Connectivity

In Alaskan waters, the highest occurrences of Pacific Lamprey are in the slope area of the Bering Sea, with some occurrences in 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). In addition, NOAA's Alaska Fisheries Science Center consistently catches Pacific Lamprey in bottom trawl surveys on the Bering Slope, but rarely on the Bering shelf or Gulf of Alaska (Siwicke and Seitz 2017). Pacific Lamprey caught by NOAA's Northwest Fisheries Science Center marine surveys and by commercial fisheries indicates they are distributed from southern California (33°N) to Haida Gwaii, British Columbia (54°N), but were concentrated from approximately Cape Mendocino (41°N) in northern California to Cape Flattery (48°N) at the northwest corner of Washington State (Orlov et al. 2008; Weitkamp et al. 2023).

Directed collections of Pacific Lamprey by observers on commercial fishing vessels starting in 2016 has increased our understanding of Pacific Lamprey marine ecology (Weitkamp et al. 2023). In particular, most lamprey are caught by fisheries targeting Pacific hake, with lesser numbers caught by shrimp and groundfish fisheries. Typical round Pacific Lamprey feeding wounds are most frequently observed on Pacific hake, suggesting they are the primary host for Pacific Lamprey, although a wide diversity of fishes were observed with lamprey wounds, indicating opportunistic feeding behavior (Clemens et al. 2019; Quintella et al. 2021; Weitkamp et al. 2023). Most (90%) lamprey caught by commercial fisheries and research surveys are small (<300 mm total length), likely in their first year of marine life.

Statistically significant associations have been reported between the relative abundance of Pacific Herring, Chinook Salmon, Pacific Cod, Walleye Pollock, and Pacific Hake in the Pacific Ocean and the abundance of adult Pacific Lamprey returning to the Columbia River Basin (Murauskas et al. 2013). These relationships may provide evidence that adult Pacific Lamprey entering the Columbia River to spawn had previously migrated with their hosts in the ocean northward of the Columbia River mouth, to feed on the aforementioned fish stocks off

Vancouver Island, British Columbia. Increasing documentation of prey parasitized or consumed by Pacific lamprey and lamprey movements should help refine these host-lamprey relationships.

Recently evidence also suggests that at least some Pacific Lamprey may migrate from the West Coast to the Bering Sea and back. An adult Pacific Lamprey originating from the Bering Sea (where it was PIT tagged) was detected at Bonneville Dam on the Columbia River, and then again in the Deschutes River (Murauskas et al. 2019). Another lamprey collected in the Bering Sea was the full sibling of a lamprey caught at Willamette Falls (Hess et al. 2022). In addition, unexpectedly few intermediate sized (300-500 mm TL) lamprey caught off the West Coast, a size that is present in the Bering Sea, further supports this notion that West Coast lamprey are surprisingly highly migratory (Weitkamp et al. 2023).

Summary of Major Threats

Key limiting factors and threats have been reviewed and identified by Clemens et al. (2019). Limiting factors in the Pacific Ocean include: 1) availability of host species, 2) contaminant loads of hosts, and 3) predation and fisheries bycatch. Key threats in the Ocean include: 1) climate change, 2) unfavorable oceanographic regimes, 3) influences of interactions between climate change and oceanographic regimes, and 4) pollution. 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 Peterson-Lewis 2009). At least 15 species of mammals, birds, and fishes have been documented to prey upon Pacific Lamprey in estuaries and the Pacific Ocean, and Pacific Lamprey has been documented to prey upon 32 species of mammals and fishes in these habitats (Clemens et al. 2019; Quintella et al. 2021), and six new species have recently been documented (Weitkamp et al. 2023), bringing the total to 38. The lack of recreational and commercial harvest for Pacific Lamprey may explain why this species has not been monitored consistently. Information on the effects of the limiting factors and threats to Pacific Lamprey in the ocean are lacking (Clemens et al. 2019).

Research and Restoration Actions

Many data gaps exist for Pacific Lamprey in the North Pacific Ocean due to the difficulty of collecting and conducting lamprey specific research in the ocean, due in large part because they are relatively rare in marine waters. The ocean life stage continues to be the stage at which very little is known, though this is slowly changing. 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 the North Pacific Ocean RMU Regional Implementation Plan (North Pacific Ocean TWG 2022) on the PLCI webpage (https://www.pacificlamprey.org/rmu/). Ocean research has the potential to fill the many data gaps on Pacific Lamprey during a key stage of their life cycle. This information can inform resource managers on the relative contributions of the marine phase in comparison with freshwater restoration efforts for Pacific Lamprey.

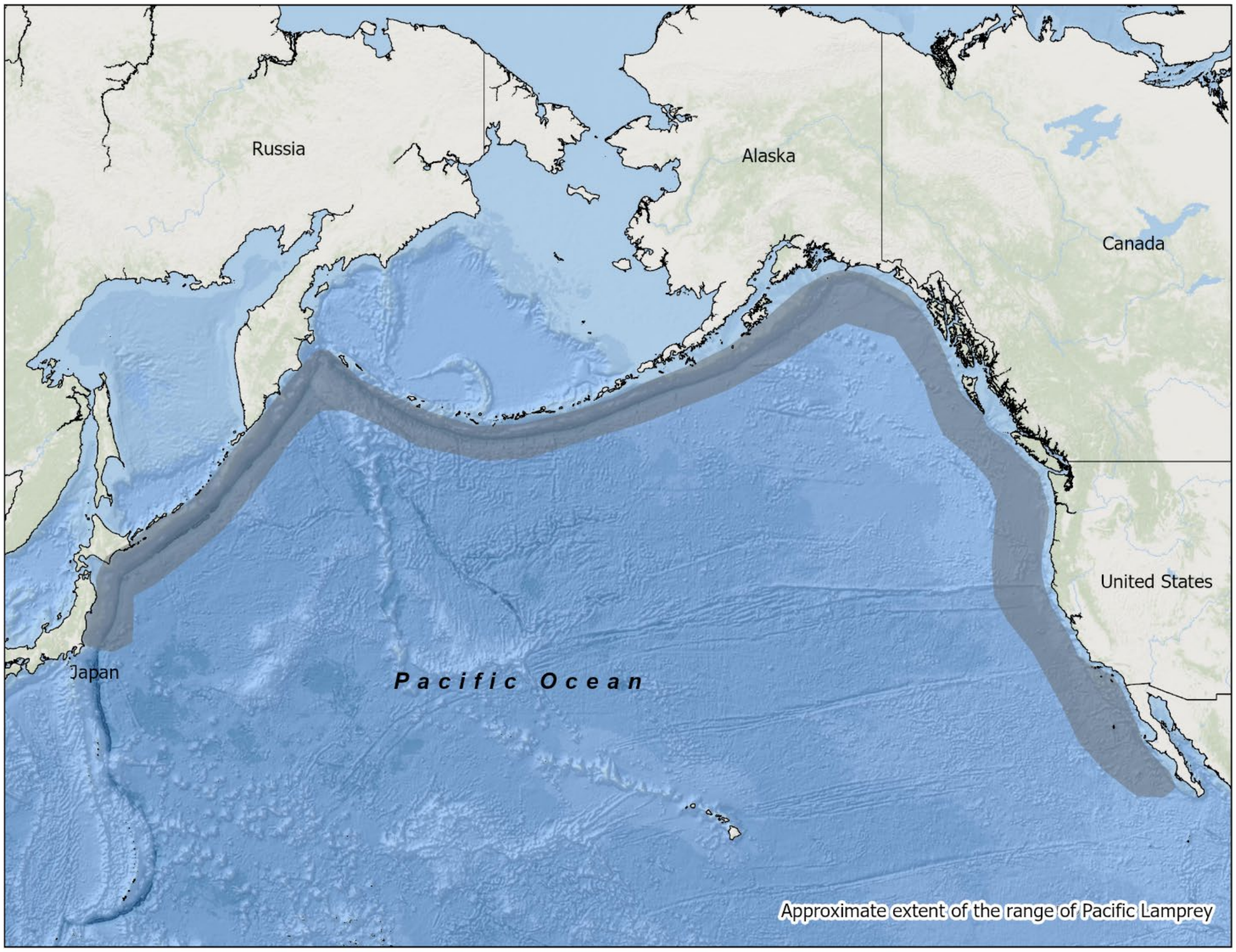

Figure 26. Map of North Pacific Ocean RMU.

6. DISCUSSION

The Pacific Lamprey Assessment integrates the best available empirical data with professional judgement to better understand population demographics and severity of environmental and anthropogenic threats with the purpose of assessing the relative risk of extirpation of Pacific Lamprey by watershed and geographic region. The NatureServe model is one of the first evaluations of Pacific Lamprey status. Over the last ten years, results of the Assessment have been used to identify and prioritize critical threats and data gaps within RMUs and guide conservation and research efforts. Spring 2022 was the third revision of the Assessment. This chapter highlights how the Assessment process has evolved since the completion of the first Assessment in 2011, how changes in Assessment results (i.e., CSRs and priority threats) may be interpreted, and finally, we highlight some of the improvements and uncertainties identified through the implementation of the Assessment.

Evolution of the Assessment

Each revision of the Assessment has used the same NatureServe model and ranking procedures to evaluate conservation risk of Pacific Lamprey; however, elements of the model were modified to improve the quality and accuracy of conservation factor inputs. For example, during the 2018 revision, methods for calculating and ranking range extent (historical distribution), area of occupancy (current distribution) and threats (scope/severity) were modified substantially from the 2011 Assessment (see USFWS 2018). These changes provided a more objective and accurate method to derive and rank these conservation factors, and also resulted in the direct change (both improvement and worsening) of CSRs in several HUCs in 2018. The 2022 Assessment revision retained previous NatureServe modifications and introduced several new modifications that did not necessarily influence a change in CSRs. These minor changes, intended to improve the interpretation of NatureServe conservation factors (i.e., refining threat category definitions), were the result of new knowledge or information gained since the previous Assessment (i.e., minor change in definition of short-term trend, change in threat categories assessed) or RMU lead or partner input (i.e., re-defining current population size; see Methods).

As our understanding of the principal threats to Pacific Lamprey has improved, the suite of threats evaluated during each Assessment has been refined accordingly. Twelve threat categories were originally proposed in the 2011 Assessment. Currently, RMUs rank up to ten of the twelve original threat categories. Specific threat categories have been completely excluded from the Assessment over time due to a lack of information (i.e., disease) or absence of evidence for risk (i.e., translocation). Other threats have been excluded on an individual RMU basis either due to lack of information (e.g., California RMUs did not rank climate change or lack of awareness) or because the threat was not applicable to an RMU (e.g., small effective population size, harvest). Additionally, the passage category was split into two separate categories in some RMUs after the 2011 Assessment to highlight the impacts of large river, mainstem impediments versus smaller, tributary barriers. Although threat categories have varied between Assessments and among RMUs, these differences do not influence the outcome of the Assessment because only the scope/severity value from the most influential threat category (i.e., highest ranking value) is input into the NatureServe model for each HUC.

The format of Assessment data collection meetings has also changed over time. In 2011, Assessment ranking information was collected during eight regional in-person work group meetings held in 2009 and 2010. In 2018, meetings were held in each RMU, either in person or by conference call. In 2022, meetings were held virtually in each RMU. Compared to in-person meetings, the virtual meeting format was not ideal for in-depth group discussions given their short duration (approximately 3-hours), but the pre-meeting Assessment questionnaire increased the efficiency of the virtual meetings and encouraged broader participation, including those who couldn't attend the virtual meeting.

A direct comparison of Assessment results is somewhat challenging given the modifications to NatureServe parameters described above. However, the quality of the information input into the model has improved with each revision. Each Assessment includes the best information available at the time and results provide a snapshot of current conditions within watersheds and geographic regions. The NatureServe model and ranking process is not perfect, but it effectively compiles and summarizes the intended information: 1) assess relative risk; 2) identify priority threats; 3) identify major data gaps; and 4) highlight major changes to population demographics and threats over time.

The relevance of Assessment results is dependent on the quality of the input information. There is still limited empirical data for some HUCs, so some ranks are based on best professional judgement (e.g., population size) or ranked as "Unknown" (e.g., short-term trend). Participation in RMU Assessment ranking meetings has remained stable or increased slightly since the 2011 Assessment, but due to the large geographic scope of many RMUs (e.g., Snake River region, California RMUs), some NatureServe ranks may be based on limited partner input. There are instances where only one agency or tribe provided ranking information for a HUC, but these partners tended to be highly knowledgeable and familiar with on the ground conditions for Pacific Lamprey in the watershed. The same seven conservation factors were assessed in each RMU (Table 1), but interpretation of the conservation factors or threats (e.g., definition of lack of awareness) may vary among regions and between Assessment revisions. To minimize differences in interpretation, RMU leads held a pre-Assessment meeting to define model parameters and provided participants with a detailed description of conservation factors prior to collecting ranking information. Assessment ranks may also be influenced by the participants perception of a conservation factor or threat. For example, threat scope/severity scores for tributary passage and stream and floodplain degradation have improved in many RMUs since the first Assessment. Partners are implementing passage and habitat improvement projects and believe the work is having a positive effect, potentially skewing threat scope/severity values.

Despite data gaps that still exist, the quality of input information and thus the quality of the Assessment overall, has improved considerably over the last 10 years. It was largely a qualitative exercise in 2011 and 2018, with most ranks based on best professional judgement. As lamprey specific funding opportunities continue to grow, interest in Pacific Lamprey increases, and conservation measures for lampreys are successfully implemented, more Assessment ranks are based on quantitative information (e.g., current distribution, population size). Each Assessment revision builds off the knowledge of previous Assessments. As we learn more about Pacific Lamprey population demographics and threats, NatureServe CSRs will inevitably change to reflect new/improved knowledge and information.

Interpretation of Assessment Results

NatureServe CSRs categorize the relative level of extinction risk facing a species. Conservation factors were ranked by RMU partners (Appendix B). Based on these ranks, CSRs are assigned on a numeric scale from highest risk (i.e., SX – Presumed Extirpated) to lowest relative risk (S5 – Secure). Results in Chapters 4 and 5 describe HUC 4 watersheds that experienced a change in CSR, either improving (e.g., S1 to S2) or worsening (e.g., S2 to S1). Within the context of the Assessment, there are several reasons a CSR may change. First, there could be a genuine on-the-ground change in the status of the population. This could include recruitment to a new site after removal of a passage barrier (e.g., California South Coast RMU), extirpation from an existing site or successful translocation into a stream that was historically occupied by Pacific Lamprey (e.g., Snake and Upper Columbia RMUs). In the 2022 Assessment, changes in CSRs were also attributable to gaining new information. Our understanding of Pacific Lamprey distribution and population size has expanded considerably in the last five years due to increased awareness and sampling efforts (e.g., environmental DNA sampling, larval lamprey focused electrofishing, telemetry studies, adult nest count surveys, adult translocation, etc.). For example, CSRs improved in two HUCs in the Upper Columbia RMU due to new information on current distribution and population size from translocation activities and field surveys. Conversely, no lamprey were documented in the Lower Salmon (Snake RMU); thus, the population size rank was changed to zero, lowering the CSR from Critically Imperiled to Possibly Extirpated.

Change in CSRs can also be related to NatureServe assignment rules or model uncertainty. The NatureServe ranking process relies primarily on a point-based approach to derive a CSR, but there are several conditions under which a specific CSR will be assigned regardless of the calculated score. For example, a minimum of two NatureServe factor categories must be ranked to calculate a CSR (i.e., two from Rarity, or one from Rarity and one from Threats). If this minimum is not met, NatureServe assigns a CSR of SU (Unrankable). If at least one Rarity category (i.e., range extent, area of occupancy, population size, ratio of area of occupancy to range extent) is ranked a zero, NatureServe automatically assigns a CSR of SX (Presumed Extirpated). If either or both area of occupancy (current distribution) or population size is given a rank of A or B (see Appendix B), NatureServe automatically assigns a CSR of S1 (Critically Imperiled). Finally, if one or more of the conservation factors has information that is less precise than required by the rating scale (i.e., selecting two data bins rather than one), NatureServe may assign a Range Status Rank, or a CSR that spans two ranks (e.g., S1S2). During Assessment ranking meetings, many RMUs selected two data bins to rank population size rather than a single bin to remain conservative and inclusive of the variation in abundance that has been observed over the last five years. This resulted in CSRs changing from Imperiled (S2) to Critically Imperiled/Imperiled (S1S2) in several HUCs within Oregon Coast and Lower Columbia RMUs. A Range Status Rank of S1S2 has a roughly equal chance of being either an S1 or S2, but further information is needed to resolve the uncertainty. As more refined information becomes available, the rank will be updated appropriately in future Assessments.

The most common reason for a change in CSR was a worsening in the scope/severity ranking of threats. Most notable was the shift in the ranking of climate change from "Unknown" in 2017 (scope/severity 0,0) to "High" in 2022 (scope/severity 4,4), leading to the worsening of CSRs in several HUCs within Oregon Coast and lower Columbia RMUs. Climate change is inextricably linked to many of the threats assessed within RMUs (e.g., water quality, dewatering, stream and floodplain degradation, predation, etc.). Consequently, it was challenging to tease out and rank climate change impacts separately from other threat impacts. Climate change will continue to have a significant impact on aquatic ecosystems and lamprey populations, and will likely remain a high-ranking threat across all RMUs in the future. For this reason, RMU leads and partners discussed the possibility of omitting climate change from future Assessments. While climate change is undoubtedly a significant threat to Pacific Lamprey across its range, it may be more beneficial and practical to understand and attempt to mediate climate change impacts within many of the other threat categories evaluated during the Assessment (e.g., high water temperatures identified in water quality).

Regional Management Unit teams rank up to ten different threat categories to identify the most influential threat (i.e., threat with highest scope/severity). For each Assessment, scope/severity values may change due to changes in the intensity of the threat, or more commonly, due to a better understanding or awareness of the threat. Understanding of threats continues to improve in each Assessment due to increases in research and monitoring (e.g., larval thermal tolerance studies, dewatering studies, juvenile outmigration monitoring, diversion entrainment studies, etc.). Due to more limited information in past Assessments, some threats were not ranked (e.g., lack of awareness, climate change) or the scope/severity values were less accurately ranked. For example, the 2022 NatureServe Assessment ranking of tributary passage increased from a Low to a Moderate threat in the Oregon North Coast sub-unit. This resulted from new information gained from recent barrier assessments and a better understanding of Pacific Lamprey passage needs, rather than a true increase in the number of barriers within these watersheds. As RMU participation increases and more lamprey research and monitoring projects are completed, we will gain information and insight into the various threats impacting lamprey and the Assessment scope/severity values will continue to change to more accurately reflect the magnitude of these threats.

Improvements and Uncertainties

The 2022 Assessment reflects an increase in knowledge and awareness of Pacific Lamprey throughout their range, but population demographic values are still known in some RMUs. Particularly noteworthy in 2022 was the evaluation of 21 new watersheds, including 19 watersheds in Puget Sound/Strait of Juan de Fuca and Washington Coast RMUs. Also, estimates of adult Pacific Lamprey abundance were calculated in several watersheds for the first time in Washington Coast, Oregon Coast and Columbia Basin RMUs using nest counts and adult counts at mainstem Columbia River dams. However, outside of these locations, there is still high uncertainty regarding adult abundance. Even when Pacific Lamprey are known to be present in a watershed, without targeted surveys and consistent data collection, it is difficult to estimate population size. Similarly, many RMUs still lack adequate information to evaluate short-term population trends. Without consistent long-term monitoring of abundance or adult count information, quantification of population trends will remain infeasible in most HUCs. While data quality and availability have improved substantially since the 2011 Assessment, there is still a scarcity of baseline population demographic information in many HUCs across the region, including those in the Alaska RMU. The level of interest and participation within the Alaska RMU has grown considerably over the last five years, but the current status of Pacific Lamprey there is still unknown. Only a few people in Alaska are currently focused on Pacific Lamprey and funding for research is limited because it is not a commercially important species.

Additionally, Alaska's vast size and remote locations make collecting information challenging. Many of these issues are also present in British Columbia, Canada, where little is known about Pacific Lamprey populations. More work will be needed to continue raising awareness of Pacific Lamprey, building a communication network among RMU partners and compiling baseline information about Pacific Lamprey across the northern extent of their range. Understanding the distribution and abundance of Pacific Lamprey in these regions may be of particular importance in the face of climate change and shifting habitat conditions.

Awareness of Pacific Lamprey improves incrementally with each Assessment. Tribes, state and federal agencies, watershed councils, and many others have played significant roles in improving the general public's awareness and appreciation of Pacific lamprey through targeted outreach, youth education events, informational brochures, and webinars. The Lamprey Technical Workgroup has played a large role in enhancing the understanding of Pacific Lamprey through the publication of technical guidance documents available on the PLCI webpage (https://www.pacificlamprey.org/ltwg/) and hosting an annual Lamprey Information Exchange to facilitate information sharing and collaboration among partners. While a growing number of projects are targeting or incorporating benefits for Pacific Lamprey, there is still room for improvement. Pacific Lamprey are still secondary to salmon in terms of funding and implementation of conservation measures. While awareness of Pacific Lamprey has improved, it has not necessarily translated into meaningful on-the-ground improvements. More efforts are needed to integrate lamprey into planning and design for fish passage/screening and habitat restoration projects, incorporating lamprey into fish salvage plans, and consideration of lamprey when dredging or implementing instream activities that may disturb or dewater habitat. The overall trend in awareness is improving, especially with regards to fish passage considerations and stream restoration, but there remains a general lack of interest in some regions where Pacific Lamprey are not considered a management or conservation priority.

High priority threats to Pacific Lamprey have generally remained the same in all RMUs since the 2011 Assessment. Change in the intensity of threats was due to an expanded understanding of threats (see above) or a true worsening of conditions. Threats such as lack of awareness, tributary passage, and stream and floodplain degradation have improved slightly over the last decade, a reflection of ongoing passage improvement and habitat restoration work happening throughout RMUs (largely driven by salmon restoration efforts). There is concern, however, with the predicted rise in the human population and an increasing amount of urban and agricultural development, that habitat degradation may be outpacing restoration efforts in some HUCs. Fish passage in tributaries is slowly improving, yet there are still thousands of impassable or partially impassable barriers that need to be addressed (e.g., culverts, low-head dams, flood control dams, diversions, tide-gates, etc.). Depending on the location, Pacific Lamprey passage requirements are still not being evaluated in barrier assessments or included in prioritization efforts. Mainstem passage continues to be the most serious threat impacting Pacific Lamprey in the Mid-Columbia, Upper Columbia and Snake RMUs. Though efforts to improve lamprey passage are ongoing (e.g., installing lamprey passage structures, modifying entrances and fishways), much of this work is only occurring at Bonneville and John Day dams and passage at other dams is still highly problematic. Further, no significant improvements have yet been made for juvenile/larval lamprey moving downstream through the dams. Assessments of downstream passage in the mainstem Columbia/Snake environment began in 2022 (Deng et al. 2023) and hopefully will lead to continued efforts in mainstem passage improvements.

The threats of water quality and dewatering have worsened over time and are exacerbated by increasing effects of climate change. Many HUCs are experiencing warmer summer water temperatures, reduced summer flows, and more frequent extreme weather events like heat waves, droughts, wildfires, and flooding. Low flows and elevated water temperatures have created optimal conditions for Smallmouth Bass *Micropterus dolomieu*, Striped Bass *Morone saxatilis*, Walleye *Sander vitreus* and other nonnative fish species. Reservoirs behind dams also create ideal habitat conditions for invasive and nonnative predatory fishes. Predation was not ranked a high priority threat during the 2022 Assessment, but was identified as a rising concern in Columbia Basin, Oregon Coast and Washington coastal RMUs. Northern Pikeminnow *Ptychocheilus oregonensis* and Walleye prey on larval and juvenile lamprey in the Lower Columbia (Carpenter et al. 2019; Bingham et al. 2024) and Smallmouth Bass predation on juvenile lamprey is well documented in the Umpqua Basin (Schultz et al. 2017), but the severity of the threat has not been quantitatively evaluated in other HUCs. Harvest impacts in California continue to pose an Insignificant or Low threat, but the degree of the impact is not well understood. Small effective population size in the Upper Columbia, Mid-Columbia and Snake River RMUs continue to be considered a threat and the scale of the impact did not change.

Three additional threats, disease, ocean conditions, and contaminants, potentially impact Pacific Lamprey populations, but there is still too little information to evaluate severity. There are very few studies regarding how pathogens may affect Pacific Lamprey (but see Shavalier et al. 2021; Jackson et al. 2019), which is why it was not evaluated as a threat during the 2022 Assessment revision. To date, the only pathogen that has been detected in more than a few instances is furunculosis *Aeromonas salmonicida* in adults and *Aeromonas hydrophila* and *Vibrio vulnificus* in larval Pacific Lamprey (Jackson et al. 2019; Jolley and Lujan 2019). Considering the artificial propagation goals within the Columbia River Basin (CRITFC 2011), as well as the potential interaction of disease and climate change, this is an area of additional research needs.

Ocean conditions may impact Pacific Lamprey at a population and species level as all Pacific Lamprey spend multiple years in this environment. Ocean conditions impact host species abundance and locations, as well as predation rates on Pacific Lamprey (Clemens et al. 2019). However, it is unknown how changes in ocean conditions or host species abundance may impact Pacific Lamprey populations (Wang et al. 2020, 2021). Due to the lack of understanding, ocean conditions were not evaluated in this Assessment, but the global nature of this threat on Pacific Lamprey warrants further research and investigation.

The impact of contaminants (currently a water quality threat) is also a poorly understood threat to Pacific Lamprey that was identified as a significant data gap during the 2022 Assessment. Until recently, few studies have examined potential impacts of contaminants on lampreys (Nilsen et al. 2015; Unrein et al. 2016; Madenjian et al. 2021; Smith et al. 2023). In light of the consumption advisory issued by the Oregon Health Authority after testing detected high levels of PCBs and mercury in lamprey tissue, contaminants may be elevated to its own threat category in future Assessment updates.

As we learn more and gain experience, we have refined the NatureServe model and the Assessment. To date, this approach has been successful. Given this success and flexibility of the model to accommodate changes when appropriate, we anticipate there will be future refinements and improvements to the Assessment, which will continue to improve its results and utility to help prioritize lamprey conservation efforts.

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APPENDICES

Appendix A. Partners who participated in RMU meetings related to the 2022 Assessment or provided data, information, and insight on Pacific Lamprey across 18 RMUs.

Ahtna Intertribal Resource Commission	Confederated Tribes of Siletz Indians	Idaho Power Company	North Fork John Day Watershed Council	Sound Salmon Solutions
Alameda County Water District	Confederated Tribes of the Colville Reservation	Jamestown S'Klallam Tribe	Northwest Fisheries Science Center - NOAA	South Bay Clean Creeks Coalition
Alameda Creek Alliance	Confederated Tribes of the Umatilla Indian Reservation	Karuk Tribe	Novo Aquatic Sciences, Inc.	Spokane Tribe of Indians
Alaska Department of Fish and Game	Confederated Tribes of Umatilla Indian Reservation	Kashia Pomo Tribe	Ojai Valley Land Conservancy	Stillwater Sciences
Altap Restoration LLC	Confederated Tribes of Warm Springs Indian Reservation	KCI Environmental	Okanogan Nation Alliance	Susitna River Coalition
Applegate Partnership and Watershed Council	Cook Inlet Aquaculture Association	King County	Orange County Water District	Terra Verde Environmental Consulting
Bear River Band of Rohnerville Rancheria	Coquille Indian Tribe	Knik Tribes	Oregon Department of Fish and Wildlife (ODFW)	The Land Conservancy of San Luis Obispo County
Benton Water Conservation District	Cow Creek Band of Umpqua Tribe of Indians	Lower Columbia Estuary Partnership	Pacific Northwest National Laboratory	Tracy Fish Collection Facility
Blue Lake Rancheria	Cowlitz Tribe	Lower Columbia Fish Enhancement Group	Pala Band of Mission Indians	Trinity Associates, LLC
Bureau of Land Management (BLM)	Cuesta College	Lower Columbia River Watershed Council	Port Gamble S’Klallam Tribe	Trinity County Resource Conservation District
Bureau of Reclamation	Curry Watershed Partnership	Lower Elwha Klallam Tribe	Portland General Electric	Trout Unlimited
Cahto Tribe of the Laytonville Rancheria	Del Norte County	Marin Water District	Quartz Valley Indian Reservation	Tyonek Tribal Conservation District

California Academy of Sciences	Douglas County Public Utility District	Mattole Salmon Group	Quileute Nation	U.S. Army Corps of Engineers
California Department of Fish and Wildlife	East Bay Municipal Utility District	McBain and Trush	Regional Water Quality Board	U.S. Environmental Protection Agency
California Department of Forestry and Fire Protection (CAL Fire)	East Bay Regional Park District	Mckenzie River Trust	Resource Conservation District of Santa Monica Mountains	U.S. Fish and Wildlife Service (USFWS)
California Department of Transportation	Feather River Fish Hatchery	McKenzie Watershed Council	Round Valley Indian Tribes	U.S. Forest Service (USFS)
California Department of Water Resources	Five Counties Salmonid Conservation Program	Mendocino County	Salmon and Steelhead Restoration Group	U.S. Geological Survey (USGS)
Campbell Global	Friends of the Napa River	Mendocino Land Trust	Salmon River Restoration Council	U.S. National Park Service (NPS)
Cascade Fisheries	Gilliam Soil and Water Conservation District	Mendocino Redwood Company	San Diego Trout	UC Santa Cruz Natural Reserves
Center for Ecosystem Management and Restoration	Grant County Public Utility District	Methow Salmon Recovery Foundation	San Francisco Public Utilities Commission	United Water Conservation District
Central Coast Salmon Enhancement	Grassroots Ecology	Molalla River Watch	Sanke River Salmon Recovery Board	University of Idaho
Chelan County Public Utility District	Greater Oregon City Watershed Council	Monterey County Water Resources Agency	Santa Barbara Land Conservancy	University of Alaska Fairbanks
Chelan Douglas Land Trust	Green Diamond Resource Company (Green Diamond)	Morrow Bay National Estuary Program	Santa Clara Valley Water District	University of California, Davis
City of Portland	Guadalupe Coyote Resource Conservation District	Napa County Resource Conservation District	Santa Margarita Ecological Reserve - SDSU	Washington Department of Fish and Wildlife (WDFW)
City of San Luis Obispo	Henry Miller Reclamation District #2131	National Marine Fisheries Service (NOAA Fisheries)	Santa Ynez Band of Chumash Indians	Washington Department of Natural Resources
Clallam County	Hoh Indian Tribe	Natural Resources Conservation Service - USDA	Sierra Club	Whatcom Conservation District

Clatsop Soil and Water Conservation District	Hood Canal Salmon Enhancement Group	Necanicum Watershed Council	Siskiyou County	Wiyot Tribe
Coast Fork Willamette Watershed Council	Hoopa Valley Tribe	Nestucca, Neskowin and Sand Lake Watershed Council	Siuslaw Watershed Council	Woodbridge Irrigation District
Coleman National Fish Hatchery	Humboldt Baykeeper	Nez Perce Tribe	Snoqualmie Valley Watershed Improvement District	Yakama Nation Fisheries
Columbia River Inter-Tribal Fish Commission (CRITFC)	Humboldt County	Nooksack Salmon Enhancement Association	Solano County Water Agency	Yakima Basin Fish & Wildlife Recovery Board
Confederated Tribes of Coos, Lower Umpqua and Siuslaw	Humboldt State University	North Clackamas Watershed Council	Sonoma County Water Agency	Yolo County Flood Control and Water Conservation District
Confederated Tribes of Grand Ronde	Idaho Department of Fish and Game (IDFG)	North Coast Watershed Association	Sonoma Ecology Center	Yurok Tribe

Appendix B. NatureServe ranking key for seven conservation factors assessed during the 2022 Pacific Lamprey Assessment. A description of conservation factors can be found in Table 1.

Rarity Factor Group

Range Extent (Historical Distribution)

Z = Zero (no occurrences believed extant)
A = <100 square km (< about 40 square mi)
B = 100-250 square km (about 40-100 square mi)
C = 250-1,000 square km (about 100-400 square mi)
D = 1,000-5,000 square km (about 400-2,000 square mi)
E = 5000-20,000 square km (about 2,000-8,000 square mi)
F = 20,000-200,000 square km (about 8000-80,000 square mi)
G = 200,000-2,500,000 square km (about 80,000-1,000,000 sq mi)
H = >2,500,000 square km (> 1,000,000 square mi)

Area of Occupancy

X = Extinct (no occurrences extant)
Z = Zero (no occurrences believed extant)
A = <0.4 square km (less than about 100 acres)
B = 0.4-4 square km (about 100-1,000 acres)
C = 4-20 square km (about 1,000-5,000 acres)
D = 20-100 square km (about 5,000-25,000 acres)
E = 100-500 square km (about 25,000-125,000 acres)
F = 500-2,000 square km (about 125,000-500,000 acres)
G = 2,000-20,000 square km (about 500,000-5,000,000 acres)

H = >20,000 square km (greater than 5,000,000 acres)

Rarity Factor Group

Population Size

X = Extinct (no occurrences extant)
Z = Zero, no individuals believed extant
A = 1 - 50 individuals
B = 50 - 250 individuals
C = 250 – 1,000 individuals
D = 1,000 – 2,500 individuals
E = 2,500 - 10,000 individuals
F = 10,000 - 100,000 individuals
G = 100,000 - 1,000,000 individuals
H = >1,000,000 individuals

Rarity Factor Group

Ratio of Historical and Current Distribution (Values in percent of historical distribution)

Z = 0.001
A = 0.05
B = 0.1
C = 0.25
D = 0.37
E = 0.5
F = 0.75
G = 0.9
H = 1.0

Trend Factor Group

Short-Term Trend (Past 36 years or 3 generations whichever is longer)

A = Severely declining (decline of >70% in population, range, area occupied, and/or # or condition of occurrences)
B = Very rapidly declining (decline of 50-70%)
C = Rapidly declining (decline of 30-50%)
D = Declining (decline of 10-30%)
E = Stable (unchanged or within +/- 10% fluctuation in population, range, area occupied, and/or number or condition of occurrences)
F = Increasing (increase of >10%)

Threats Factor Group

Threat Scope

High (4) = 71-100% of total population, occurrences, or area affected
Moderate (3) = 31-70% of total population, occurrences, or area affected
Low (2) = 11-30% of total population, occurrences, or area affected
Insignificant (1) = <10% of total population or area affected
Unknown (0) = Scope could not be determined

Threat Severity

High (4) = Near-total destruction of suitable habitat and/or functional loss of Pacific Lamprey from this watershed; (>100 years for recovery)
Moderate (3) = Long-term degradation or reduction of suitable habitat and/or functional loss of Pacific Lamprey from this watershed (50-100 years for recovery)
Low (2) = Reversible degradation of or reduction of habitat and/or measurable reduction of Pacific Lamprey in watershed (2-3 generations for recovery).
Insignificant (1) = Essentially no reduction or degradation due to threats or able to recover quickly from minor temporary loss (within 2 generations)
Unknown (0) = Severity could not be determined

Appendix C. NatureServe Conservation Status Rank calculation example including Factor and Category weights. A detailed description of how CSRs were calculated with the 2009 version of the rank calculator can be found in NatureServe (2009).

Factor Category	Conservation Factor	Factor Ranking	NatureServe Assigned Point Value	Factor Weight	Weighted Point Value	Category Sub-Score	Category Weight	Category Score
Rarity	Range Extent (Historic)	D	2.36	1	2.36			
	Area of Occupancy	E	3.14	1	3.14			
	Ratio (Current/Historic)	B	0.79	1	0.79			
	Population Size	D	2.36	1	2.36			
		Rarity subtotals:		4	8.65	2.16	0.60	1.30
Threats	Overall Threat	B	0.92	1	0.92			
		Threat subtotal:		1	0.92	0.92	0.30	0.28
Trends	Short-term Trend	B	1.1	1	1.1			
		Trend subtotal:		1	1.1	1.1	0.10	-0.11
S1 = score ≤ 1.5; **S2** = 1.5 <score ≤ 2.5; **S3** = 2.5 < score ≤ 3.5; **S4** = 3.5 < score ≤ 4.5; **S5** = score > 4.5; **SU** = score containing U (unknown); **SX** = Score containing X (extirpated); **SH** = Score containing Z (Zero)						**Calculated Score**		**1.47**
						Calculated CSR		**S1**

Appendix D. Population demographic and conservation status ranks of the Hydrologic Unit Code 4 (HUC 4) watersheds located in Oregon, Washington and Idaho. Note - steelhead intrinsic potential, coho and/or chinook distribution was used as a surrogate estimate of historical lamprey range extent in areas where historical occupancy information was not available. Additionally, translocation is included in current distribution, population size and/or short-term trend estimates within the Snake (12 HUCs), Upper Columbia (8 HUCs) and Mid-Columbia (1 HUC) RMUs. Population and short-term trend data quality rankings are defined as follows: 0 = no information available, 1 = largely undocumented and/or anecdotal information, 2 = best professional judgement, 3 = partial adult/nest count data from <1/2 of potential habitat in watershed, 4 = partial adult/nest count data from >1/2 of potential habitat in watershed with some estimate of error, 5 = comprehensive (>90%) adult/nest count census with some estimate of error.

OREGON SOUTH COAST SUB-UNIT											
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km^2)** Historical Distribution	**Area of Occupancy (km^2)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Pop. Size Data Quality**	**Short-Term Trend (% decline)**	**Trend Data Quality**	**Threat: Scope**	**Threat: Severity**
North Umpqua	17100301	S1S2	2247	196	0.09	250 - 2500	5	Stable	5	High	High
South Umpqua	17100302	S1	3235	375	0.12	250 - 2500	2	Unknown	2	High	High
Umpqua	17100303	S1S2	2857	718	0.25	1000 - 10,000	4	Unknown	2	High	High
Coos	17100304	S1S2	1615	435	0.27	250 - 2500	4	Unknown	2, 3	High	High
Coquille	17100305	S2	2202	508	0.23	2500 - 10,000	4	Unknown	2, 3	High	High
Sixes	17100306	S1	1043	222	0.21	Unknown	0	Unknown	0	High	High
Upper Rogue	17100307	S1	2996	106	0.04	Unknown	0	Unknown	0	High	High
Middle Rogue	17100308	S1	1925	165	0.09	Unknown	0	Unknown	0	High	High
Applegate	17100309	S1	1405	137	0.10	Unknown	1	Unknown	0	High	High
Lower Rogue	17100310	S1	1406	245	0.17	Unknown	0	Unknown	0	High	High
Illinois	17100311	S1	1536	199	0.13	Unknown	0	Unknown	0	High	High
Chetco	17100312	S1	920	209	0.23	Unknown	0	Unknown	0	High	High
OREGON NORTH COAST SUB-UNIT											

Watershed	HUC Number	Conservation Status Rank	Range Extent (km²) Historical Distribution	Area of Occupancy (km²) Current Distribution	Ratio of Area of Occupancy to Range Extent	Population Size (adults)	Pop. Size Data Quality	Short-Term Trend (% decline)	Trend Data Quality	Threat: Scope	Threat: Severity
Necanicum	17100201	S1	327	66	0.20	250 - 1000	5	Unknown	2	High	High
Nehalem	17100202	S1S2	2061	420	0.20	1000 - 10,000	5	Unknown	2	High	High
Wilson-Trask-Nestucca	17100203	S1S2	2175	441	0.20	1000 - 10,000	5	Unknown	2	High	High
Siletz-Yaquina	17100204	S1S2	1843	397	0.22	1000 - 10,000	4	Unknown	2	High	High
Alsea	17100205	S1S2	1651	370	0.22	1000 - 10,000	3	Unknown	2	High	High
Siuslaw	17100206	S2	1864	535	0.29	1000 - 10,000	4	Unknown	2	High	High
Siltcoos	17100207	S1	332	77	0.23	50 - 250	3	Unknown	2	High	High
WILLAMETTE											
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km²) Historical Distribution**	**Area of Occupancy (km²) Current Distribution**	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Pop. Size Data Quality**	**Short-Term Trend (% decline)**	**Trend Data Quality**	**Threat: Scope**	**Threat: Severity**
Middle Fork Willamette	17090001	S1	1366	107	0.08	50 - 250	3, 4	Unknown	0	High	High
Coast Fork Willamette	17090002	S1	642	79	0.12	250 - 1000	3, 4	Unknown	0	High	High
Upper Willamette	17090003	S2	3683	507	0.14	10,000 - 100,000	3, 4	Unknown	0	High	High
McKenzie	17090004	S2	1182	145	0.12	250 - 1000	3, 4	Stable	3	Moderate	Moderate
North Santiam	17090005	S1	872	107	0.12	1000 - 2500	3, 4	Unknown	0	High	High
South Santiam	17090006	S1	1334	228	0.17	1000 - 2500	3, 4	Unknown	0	High	High
Middle Willamette	17090007	S2	1491	206	0.14	10,000 - 100,000	3, 4	Unknown	0	High	High
Yamhill	17090008	S1	1736	175	0.10	1000 - 2500	3, 4	Unknown	0	High	High

Molalla-Pudding	17090009	S1	1543	158	0.10	1000 - 2500	3, 4	Unknown	0	High	High
Tualatin	17090010	S1	1576	207	0.13	250 - 1000	3, 4	Unknown	0	High	High
Clackamas	17090011	S3	1804	212	0.12	10,000 - 100,000	2, 3	Stable	3	Moderate	Moderate
Lower Willamette	17090012	S2	866	329	0.38	10,000 - 100,000	2, 3	Stable	3	High	High
LOWER COLUMBIA											
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km²)** Historical Distribution	**Area of Occupancy (km²)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Pop. Size Data Quality**	**Short-Term Trend (% decline)**	**Trend Data Quality**	**Threat: Scope**	**Threat: Severity**
Lower Columbia-Sandy	17080001	S1	1325	312	0.24	50 - 1000	4	Unknown	1	High	High
Lewis	17080002	S1	364	140	0.38	50 - 250	2, 3	Unknown	1	High	High
Upper Cowlitz	17080004	SH	296	0	0.00	0	5	Unknown	1	High	High
Lower Cowlitz	17080005	S2	1246	539	0.43	250 - 2500	2, 3	Unknown	1	High	High
Lower Columbia-Clatskanie	17080003	S1S2	1688	501	0.30	250 - 2500	2, 3	Unknown	1, 2	High	High
Lower Columbia	17080006	S1	1216	330	0.27	250 - 1000	2, 3	Unknown	1, 2	High	High
MID-COLUMBIA											
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km²)** Historical Distribution	**Area of Occupancy (km²)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Pop. Size Data Quality**	**Short-Term Trend (% decline)**	**Trend Data Quality**	**Threat: Scope**	**Threat: Severity**
Walla Walla	17070102	SH	1000 - 5000	0	0.00	0 - 50	3	Unknown	2, 3	High	High
Umatilla	17070103	S1	3814	199	0.05	1000 - 2500	5	10 - 30%	4	High	High
Willow	17070104	SH	1640	Unknown	Unknown	0	1	Unknown	0	High	High

Middle Columbia-Hood	17070105	S2	3267	454	0.14	1000 - 10,000	3, 4	10 - 50%	2, 3	High	High
Klickitat	17070106	S1	2410	81	0.03	1000 - 10,000	3	50 - 70%	2	High	High
Upper John Day	17070201	S1	4049	231	0.06	250 - 1000	1	Unknown	0	High	High
North Fork John Day	17070202	S1	3726	178	0.05	250 - 2500	2	Unknown	0	High	High
Middle Fork John Day	17070203	S1	1614	119	0.07	250 - 2500	2	Unknown	0	High	High
Lower John Day	17070204	S1	5909	333	0.06	250 - 1000	2, 3	Unknown	0	High	High
Upper Deschutes	17070301	SX	1000 - 5000	Extinct	--	Extinct	2	Unknown	0	High	High
Little Deschutes	17070302	SX	--	Extinct	--	Extinct	2	Unknown	0	High	High
Beaver South Fork	17070303	SX	1000 - 5000	Extinct	--	Extinct	2	Unknown	0	High	High
Upper Crooked	17070304	SX	1000 - 5000	Extinct	--	Extinct	2	Unknown	0	High	High
Lower Crooked	17070305	SX	1000 - 5000	Extinct	--	Extinct	2	Unknown	0	High	High
Lower Deschutes	17070306	S2	4270	311	0.07	2500 - 10,000	4	10 - 30%	2, 3	High	High
Trout	17070307	SH	1000 - 5000	0	0.00	0	2	Unknown	0	High	High
SNAKE											
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km^2)** Historical Distribution	**Area of Occupancy (km^2)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Pop. Size Data Quality**	**Short-Term Trend (% decline)**	**Trend Data Quality**	**Threat: Scope**	**Threat: Severity**
Lower Clearwater	17060306	S1	2564	376	0.15	50 - 250	3	>10%	1	High	High
Lower North Fork Clearwater	17060308	SX	1000 - 5000	0	0.00	Extinct	--	Unknown	--	High	High
Upper North Fork Clearwater	17060307	SX	1000 - 5000	0	0.00	Extinct	--	Unknown	--	High	High

Middle Fork Clearwater	17060304	S1	320	54	0.17	1 - 50	2	>70%	2	High	High
South Fork Clearwater	17060305	S1	1738	141	0.08	50 - 250	3	Unknown	2	High	High
Lochsa	17060303	S1	1556	93	0.06	50 - 250	3	>70%	2	High	High
Lower Selway	17060302	S1	1315	80	0.06	50 - 250	2	>70%	2	High	High
Upper Selway	17060301	S1	1285	38	0.03	1 - 50	2	>70%	2	High	High
Lower Snake-Asotin	17060103	S1	1560	119	0.08	50 - 250	4	Unknown	2	High	High
Lower Grande Ronde	17060106	S1	2770	141	0.05	50 - 250	4	Unknown	2	High	High
Upper Grande Ronde	17060104	S1	2980	174	0.06	1000 - 2500	4	Unknown	2	High	High
Wallowa	17060105	S1	1000 - 5000	4 - 20	0.05	50 - 250	2	Unknown	2	High	High
Imnaha	17060102	S1	1608	12	0.01	1 - 50	--	>70%	--	High	High
Mainstem Snake River-Hells Canyon	17060101	S1	1118	126	0.11	1 - 50	--	Unknown	--	High	High
Lower Snake-Tucannon	17060107	S1	3168	190	0.06	1 - 50	3	>70%	2	High	High
Lower Snake	17060110	S1	794	123	0.15	--	--	--	--	High	High
Lower Salmon	17060209	SH	1632	211	0.13	0	--	Unknown	--	High	High
Little Salmon	17060210	SH	739	15	0.02	0 - Extinct	--	Unknown	--	High	High
South Fork Salmon	17060208	S1	1774	104	0.06	50 - 250	4	Unknown	2	High	High
Middle Salmon-Chamberlain	17060207	S1	2366	190	0.08	0 - 50	--	>70%	--	High	High
Lower Middle Fork Salmon	17060206	S1	1768	87	0.05	1 - 50	--	>70%	--	High	High
Upper Middle Fork Salmon	17060205	S1	2092	4 - 20	0.01	1 - 50	--	>70%	--	High	High
Middle Salmon-Panther	17060203	S1	2071	114	0.06	1 - 50	--	Unknown	--	High	High

Lemhi	17060204	SH	250 - 1000	0	0.00	0 - Extinct	--	Unknown	--	High	High
Pahsimeroi	17060202	SH	250 - 1000	0	0.00	0 - Extinct	--	Unknown	--	High	High
Upper Salmon	17060201	SH	1000 - 5000	0	0.00	0 - Extinct	--	Unknown	--	High	High
UPPER COLUMBIA											
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km²)** Historical Distribution	**Area of Occupancy (km²)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Pop. Size Data Quality**	**Short-Term Trend (% decline)**	**Trend Data Quality**	**Threat: Scope**	**Threat: Severity**
Smilkameen	17020007	S1	<100	4 -20	0.37	1 - 50	4	10 - 50%	2	High	High
Okanogan	17020006	S1	1913	227	0.12	50 - 250	4	50 - >70%	2	High	High
Methow	17020008	S1	3471	185	0.05	250 -1000	4	50 -70%	2	High	High
Chelan	17020009	SH	100-250	0	0.00	0	--	Unknown	--	High	High
Entiat	17020010	S1	2730	260	0.10	250 - 1000	--	10 - 50%	--	High	High
Wenatchee	17020011	S1	2454	129	0.05	250 -1000	3	10 - 50%	2	High	High
Crab Creek	17020013, 17020015	SH	1000-5000	0	0.00	0	--	Unknown	--	High	High
Upper Yakima	17030001	S1	3885	179	0.05	50 - 250	3	30 - 50%	2	High	High
Lower Yakima	17030003	S1	3743	421	0.11	250 - 1000	3	10 - 30%	2, 3	High	High
Naches	17030002	S1	2078	103	0.05	50 - 250	4	30 - 50%	2	High	High
Kettle, Colville, Sanpoil	17020002-004	SH	<100	0	0.00	Extinct	--	Unknown	--	High	High
WASHINGTON COAST											
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km²)** Historical Distribution	**Area of Occupancy (km²)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Pop. Size Data Quality**	**Short-Term Trend (% decline)**	**Trend Data Quality**	**Threat: Scope**	**Threat: Severity**
Hoh-Quillayute	17100101	S2	1804	294	0.16	Unknown	--	Unknown	--	Moderate	High
Queets-Quinault	17100102	S1	2024	145	0.07	Unknown	--	Unknown	--	Moderate	High

Upper Chehalis	17100103	S2	2643	502	0.19	1000 - 2500	--	Stable	--	High	Moderate
Lower Chehalis	17100104	S2	1866	391	0.21	1000 - 2500	--	Stable	--	High	High
Grays Harbor	17100105	S2	1248	145	0.12	250 - 1000	--	10 - 30%	--	Moderate	Moderate
Willapa Bay	17100106	S2	2364	502	0.21	1000 - 2500	--	10 - 30%	--	High	High
PUGET SOUND/STRAIT OF JUAN DE FUCA											
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km^2)** Historical Distribution	**Area of Occupancy (km^2)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Pop. Size Data Quality**	**Short-Term Trend (% decline)**	**Trend Data Quality**	**Threat: Scope**	**Threat: Severity**
Strait of Georgia	17110002	S1	483	58	0.12	20 - 250	--	Unknown	--	High	Moderate
Nooksack	17110004	S1S2	1667	160	0.10	250 - 2500	--	Stable	--	High	High
Upper Skagit	17110005	S1	2726	67	0.02	Unknown	--	Unknown	--	Moderate	Moderate
Sauk	17110006	S2	1157	77	0.07	Unknown	--	Unknown	--	Moderate	Moderate
Lower Skagit	17110007	S1	842	205	0.24	50 - 250	--	Unknown	--	High	High
Stillaguamish	17110008	S1	1278	144	0.11	1 - 50	--	10 - 30%	--	Moderate	High
Skykomish	17110009	S1	1514	84	0.06	1 - 50	--	Unknown	--	High	Moderate
Snoqualmie	17110010	S1	1258	114	0.09	50 - 250	--	Unknown	--	High	Moderate
Snohomish	17110011	S1	513	99	0.19	50 - 1000	--	Unknown	--	High	Moderate
Lake Washington	17110012	SH	873	0	0.00	0	--	Unknown	--	High	High
Duwamish	17110013	S1	831	62	0.07	Unknown	--	Unknown	--	High	Moderate
Puyallup	17110014	S1	1692	118	0.07	50 - 250	--	Unknown	--	Moderate	Moderate
Nisqually	17110015	S1	1085	73	0.07	1 - 50	--	Unknown	--	Moderate	Moderate
Deschutes	17110016	SH	257	0	0.00	Unknown	--	Unknown	--	Unknown	Unknown
Skokomish	17110017	S1	447	35	0.08	50 - 250	--	Unknown	--	Moderate	High
Hood Canal	17110018	S1	1390	69	0.05	50 - 250	--	Unknown	--	Moderate	Moderate
Puget Sound	17110019	S1	1533	60	0.04	Unknown	--	Unknown	--	Unknown	Unknown
Dungeness-Elwha	17110020	S1	1331	80	0.06	250 - 1000	--	>10%	--	High	High
Crescent-Hoko	17110021	S1	721	119	0.17	1000 - 2500	--	Unknown	--	High	High

Appendix E. Population demographic and conservation status ranks of the Hydrologic Unit Code 4 (HUC 4) watersheds located in California. Note - range extent and area of occupancy (4th order streams and above) were calculated directly from the linear extent of both historical range specific to Pacific Lamprey and current occupancy adjusted to an area value at 1 km:1 km2 (Reid and Goodman 2017).

CALIFORNIA SOUTH COAST									
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km)** Historical Distribution	**Area of Occupancy (km)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Short-Term Trend (% decline)**	**Threat: Scope**	**Threat: Severity**
Santa Barbara Coastal	18060013	SH	7	--	0.00	Absent	>70%	Moderate	Moderate
Ventura	18070101	S1	74	--	0.00	Unknown	50 - 70%	Moderate	High
Santa Clara	18070102	S1	423	--	0.00	Unknown	50 - 70%	High	Moderate
Calleguas	18070103	--	0	--	0.00	--	--	--	--
Santa Monica Bay	18070104	SH	20	--	0.00	Absent	>70%	High	High
Los Angeles	18070105	SH	159	--	0.00	Absent	>70%	High	High
San Gabriel	18070106	SH	124	--	0.00	Absent	>70%	High	Moderate
Seal Beach	18070201	--	0	--	0.00	--	--	--	--
San Jacinto	18070202	--	0	--	0.00	--	--	--	--
Santa Ana	18070203	S1	357	--	0.00	Unknown	50 - 70%	Moderate	High
Newport Bay	18070204	--	0	--	0.00	--	--	--	--
Aliso-San Onofre	18070301	--	0	--	0.00	--	--	--	--
Santa Margarita	18070302	S2	83	--	0.90	Unknown	Increasing	High	Moderate
San Luis Rey-Escondido	18070303	SH	118	--	0.00	Absent	>70%	High	Moderate
San Diego	18070304	SH	227	--	0.00	Absent	>70%	High	High
Cottonwood-Tijuana	18070305	SH	99	--	0.00	Absent	>70%	High	High
SAN JOAQUIN									

Watershed	HUC Number	Conservation Status Rank	Range Extent (km) Historical Distribution	Area of Occupancy (km) Current Distribution	Ratio of Area of Occupancy to Range Extent	Population Size (adults)	Short-Term Trend (% decline)	Threat: Scope	Threat: Severity
Kings - Upper	18030010	SX	177	0	0.00	Absent	--	High	High
Mill	18030008	SX	41	0	0.00	Absent	--	--	--
San Joaquin - Middle-Upper	18040001	S2	295	293	0.99	Unknown	50 - 70%	High	High
San Joaquin - Middle-Lower	18040002	S2	523	521	1.00	Unknown	50 - 70%	High	Moderate
San Joaquin Delta	18040003	S2	281	281	1.00	Unknown	50 - 70%	High	Moderate
Calaveras / Mormon Slough	18040004	S1	68	68	1.00	Unknown	50 - 70%	High	Moderate
Cosumnes / Lower Mokelumne	18040005	S2	185	160	0.86	Unknown	50 - 70%	High	Moderate
San Joaquin - Upper	18040006	SX	235	0	0.00	Absent	--	High	High
Upper Chowchilla-Upper Fresno	18040007	--	0	--	0.00	--	--	High	High
Merced - Upper	18040008	SX	218	0	0.00	Absent	--	High	High
Tuolumne - Upper	18040009	SX	284	0	0.00	Absent	--	High	High
Stanislaus - Upper	18040010	SX	354	6	0.02	Unknown	50 - 70%	High	High
Calaveras - Upper	18040011	S1	131	14	0.11	Unknown	50 - 70%	High	High
Mokelumne - Upper	18040012	SX	197	0	0.00	Absent	--	High	High
Cosumnes - Upper	18040013	S2	148	148	1.00	Unknown	50 - 70%	High	Low
Panoche-San Luis Reservoir	18040014	--	0	--	0.00	--	--	--	--
CALIFORNIA SOUTH CENTRAL COAST									
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km)** Historical Distribution	**Area of Occupancy (km)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Short-Term Trend (% decline)**	**Threat: Scope**	**Threat: Severity**
San Francisco Coastal South	18050006	S3	80	80	1.00	Unknown	50 - 70%	Low	Low
San Lorenzo-Soquel	18060001	S1	46	46	1.00	Unknown	50 - 70%	Moderate	Moderate

Pajaro	18060002	S2	340	323	0.95	Unknown	50 - 70%	High	Moderate
Salinas	18060005	S2	625	483	0.77	Unknown	50 - 70%	High	Moderate
Alisal-Elkhorn Sloughs	18060011	S1	1	1	1.00	Unknown	50 - 70%	High	High
Carmel	18060012	S1	71	69	0.97	Unknown	50 - 70%	High	Moderate
Central Coastal	18060006	S2	161	79	0.49	Unknown	50 - 70%	High	Low
Cuyama (trib. Santa Maria)	18060007	SH	210	--	0.00	Absent	--	High	High
Santa Maria	18060008	SH	155	--	0.00	Absent	--	High	Moderate
San Antonio	18060009	SH	25	--	0.00	Absent	--	High	High
Santa Ynez	18060010	SH	222	--	0.00	Absent	--	High	High
Estrella (trib. Salinas)	18060004	--	0	--	0.00	--	--	--	--
CALIFORNIA SAN FRANCISCO BAY									
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km)** Historical Distribution	**Area of Occupancy (km)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Short-Term Trend (% decline)**	**Threat: Scope**	**Threat: Severity**
Suisun Bay (Pacheco)	18050001	S1	79	65	0.82	Unknown	50 - 70%	Moderate	Moderate
San Pablo (Napa/Sonoma)	18050002	S2	122	122	1.00	Unknown	50 - 70%	Moderate	Moderate
Coyote (Coyote/Guadalupe)	18050003	S2	174	147	0.84	Unknown	50 - 70%	High	Moderate
San Francisco (Alameda)	18050004	S2	207	169	0.82	Unknown	50 - 70%	High	Moderate
CALIFORNIA NORTH CENTRAL COAST									
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km)** Historical Distribution	**Area of Occupancy (km)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Short-Term Trend (% decline)**	**Threat: Scope**	**Threat: Severity**
Big-Navarro-Garcia	18010108	S2	375	375	1.00	Unknown	50 - 70%	High	Low
Gualala-Salmon	18010109	S2	70	70	1.00	Unknown	50 - 70%	High	Low
Russian	18010110	S2	348	312	0.90	250-1000	50 - 70%	Moderate	Moderate
Bodega Bay	18010111	S2	36	36	1.00	Unknown	50 - 70%	High	Low

Tomales-Drake Bays	18050005	S1	37	37	1.00	Unknown	50 - 70%	Moderate	High
SACRAMENTO									
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km)** Historical Distribution	**Area of Occupancy (km)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Short-Term Trend (% decline)**	**Threat: Scope**	**Threat: Severity**
Upper Pit	18020002	SX	291	0	Absent	--	--	High	High
Lower Pit	18020003	SX	413	0	Absent	--	--	High	High
McCloud	18020004	SX	160	0	Absent	--	--	High	High
Sacramento headwaters	18020005	SX	127	0	Absent	--	--	High	High
Sacramento - Upper Clear	18020112	S1	54	15	0.28	Unknown	50 - 70%	High	Moderate
Upper Cow - Battle	18020118	S1	57	57	1.00	Unknown	50 - 70%	Moderate	Moderate
Lower Cow - Lower Clear	18020101	S2	216	214	0.99	Unknown	50 - 70%	High	Low
Mill - Big Chico	18020119	S2	286	258	0.90	Unknown	50 - 70%	High	Moderate
Butte - Upper	18020120	S1	68	25	0.36	Unknown	50 - 70%	High	Low
Butte - Lower	18020105	S2	194	194	1.00	Unknown	50 - 70%	High	Low
Feather - North Fork	18020121	SX	309	--	0.00	Absent	--	High	High
Feather - N.F. East Branch	18020122	SX	295	--	0.00	Absent	--	High	High
Feather - Middle Fork	18020123	SX	349	1	0.00	Absent	--	High	High
Feather - Lower	18020106	S2	215	212	0.98	Unknown	50 - 70%	Moderate	Moderate
Honcut headwaters	18020124	S2	29	29	1.00	Unknown	50 - 70%	High	Low
Yuba - Upper	18020125	S1	426	48	0.11	Unknown	50 - 70%	High	High
Yuba - Lower	18020107	S1	40	40	1.00	Unknown	50 - 70%	Moderate	Moderate
Bear - Upper	18020126	SX	94	--	0.00	Absent	--	High	High
Bear - Lower	18020108	S2	48	47	0.97	Unknown	50 - 70%	High	Low
Upper Coon - Upper Auburn	18020127	--	0	--	--	--	--	--	--
American - North Fork	18020128	SX	297	--	0.00	Absent	--	High	High
American - South Fork	18020129	SX	199	--	0.00	Absent	--	High	High

American - Lower	18020111	S2	105	91	0.86	Unknown	50 - 70%	Moderate	Moderate
Cottonwood headwaters	18020113	S2	103	103	1.00	Unknown	50 - 70%	High	Low
Cottonwood - Lower	18020102	S2	131	131	1.00	Unknown	50 - 70%	Moderate	Moderate
Upper Elder - Upper Thomes	18020114	S2	52	52	1.00	Unknown	50 - 70%	High	Low
Sacramento - Lower Thomes	18020103	S2	467	466	1.00	Unknown	50 - 70%	Moderate	Moderate
Stony - Upper	18020115	SX	213	--	0.00	Absent	--	High	High
Sacramento - Stone Corral	18020104	S2	213	213	1.00	Unknown	50 - 70%	Moderate	Moderate
Cache - Upper	18020116	SX	296	--	0.00	Absent	--	High	High
Cache - Lower	18020110	SH	88	--	0.00	Absent	--	High	High
Putah - Upper	18020117	SX	108	--	0.00	Absent	--	High	High
Sacramento - Lower	18020109	S2	450	414	0.92	Unknown	50 - 70%	Moderate	Moderate
CALIFORNIA NORTH COAST									
Watershed	**HUC Number**	**Conservation Status Rank**	**Range Extent (km)** Historical Distribution	**Area of Occupancy (km)** Current Distribution	**Ratio of Area of Occupancy to Range Extent**	**Population Size (adults)**	**Short-Term Trend (% decline)**	**Threat: Scope**	**Threat: Severity**
Williamson	18010201	SX	136	0	0.00	Absent	--	--	--
Sprague	18010202	SX	427	0	0.00	Absent	--	--	--
Upper Klamath Lake	18010203	SX	92	0	0.00	Absent	--	--	--
Lost	18010204	SX	48	0	0.00	Absent	--	--	--
Butte	18010205	--	NA	--	--	--	--	--	--
Upper Klamath	18010206	S2	288	164	0.57	250-1000	50 - 70%	High	Moderate
Shasta	18010207	S1	84	84	1.00	250-1000	50 - 70%	Moderate	Moderate
Scott	18010208	S2	139	139	1.00	250-1000	50 - 70%	Moderate	Moderate
Salmon	18010210	S2	161	161	1.00	1000-2500	50 - 70%	High	Low
Trinity	18010211	S2	449	316	0.70	1000-2500	50 - 70%	Moderate	Moderate
South Fork Trinity	18010212	S2	249	249	1.00	1000-2500	50 - 70%	Moderate	Moderate
Lower Klamath	18010209	S2	373	373	1.00	1000-2500	50 - 70%	High	Low

Lower Eel	18010105	S2	517	517	1.00	1000-2500	50 - 70%	High	Moderate
Middle Fork Eel	18010104	S2	220	220	1.00	1000-2500	50 - 70%	High	Moderate
South Fork Eel	18010106	S2	225	225	1.00	1000-2500	50 - 70%	High	Moderate
Upper Eel	18010103	S2	241	160	0.66	1000-2500	50 - 70%	High	Moderate
Smith	18010101	S3	227	227	1.00	Unknown	50 - 70%	Moderate	Insignificant
Mad-Redwood	18010102	S2	401	362	0.90	Unknown	50 - 70%	High	Low
Mattole	18010107	S2	154	154	1.00	Unknown	50 - 70%	High	Low