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Regional Implementation Plan for Measures to Conserve Pacific Lamprey (*Entosphenus tridentatus*), California – San Francisco Bay Regional Management Unit

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key words: Pacific Lamprey, conservation measures, NatureServe, limiting factors

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Acronym List

ACWD	Alameda County Water District
BLM	Bureau of Land Management
CA	California
CalTrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
EBMUD	East Bay Municipal Utilities District
ESA	Endangered Species Act
ESRI	Environmental Systems Research Institute
GCRCD	Guadalupe Coyote Resource Conservation District
HUC	Hydrologic Unit Code
Km	Kilometer
MCZ	Museum Comparative Zoology (Harvard) - Ichthyological collection
NCRCD	Napa County Resource Conservation District
NOAA	National Oceanographic and Atmospheric Administration
PG&E	Pacific Gas and Electric Company
PLCI	Pacific Lamprey Conservation Initiative
RKM	River Kilometer
RM	River Mile
RMU	Regional Management Unit
SCWD	Santa Clara Water District
SFPUC	San Francisco Public Utilities Commission
SU	Stanford University - Ichthyological collection
UCD	University California Davis - Ichthyological collection
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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Introduction

Pacific Lamprey, *Entosphenus tridentatus*, were historically widely distributed from Mexico north along the Pacific Rim to Japan. They are culturally important to indigenous people throughout their range, and play a vital role in the ecosystem: cycling marine nutrients, passing primary production up the food chain as filter feeding larvae, promoting bioturbation in sediments, and serving as food for many mammals, fishes and birds. Recent observations of substantial declines in the abundance and range of Pacific Lamprey have spurred conservation interest in the species, with increasing attention from tribes, agencies, and others.

In 2003 the U.S. Fish and Wildlife Service (USFWS) was petitioned by 11 conservation groups to list four species of lamprey in Oregon, Washington, Idaho, and California, including the Pacific Lamprey, under the Endangered Species Act (ESA) (Nawa et al. 2003). The USFWS review of the petition indicated a likely decline in abundance and distribution in some portions of the Pacific Lamprey's range and the existence of both long-term and proximate threats to this species, but the petition did not provide information describing how the portion of the species' petitioned range (California, Oregon, Idaho, and Washington) or any smaller portion is appropriate for listing under the ESA. The USFWS was therefore unable to define a listable entity based on the petition and determined Pacific Lamprey to be ineligible for listing (USFWS 2004).

It is the USFWS's strategy to improve the status of lampreys by proactively engaging in a concerted conservation effort. This collaborative effort, through the development and implementation of the Pacific Lamprey Conservation Initiative (PLCI) initiated in 2004, will facilitate opportunities to address threats, restore habitat, increase our knowledge of Pacific Lamprey, and improve their distribution and abundance in the United States portion of their range. The approach of the PLCI is to use the best scientific and empirical information available to assess current issues affecting the viability of Pacific Lamprey throughout its range in the western United States, to resolve knowledge gaps that limit our ability to conserve the species and to identify the specific conditions that must be addressed in order to conserve both regional and local populations. This document reviews risks identified in the Assessment and Template for Conservation Measures in California (Goodman and Reid 2012, USFWS 2019, Boyce and Reid 2022) and updates earlier implementation plans (Goodman and Reid 2015), including completed, ongoing and proposed implementation actions to aid in conservation of the species. These documents do not represent analyses required by the Endangered Species Act to determine if a species is warranted for listing as a threatened or endangered.

The Assessment and Template for Conservation Measures in California includes introductory chapters describing the overall assessment and conservation strategy of the PLCI, general biology of and threats to Pacific Lamprey, and methodology. Successive chapters focus on Pacific Lamprey in the California Region as a whole and in seven specific geographic subregions (Regional Management Units - RMU's) within California. Each RMU is further examined at the watershed level, using 4th field Hydrologic Unit Code watersheds (HUC). Habitat conditions, population status and threats are evaluated for each HUC. The demographic information and identified threats were then used to qualitatively assess the relative risks of extirpation for Pacific Lamprey within each HUC using a NatureServe Assessment Model.

Implementation Plans

We use the combined results of viability and threats assessments in the California Assessments, review of available literature, site visits, the authors' experience with lampreys and discussions with stakeholders to develop implementation plans for each of seven RMU's (Figure 2, Appendix A); identifying conservation efforts, knowledge gaps and implementation projects that we believe will reduce risks to Pacific Lamprey within each RMU and its HUCs, thereby promoting conservation and management of the species range-wide.

Regional Conservation Strategy

The California regional conservation strategy uses the combined results of the viability and threats assessments in the 2012, 2018 and 2022 California Assessments to develop implementation plans for each Regional Management Unit (RMU). These plans will identify specific conservation efforts, knowledge gaps and key implementation projects that we believe will reduce risks to Pacific Lamprey within

each of California's seven RMU's and their component HUC watersheds, thereby promoting the conservation and management of Pacific Lamprey both locally and range-wide. They are intended to provide a tool to managers and conservation biologists to guide conservation efforts, prioritize projects, and monitor progress. Ultimately, the various subregional plans will be incorporated into a regional plan for the whole of California and coordinated with implementation efforts in other regions.

Our current understanding of the biology and conservation needs of the Pacific Lamprey is relatively limited. Unlike western salmonids, which have long commercial management histories and have been extensively studied, little attention has been given to Pacific Lampreys in the past. Therefore, key conservation needs include the incorporation of lampreys into existing conservation and restoration projects, education of stakeholders and the general public, as well as filling major gaps in our basic understanding of their life history, distribution, behavior, habitat utilization and sensitivity to environmental factors such as temperature, flow regimes, and eutrophication. Nevertheless, it is also a primary goal of this implementation strategy to move forward with prioritized on-the-ground projects and recognized conservation needs that can be rapidly addressed over the next five year to directly benefit Pacific Lamprey. Crucial to the success of this strategy is the collaboration of multiple and diverse stakeholders working together proactively to promote the conservation of a keystone species integral to the health and ecological function of western rivers. Both the Conservation Assessments and Implementation Plans are intended as living documents that will be updated as we develop new information and understanding of lamprey conservation status and as implementation progresses. Already, many of the proposed implementation projects from earlier plans have been initiated or are well underway. It is our goal to continue this progress.

Implementation Planning - Methodology

The initial phase of this implementation planning was assessment of population status and identification of threats within individual 4th field Hydrologic Unit Code watersheds (HUCs) through the 2012, 2018 California Assessment process (Goodman and Reid 2012, USFWS 2019). These results are incorporated into the implementation plans, where they serve to prioritize populations of particular concern and specific threats that need to be addressed by proposed implementation actions. The results of the 2012, 2018 and updated 2022 California Assessments are summarized herein, but the Assessments contain additional detail and background for the reader, including introductory chapters describing the overall assessment and conservation strategy of the PLCI, general biology of and threats to Pacific Lamprey, and methodology. Successive chapters focus on Pacific Lamprey in California as a whole and in specific geographic subregions, describing conditions, population status and threats at the watershed level. The demographic information and identified threats were then used to qualitatively assess the relative risks of extirpation for Pacific Lamprey within each watershed using a NatureServe Assessment Model (see Reid and Goodman (2012; USFWS 2019, Boyce and Reid 2022).

Collaborative stakeholder discussions and site visits were held in each HUC to seek out local experience, conservation concerns and suggestions for information needs and conservation actions (see Figure 2 and Appendix A for stakeholder discussions and workshops). Outreach and information gatherings included multiple stakeholder discussions or workshops and included over 200 different stakeholders. Stakeholder discussions also provided an opportunity to increase collaboration, raise general awareness and promote participation in lamprey conservation, as well as to inform the PLCI team of ongoing conservation actions in local watersheds.

The development of specific information needs and actions to be incorporated into the present implementation plan was guided by the 2012, 2018 and 2022 threat assessments and drew upon various sources of information, including review of available literature, site visits, the authors' experience with lampreys across California and discussions with local stakeholders. For each recognized threat, actions were developed that would specifically address that threat, or would provide information needed for further assessment and development of mitigation measures. Final development of proposed actions incorporated the results of stakeholder meetings, workshops, ongoing conversations with stakeholders and local biologists, site visits, and the experience of the PLCI team. The principal goal of the implementation plans is to identify specific conservation efforts, knowledge gaps and key implementation projects that we believe will reduce risks to Pacific Lamprey within each RMU and its component watersheds (HUC). However, there were also certain conservation efforts that are universal within the RMU, and often the broader region as well. These include outreach, education coordination and incorporation of lampreys into existing aquatic conservation efforts, as well as basic research into aspects of lamprey life-history that directly relate to their conservation needs.

All proposed actions and conservation needs were entered into an implementation database that incorporates:

1) Information on the threat addressed,
2) Description of the action and its rationale,
3) Scale and location of the action,
4) Prioritization factors,
5) Feasibility factors,
6) Additional benefits of the project, and
7) General status and details of the project.

Actions are grouped into the following categories:

1) Assessment - assessment of potential threats or project needs.
2) Coordination - including, outreach, collaboration and incorporation of lampreys into existing conservation efforts.
3) Research - information needs that directly relate to their conservation needs or are needed to assess general threats.
4) Survey/monitor - distribution of lampreys, suitable habitat, monitor populations or mapping of point threats (e.g. diversions, barriers).
5) Instream/on-the-ground projects

See Appendix B for specific fields and details of the database structure.

Prioritization of conservation actions is facilitated through the implementation database by inclusion of separate factors that may guide selection of individual projects. Priorities will be influenced by such factors as the specific needs of Pacific Lamprey in an area (region or HUC), the level of threat addressed (scale, scope or severity), habitat gained, specific funds available, capabilities of participants, and stakeholder or program goals. Therefore, actions in the database were not prioritized explicitly, allowing for flexibility to accommodate a broad suite of applications. Instead, a framework is provided with a series of factors ranked independently that may contribute to a prioritization scheme. Factors evaluated for each action include the scope, scale and severity of threats addressed, effectiveness in addressing the threat, and quantity of habitat gain. These factors may be used in combination to guide strategic conservation measures in a variety of implementation scenarios.

The implementation database is intended as a living document that evolves with our understanding of threats to Pacific Lamprey, their conservation needs and the status of specific conservation projects. It is intended to provide a tool to managers and conservation biologists to address the specific needs of Pacific Lamprey, guide conservation efforts, prioritize projects and monitor progress. See Appendix C for proposed implementation tasks and contact information.

Figure 1. Map of seven California Regional Management Units (RMUs).

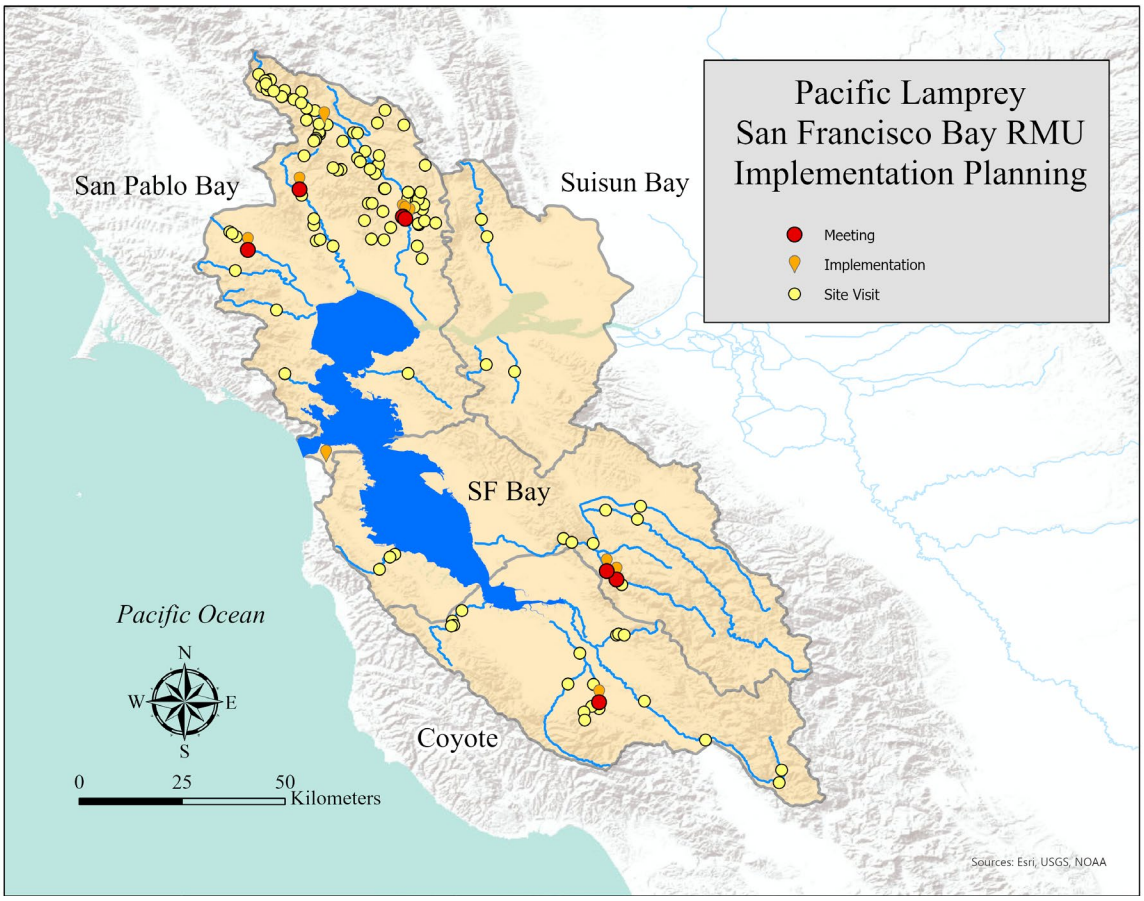

Figure 2. Map of stakeholder discussions, workshops, and site visits that informed the development of the San Francisco Bay implementation plan.

San Francisco Bay RMU - Status and Distribution of Pacific Lamprey

The San Francisco Bay Subregion 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 coastal subregions (Figure 3, Table 1). It includes four broader watersheds (4th field HUCS), ranging from 1,695−3,171 km^2 (Table 1). The subregion occupies the Central Californian Chaparral / Oak Woodlands ecoregion. The population status and distribution of Pacific Lamprey in the San Francisco Bay RMU are reviewed below and in Table 2 (adapted from 2012 Assessment with current information).

Historical Range Extent

Pacific Lamprey are assumed to have been widely distributed and abundant historically in the larger San Francisco Bay streams, except perhaps in the higher gradient reaches of small or seasonal tributaries, based on historical records, current distribution, available habitat and lack of natural barriers. However, review of historical collections from San Francisco Bay drainages finds no vouchered historical records in streams < 225 km^2, in spite of a long history of scientific collections (Table 1; Leidy 2007). A similar pattern was found along the California coast, where

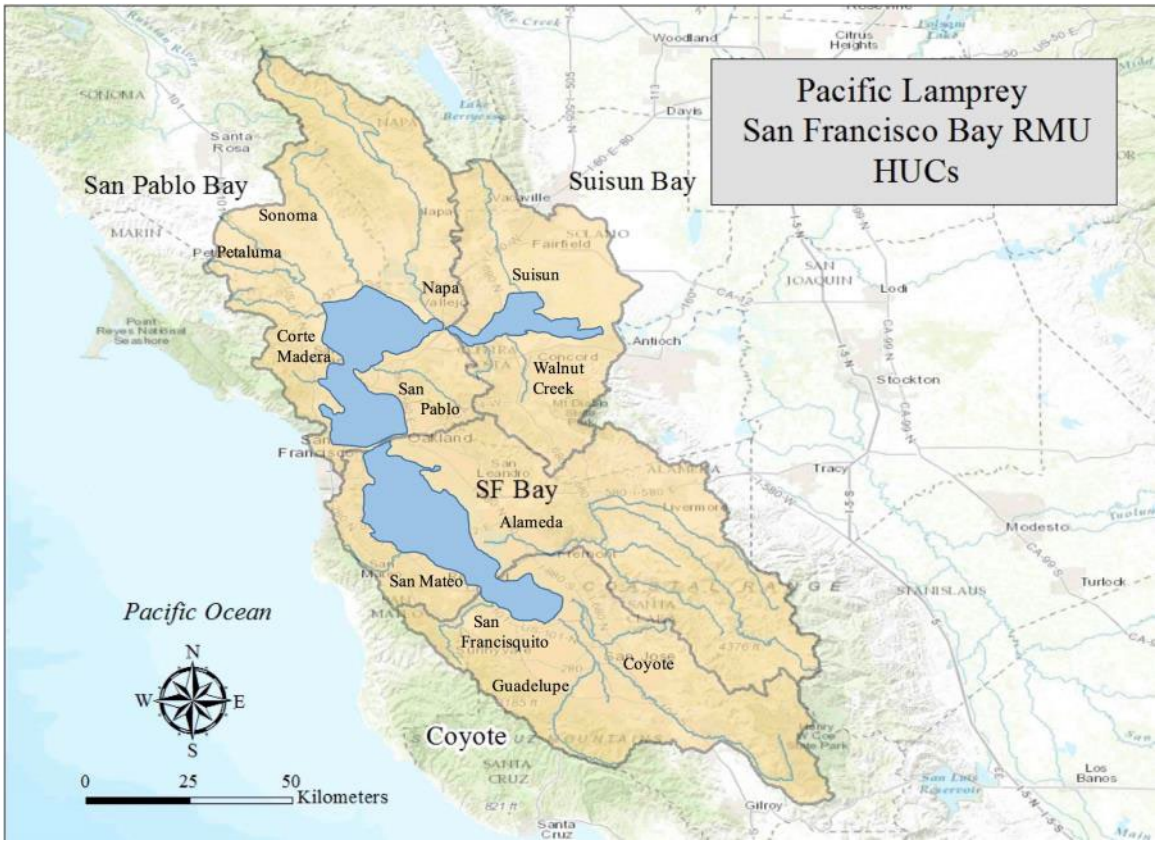

Figure 3. Map of the San Francisco Bay Regional Management Unit (RMU) and its watersheds (4th field HUCs). Drainages mentioned in the text and tables are labeled.

Pacific Lamprey were found in all drainages > 100 km^2, irregularly in drainages from 50-100 km^2, and in only three drainages < 50 km^2 (Reid and Goodman 2016). The evidence suggests that there is little, if any, use of smaller coastal drainages (< 25 km^2) that directly enter the sea. The factors causing Pacific Lamprey not to use smaller coastal streams is not known, but may include lack of sufficient attraction flow, intermittent connection to the ocean, insufficient rearing habitat or inconsistent hydrology (Shapovalov and Taft 1954; Reid and Goodman 2016).

Historical freshwater records support Pacific Lamprey presence in only seven drainages (all ≥ 225 km^2): Sonoma, Napa, Pacheco (Walnut-San Ramon), Alameda, Coyote, Guadalupe and possibly Suisun drainages (Table 1). There are unvouchered reports from the Suisun Drainage of "juvenile" lamprey noted by CDFW from 1975 in Green Valley Creek, and reports by residents of lampreys in Suisun Creek, also noted by CDFW in 1980 (Leidy 2007). There is an additional record of lamprey collected from Green Valley Creek in 1998 that we have not examined (UCD-001-01-25). At this time, identification to species is not possible, however these records do confirm the historical suitability of available habitat for lampreys in the Suisun Drainage. Leidy (2007) also lists Pacific Lamprey as present in the Petaluma River, but does not mention the drainage in his historical or current species accounts for lampreys. We also found no historical records and did not encounter lampreys in recent surveys.

There are two records for lampreys that appear to be estuarine and are not likely related to reproductive populations in their respective freshwater drainages. The first is a record from "San Mateo" in 1860 (MCZ-25124, high quality photos examined). However, it is a small immature adult (300mm TL), and could be in feeding stage from the bay or a very small in-migrating adult, based on the separation of the dorsal fins (ca. 2.5 cm separation). It is not clear whether it was caught in freshwater or the estuary. The second is a 147mm macropthalmia, apparently from San Rafael Bay (SU 8475; listed under Corte Madera Watershed in Leidy 2007). We did not encounter lampreys in recent surveys of both streams.

We consider all streams with drainage areas greater than 100 km^2 to have been potentially occupied in the past. San Mateo Creek (86 km^2) is excluded from this calculation, in spite of the possible 1860 record, due to its size and the drainage has been blocked 5 miles from the estuary by the impassable Crystal Springs Dam since 1888. It is possible that lampreys utilized smaller drainages in the past, but we have not identified any record of them. Additionally, the occupancy pattern in San Francisco Bay streams aligns with the minimum drainage size where lampreys are found in coastal streams (Reid and Goodman 2016).

Table 1. Historical records and current presence in San Francisco Bay RMU drainages. Historical records and current presence are indicated with “P”. Drainages where recent surveys by the authors found no Pacific Lamprey are marked with an "x". Asterixes ("*") are uncertain records discussed in text.

Historic Record	Current Presence	Area Km^2	Drainage
Suisun HUC			
P	P	374	Pacheco (Walnut) Creek
*	*	225	Suisun Creek
-	-	85	Mount Diablo Creek
-	x	62	Arroyo del Hambre
San Pablo HUC			
P	P	977	Napa River
P	P	362	Sonoma Creek
*	x	326	Petaluma River
-	x	106	San Pablo Creek
-	x	61	Novato Creek
-	x	48	Corte Madera Creek
San Francisco HUC			
P	P	1,693	Alameda Creek
-	-	120	San Lorenzo Creek
-	x	118	San Leandro Creek
*	x	86	San Mateo Creek
Coyote HUC			
P	P	938	Coyote Creek
P	2002	423	Guadalupe River
-	x	120	San Francisquito Creek
-	-	107	San Tomas Aquinas Creek
-	-	102	Calabazas Creek
-	-	63	Permanente Creek
-	-	54	Stevens Creek

Current Occupancy

Pacific Lamprey currently occupy anadromous, habitat in most of the same larger streams entering San Francisco and San Pablo bays where they were found in the past (see above). However, their distribution is generally limited to the mainstems and major tributaries. Recent surveys targeting lampreys substantiate their absence in smaller streams. Although adult Pacific lampreys were observed in Guadalupe Creek in the early 2000's (M. Moore, Santa Clara Water District, pers. com. 2016), no adults have been seen in the Guadalupe or its tributary Alamitos Creek since 2002 (Leidy

2007, R. Castillo, pers. com. 17 January 2017), and no ammocoetes were found in recent surveys (Reid and Goodman, unpub data, Figure 2). Adult Pacific Lamprey may also have been observed in Los Gatos Creek (tributary to the Guadalupe) in the early 2000's by local citizen naturalists (L. Johmann, pers. com. 16 August 2016; R. Castillo, pers. com. 22 August 2016). In Suisun Bay, limited surveys of Suisun Creek in 2013 did not encounter ammocoetes, however additional effort is warranted (Reid, unpubl. data, Figure 2).

The primary constraints on the distribution of the species in currently occupied drainages are large dams on the mainstems or major tributaries, instream structures, seasonal reaches, sediment anoxia, and lack of suitable rearing habitat in moderate to higher gradient tributaries (Goodman and Reid 2012; USFWS 2019).

Ratio of Current Occupancy to Historical Range Extent

On the whole, the broader San Francisco Bay subregion has seen moderate loss of historical distribution by obstruction of passage in some drainages (Table 2). The apparent recent disappearance of Pacific Lamprey from the Guadalupe drainage, based on recent ammocoete surveys by the authors and lack of adult sightings by community observers, suggests further contraction in the absence of changes caused by passage constraints (e.g. dams and instream structures). It is not known whether this represents a permanent loss from the system or a temporary state caused by recent drought conditions or other habitat modifications.

Population Size

Population size (adults) in the subregion, similar to all other areas, is poorly understood and not formally monitored. The only relative certainty is that populations have declined substantially, as they have throughout the range (Goodman and Reid 2012; USFWS 2019; Reid and Goodman 2016).

Short Term Trend

Declines within occupied HUCs inside the Golden Gate may be similar to those in coastal Californian RMU's, as well as the Oregon Coast at Winchester Dam on the North Fork Umpqua River (Goodman and Reid 2012). However, the lack of monitoring of adult migrations makes any quantification of population trends impossible. Again, the apparent recent disappearance of Pacific Lamprey from the Guadalupe drainage, based on recent ammocoete surveys by the authors and lack of adult sightings by community observers, suggests further contraction in the absence of changes in passage constraints (e.g. dams and instream structures). It is not known whether this represents a permanent loss from the system or a temporary state caused by recent drought conditions or other habitat modifications.

NatureServe Risk Ranks

NatureServe risk ranks varied from imperiled to vulnerable (S2-S3). Populations in all HUCs are subject to metapopulation declines caused by regional threats outside the watershed. See discussion of threats below.

Table 2. Conservation Status Ranks and Population demographics in the 4th Field watersheds (HUC) in the CA San Francisco Bay Region. Note that historical and current occupancies are linear stream distances (4th order and above), reflecting improved distribution data since the 2012 Assessment. Principal occupied drainages for each watershed are in parentheses**.** NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure. Adapted from the 2018 Assessment (USFWS 2019); note an updated assessment is expected in late 2022.

Watershed	Conservation Status Rank	Historical Occupancy (km)	Current Occupancy (km)	Ratio Current/ Historical	Population Size (adults)	Short-Term Trend (% Decline)
Suisun Bay (Pacheco)	S1	79	65	0.82	Unknown	50 - 70%
San Pablo (Napa/Sonoma)	S2	122	122	1	Unknown	50 - 70%
Coyote (Coyote/Guadalupe)	S2	174	147	0.84	Unknown	50 - 70%
San Francisco (Alameda)	S2	207	169	0.82	Unknown	50 - 70%

San Francisco Bay RMU - Threats and Limiting Factors to Pacific Lamprey

Threats and limiting factors to Pacific Lamprey in the San Francisco Bay RMU are provided in Table 3 for the principal five threats, also discussed below. The remaining threat categories were either of low risk throughout the RMU or were not considered in this assessment as a whole due to lack of information (see discussion under Goodman and Reid 2012, Chap. 4 - California Regional Summary: Small Population Size, Disease, Lack of Awareness, Ocean Conditions, and Climate Change). Populations in all HUCs are subject to metapopulation declines caused by regional threats outside the watershed.

The primary threats in the San Francisco Bay RMU were water quality (including anoxic substrate conditions), dewatering and passage. Most threats were ranked at high to moderate, with no severe threats in any HUCs.

Passage (dams, culverts, water diversions, tide gates, other barriers)

Major barriers to passage were found in most historically occupied drainages. In the Walnut Creek drainage (Suisun HUC), Walnut Creek is blocked 18 km from the mouth by a 15' drop structure and San Ramon Creek is blocked 4.3 km from its confluence with Walnut Creek, apparently blocking access to the rest of the drainage. The only major barrier in the Napa and Sonoma drainages (San Pablo HUC) blocking substantial suitable habitat is the dam on Conn Creek (Napa), blocking about 40 km of historically inhabited tributary habitat. Passage on Alameda Creek (San Francisco HUC) is substantially impeded low in the drainage at the Bart Weir by an inflatable dam (ACWD Rubber Dam #1) and further upstream by a second temporal inflatable dam (ACWD Rubber Dam #3). Fish ladders are in construction phases for both.

There are also three major dams in the system blocking tributaries (Calaveras, San Antonio, Laguna del Valle), although it is unclear how suitable upstream habitat would be, due to higher gradients and seasonal flow patterns. Smaller drainages in the San Francisco RMU (San Lorenzo, San Leandro and San Mateo) all have major dams blocking passage relatively low in the drainages. In the Coyote HUC, Coyote Creek itself is completely blocked by a series of major dams, starting at RKM 30. Guadalupe Creek and its tributaries are blocked by dams higher in their drainages, which may not be blocking much suitable habitat upstream, but there are also a number of smaller instream structures in the lower reaches of Guadalupe, Alamitos and Los Gatos creeks that will need to be assessed. San Francisquito, a smaller drainage (120 km^2) without historical records, also has a major dam (Searsville) blocking much of its drainage.

Table 3. NatureServe risk ranks, maximum threat level and principal threat rankings for Pacific Lamprey within the San Francisco Bay RMU, grouped by major drainages. NatureServe ranks: SX, Extinct; SH, Believed extinct; S1, Critically imperiled, S2, Imperiled, S3, Vulnerable, S4 Apparently secure, and S5. Maximum threat ranks: X, Extinct due to dams (prior to 1985); and A to H, substantial and imminent threat to unthreatened. Individual threat rankings for Scope and Severity: 1 to 4, Insignificant to High; U = Unknown Secure. Adapted from the 2018 Assessment (USFWS 2019); note an updated assessment is expected in late 2022.

			Individual Threats (Scope - Severity)				
Watershed	**Risk Rank**	**Maximum Threat**	**Passage**	**Dewatering /Flow**	**Stream Degradation**	**Water Quality**	**Predation**
Suisun Bay	S2	C	3 - 3	3 - 3	3 - 3	4 - 2	3 - 3
San Pablo Bay	S3	C	1 - 3	3 - 3	3 - 2	4 - 2	3 - 3
San Francisco Bay	S2	B	3 - 4	3 - 3	3 - 3	4 - 3	3 - 3
Coyote	S2	B	3 - 3	3 - 3	3 - 3	4 - 3	3 - 3

Dewatering and Stream Flow Management (reservoirs, water diversions, instream projects)

Dewatering of streams (anthropogenic), resulting in reduced summer flows, is ranked as moderate in scope and severity throughout the San Francisco Bay RMU due to urbanization, extensive agriculture (e.g. viticulture) and groundwater pumping, which has become more common. Although lampreys are primarily using the mainstems and larger tributaries groundwater pumping, surface diversions and small pumps exacerbate naturally arid summer conditions making smaller streams generally unsuitable for year-round rearing. Water storage reservoirs also reduce available flow and artificially manage winter and spring flow events, reducing flow events that are crucial for outmigration of macropthalmia (Goodman et al. 2015).

Stream and Floodplain Degradation (channelization, loss of side channel habitat, scouring)

Stream degradation was generally ranked as moderate in scope and severity, primarily due to widespread channelization and down-cutting, as well as active channel constraint in urban areas. Channelization increases the energy of higher flows and reduces both habitat diversity and development of suitable depositional habitat for rearing ammocoetes.

Water Quality (Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source)

Water quality issues were generally ranked as widespread and moderate in severity throughout the RMU. Low summer flows and urban runoff result in high temperatures and nutrient levels, with low oxygen levels in summer refuge areas used by both adult lampreys and ammocoetes. Both agricultural and urban runoff may also be contributing to a high contaminant level in streams and sediments. The specific effects of most of these factors on lampreys is not known, however high temperatures and low oxygen in holding areas is a known cause of summer mortality.

Predation

Illegal capture and consumption of lampreys by the large urban homeless populations, particularly in southern bay tributaries (Alameda, Coyote and Guadalupe) has emerged as a potential, but as yet unassessed, threat (GCRCD 2005).

Predation by natural wildlife is not considered a major threat in most San Francisco Bay streams, although non-native predatory fishes are common in the mainstems and reservoirs (incl. basses, sunfishes, carp and various catfishes). The impact on local populations is not known, but was not generally considered a major threat to lamprey populations and may be ameliorated by the generally nocturnal activity patterns of lampreys and downstream migration during periods of high flow and turbidity. Sacramento Pikeminnow *Ptychocheilus grandis* are present in larger mainstems but are native. Seals and sea lions are known to feed on migrating runs of adult lampreys near the mouths of rivers, as do eagles and ospreys. However, the nature or severity of pinniped predation in San Francisco Bay has not been assessed. Predation threats were ranked as Unknown, although they are proposed for assessment.

San Francisco Bay RMU – Implementation Plan

This plan is intended to identify conservation efforts, knowledge gaps and implementation projects that will reduce risks to Pacific Lamprey within the San Francisco Bay RMU and its component HUCs, thereby promoting the conservation and management of the species range-wide. A summary of the implementation-specific segment of the plan is provided below, with details available in the Implementation Database (Appendix C).

General Conservation Needs within the North Central Coast RMU

There are some general conservation needs that pertain to all HUCs within the San Francisco Bay RMU. These include coordination efforts (outreach, education, and incorporation of lampreys into existing aquatic conservation efforts), as well as basic research into aspects of lamprey life-history that directly relate and are applicable to their conservation needs region-wide. There are also common needs for distribution surveys, population monitoring, habitat assessments and barrier mapping.

Coordination

As in most of the region, the lack of awareness, understanding, and consideration of lampreys by the general public, resource managers and restoration projects in the San Francisco Bay RMU has resulted in the conservation needs of Pacific Lamprey being ignored or actively imperiled. A major goal of the PLCI implementation is to increase awareness of Pacific Lamprey, attract more participation by stakeholders, and promote consideration of its conservation needs by providing outreach, training and local education to stakeholders, resource managers, and community members.

A specific regional focus is proposed for coordination with other passage stakeholders (e.g., ACWD, EBMUD, SFPUC, SCWD, CalTrans, CDFW, local municipalities, landowners and USFWS) to ensure lamprey needs are considered in existing passage structures, as well as current and future projects. Passage obstruction has been identified as one of the primary threats to Pacific Lamprey region-wide, isolating over 40% of potential anadromous habitat and eliminating the ecological role of Pacific Lamprey in reaches above barriers. Furthermore, active passage programs/projects focusing on salmonids often ignore the needs of or actively block lampreys due to their design and/or management (Goodman and Reid 2017).

A specific regional focus is also proposed for increasing awareness of adverse impacts caused by surface diversions, groundwater pumping and seasonal desiccation. Water withdrawals reduce flows or dewater smaller tributaries and some mainstem rivers. Even a short-term loss of surface flow is lethal to over-summering adults and resident ammocoete populations and may result in the local loss of up to seven year classes. Higher temperatures caused by lower flows and increased nutrient loading promote algal blooms in mainstem rivers that further degrade habitat used by over-summering adults and ammocoetes, which cannot tolerate anoxic conditions in the sediment or water column. Much of the impacted habitat is in lower stream reaches generally not considered as summer habitat for protected salmonids and therefore not managed to higher standards.

General research needs

Passage: Although passage obstruction is identified as a primary threat to Pacific Lamprey region-wide, there is limited information on how lampreys move past barriers or how to design instream structures to facilitate lamprey passage. Therefore, a number of basic research goals will investigate and develop designs or management

approaches for passage at culverts, low-head dams or weirs, and fish ladders. Other projects include investigation of entrainment risk from small-scale (<4") unscreened pumping stations and development of downstream passage/screening criteria for ammocoetes and emigrating juveniles.

Ammocoete habitat: Ammocoetes are highly dependent on the habitat provided by fine sediments during their 5–7 year instream development. We know little about fine-scale habitat selection by ammocoetes, nor about the effect of sediment conditions on ammocoete populations or system carrying capacity. Therefore, a number of basic research goals will investigate sediment habitat needs of ammocoetes, the role of temperature and dissolved oxygen levels in sediment habitat quality, the impact of eutrophication and associated algal development on sediment conditions, and mitigation measures for use during in-water projects to reduce mortality of ammocoetes.

Adult holding habitat: A common life history pattern is for adult lamprey to hold over in freshwater streams and rivers during the summer/winter and spawn the following spring. Observations of dead adults in summer months, outside the expected spawning period, may be indicative of pre-spawn mortality caused by high water temperatures and low dissolved oxygen (DO) during the holding period. Research is proposed to determine thermal and DO tolerances for adult lamprey during the summer holding period.

Due to our limited understanding of the specific distribution and population dynamics of Pacific Lamprey, distributional surveys of ammocoetes, adult spawning areas, and over-wintering habitat, as well as adult population surveys, population monitoring and assessment of emigration timing for macropthalmia are recommended for each occupied HUC. Although the need for these surveys are common to all occupied HUCs, they are specified individually for each HUC in the database due to differences in threat level, stakeholders and project development, and to facilitate progress monitoring within individual HUCs.

Similarly, general survey and assessment of potential instream barriers (including low-head dams, diversions and culverts) is recommended for all HUCs to assess and prioritize conservation needs related to lamprey passage and/or entrainment.

Below are brief summaries of principal implementation needs and proposed projects in each of the San Francisco Bay HUCs. Details are available in the Implementation Database.

Suisun Bay

The two principal occupied drainages in the Suisun Bay HUC are Pacheco-Walnut Creek (374 km^2) and the Suisun-Green Valley Creek (225 km^2) drainages. The remainder are smaller ($\leq$ 85 km^2) and often seasonal without historical records of lampreys.

The primary concerns in the HUC are passage barriers, water quality and substrate conditions in the Walnut Creek drainage (Figure 4). The north-side drainages (Suisun and Green Valley Creeks) have not been specifically assessed for lampreys or their habitat needs.

Figure 4. Walnut Creek drop structure (10') at RKM 11, just north of Highway 242 and south of Willow Pass Road, showing late summer flow conditions (August 2012). Note dense algal and aquatic macrophyte growth indicative of high nutrients, low flow and warm temperatures that may result in low oxygen levels.

San Pablo Bay

The two principal occupied drainages in the San Pablo Bay HUC are the Napa (977 km^2) and Sonoma (362 km^2) drainages. The Petaluma Drainage (326 km^2) is relatively large, however the majority of the mainstem is estuarine and seasonal above tidal influence. Recent surveys identified little suitable habitat for lampreys, and there are no historical records from freshwater in the drainage. San Pablo Creek (106 km^2), an unoccupied drainage on the east side of the bay, has the majority of its watershed blocked at RKM 14 by an impassable earthen dam built in 1919. The remainder are smaller ($\leq$ 61 km^2) and often seasonal without historical records of lampreys.

The primary concerns in the HUC are seasonal channel desiccation and water quality issues in the mainstems and lower reaches of principal tributaries; passage issues are relatively limited in Napa and Sonoma and are generally being addressed where feasible (Figure 5). Hennessy Dam blocks historical habitat upstream in Conn Creek.

Figure 5. The Greenwood Road culvert was initially identified as a total barrier to Pacific Lamprey on mainstem Napa River, although resident brook lamprey occur upstream, indicating habitat suitability. The culvert was removed in 2015 by NRRCD and replaced by a bridge, opening access to 2.75 mi of habitat below Kimball Canyon Dam.

San Francisco Bay

This HUC contains a single occupied drainage, Alameda Creek (1,693 km^2), the largest in the San Francisco RMU. Two additional East Bay drainages with original watersheds > 100 km^2 are currently unoccupied and lack historical records. San

Lorenzo (120 km^2) is blocked by a number of dams on the mainstem and tributaries, as well as by concrete channels where it passes through urbanized reaches. San Leandro creek (118 km^2) is blocked by a large impassable dam at RKM 8 built in 1875. Both are highly urbanized in their lower reaches. The remainder are smaller (≤ 61 km^2) and often seasonal or urban streams without historical records of lampreys.

The primary concerns in the HUC are providing passage on the mainstem of Alameda Creek and evaluating habitat availability, flow and water quality in the Arroyo de la Laguna sub-drainage. Passage on Alameda Creek (San Francisco HUC) is substantially impeded low in the drainage at the Bart Weir by an inflatable dam (ACWD Rubber Dam #1) and further upstream by a second temporal inflatable dam (ACWD Rubber Dam #3). Fish ladders are in planning and construction phases for both (Figure 6).

Coyote

The two principal occupied drainages in the Coyote HUC are Coyote Creek (938 km^2) and Guadalupe River, including Los Gatos and Alamitos creeks (423 km^2). Three additional intermediate-sized drainages on the San Francisco Peninsula lack current or historical records, however they meet the criteria of drainages > 100 km^2. They are San Francisquito (120 km^2), San Tomas Aquinas (107 km^2) and Calabazas (102 km^2) creeks. The remainder are smaller drainages (≤ 63 km^2) and without current or historical records of lampreys.

The primary concern in the HUC is insuring water management that prevents seasonal channel desiccation and adverse sediment conditions in the mainstems. There are a number of smaller instream structures in the lower reaches of Guadalupe, Alamitos and Los Gatos creeks that should be assessed for passage and resolved if deemed a passage impediment (Figure 7). The impact of local collection of lampreys by the homeless population is unresolved and should be assessed and resolved if posing an active threat.

Figure 6. Providing passage for Pacific Lamprey at the Bart Weir and ACWD Rubber Dam #2 on Alameda Creek is a primary implementation need in the San Francisco Bay HUC (top). This is the lowest major passage barrier on Alameda Creek. A fish ladder is currently in planning and construction phases. Pacific Lamprey were observed attempting to pass the structure during elevated flows in March of 2017, and none were seen make it to the top (bottom; pers. comm. Jeff Miller and Dan Sarka, Alameda Creek Alliance).

Figure 7. The Guadalupe Creek diversion structure located approximately 13 mi upstream of San Francisco Bay. This structure should be assessed for lamprey passage and its potential to serve as a monitoring site.

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Appendices

Appendix A. Stakeholder implementation meetings, discussions and workshops. For map of implementation site visits, see Figure 2.

Meeting Type	Location	Date
2012 Threat Assessment:	Napa	6 Jul 2011
	Napa	3 Apr 12
	Napa	9 May 12
Lamprey summit:	Portland, OR	20 Jun 2012
2015 Implementation planning:	Sunol Park, Alameda Creek	19 Nov 13
	Petaluma - Kashia Pomo Tribe	22 Sep 15
	Fremont, Alameda Creek	10 May 2016
	Napa RCD, Napa River	8 Aug 2016
	San Jose, Coyote/Guadalupe	11 Aug 2016
	Glen Ellen, Sonoma Creek	16 Dec 2016
Stakeholder Discussions:		
Friends of the Napa, community members	Napa	14 Dec 2016

Appendix B. Data fields and criteria / coding used in Implementation tables.

HUC IDENTIFIER

FID - Feature ID ESRI
HUC - USGS Hydrologic Unit Code Levels 1-4
Name - HUC Name (USGS)

THREAT

Threat_Category:

- Passage
- Dewatering/Flow
- StreamDegradation
- Water Quality
- Predation
- Population
- Other

Subcategory- depends on threat category

- T_Scope- from Calif. Conservation Assessment (Goodman & Reid 2012)
- T_Severity- from Calif. Conservation Assessment (Goodman & Reid 2012)
- T_Overall- from Calif. Conservation Assessment (Goodman & Reid 2012)
- Threat- brief description of the threat addressed.

ACTION and RATIONALE

Description- short description of proposed action
Type- type of action proposed

- Assessment - assessment of potential threats or project needs.
- Coordination - including, outreach, collaboration and incorporation of lampreys into existing conservation efforts.
- Research - information needs that directly relate to their conservation needs or are needed to assess general threats.
- Survey/monitor - distribution of lampreys, suitable habitat, monitor populations or mapping of point threats (e.g., diversions, barriers).
- Instream - on the ground projects
- Rationale- rationale for action or benefit to lampreys
- Habitat gain- in linear miles of suitable habitat
- Adult- lifestage addressed (checked)
- Juv- lifestage addressed (checked)
- Larvae- lifestage addressed (checked)

SCALE and LOCATION

Scale- area impacted or addressed by action:

- Point (Lat/Long)
- Stream
- Mainstem
- Watershed
- HUC
- Basin
- Subregion
- Region - CA

Location - description, as specific as possible, depends on scale
Lat - Decimal degrees NAD83
Long - Decimal degrees NAD83

PRIORITIZATION

Scale of threats addressed

4 - Regional: Action addresses threat in >50% of region (action's impact, not overall threat)
3 - Multi-HUC: Action addresses a threat in multiple HUC's (<50% of region)
2 - HUC: Action addresses a threat in a single HUC
1 - Drainage: Action addresses threat within a drainage, reach or site, w/o broader impacts

Scope of threats addressed

4 - High: 71-100% of total population, occurrences, or area affected
3 - Medium: 31-70% of total population, occurrences, or area affected
2 - Low: 11-30% of total population, occurrences, or area affected
1 - Insignificant: <10% of total population or area affected

Severity of threats addressed

4 - High: 71-100% degradation or reduction of habitat/habitat function, and/or 71-100% reduction of population within scope
3 - Medium: 31-70% degradation or reduction of habitat/habitat function, and/or 31-70% reduction of population within scope
2 - Low: <30% degradation or reduction of habitat/habitat function, and/or <30% reduction of population within scope
1 - Unknown or n/a: Severity of threat unknown, or assessment and severity not applicable

Effectiveness of action

4 - High: Removes or causes threat to be insignificant; or provides all information needed to address threat (ie. Assessments, Coord., Research, Survey)
3 - Medium: Substantially reduces threat; or provides substantial information/collaboration
2 - Low: Has some effect on threat, but does not reduce it substantially; or provides minimal information/collaboration

1 - Insignificant: Minimally effective or not targeted at a known threat

Feasibility

Technical difficulty
4 - Simple: Utilizes simple technology or readily achievable methods
3 - Moderate: Moderately complex, but utilizes existing technology and standard methods
2 - Difficult: Requires high level of engineering, assessment, development or multiple stakeholder support development
1 - Unfeasible: Not likely to be possible at this time (5 years) due to excessive technical difficulty or complicated economic or political issues

Duration to implement
4 - Short: 0-2 years
3 - Medium: 3-5 years
2 - Long: > 5 years
1 - Extended: extended time frame or perpetual

Readiness
4 - Underway: Already underway or funded
3 - High: Can be initiated in the next two years.
2 - Medium: Could be initiated in the next 3-5 years.
1 - Low: May take five or more years for additional assessment and planning

Cost
4 - Inexpensive: $ < 10 k
3 - Moderate: $ 10-50 k
2 - Expensive: $ 50-250 k
1 - Very Expensive: $ 250 k - millions

Funding Source
4 - Funded: Funding has been obtained
3 - Identified: Appropriate funding sources identified and likely to participate
2 - Unspecified: Various appropriate funding sources exist but have not been selected
1 - Uncertain: Funding is uncertain

Partner participation
4 - High: All potential stakeholders are supportive
3 - Medium: Necessary stakeholders are supportive
2 - Low: Additional stakeholders need to be incorporated
1 - Problematic: Necessary stakeholders are not supportive

Prerequisites: Brief description of additional actions needed.

Additional Benefits

Prerequisite for other actions: Is action necessary prior to other implementation actions?
1 - Yes

2 - No

Additional benefits

4 - High:	Will have substantial benefits beyond the specific goals of the action (e.g., outreach, technology, precedent setting)
3 - Medium:	Will provide additional benefits to conservation efforts outside the drainage
2 - Low:	Localized benefits to species or stakeholders
1 - Insignificant:	Benefits restricted to action purpose only

Public awareness

4 - High:	High public awareness and positive outreach benefit
3 - Medium:	Increased stakeholder awareness and benefit outside of action area
2 - Low:	Unlikely to come to attention of public outside action area
1 - Insignificant:	Will probably not be noticed by anyone except those carrying out the action

Status

Status

- 'No status'
- Proposed
- Funded
- Underway
- Ongoing
- Completed

Work in Progress:	Brief description of current work underway or completed
Implementing Entity:	Lead entity, and partners
Contact:	Primary contact for threat or action
Cost:	Approximate (this is difficult)
Funding Source:	Current or potential
Funds available:	Percent (%) of total cost
Stakeholders:	Involved/effected parties - not necessarily implementer or funder

Notes:

Appendix C. Proposed implementation tasks and needs - San Francisco Bay.

The Implementation Database is intended as a living document that will be updated as we develop new information and improve our understanding of lamprey conservation status and as implementation progresses and the status of individual projects changes. A current version of the Implementation Database is maintained at the Arcata USFWS Field Office. Interested stakeholders can contact us either for electronic access to the implementation database, to provide updated information or to recommend additional projects.

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Appendix D. Proposed implementation tasks and needs - San Francisco Bay. Listed items include tasks and needs that are general to the state, as well as specific to individual HUC's within the San Francisco Bay RMU.

HUC	Threat Category	Subcategory	Action Description	Type	Status
REGIONAL					
Statewide	Dewatering/ Flow	Dewatering	Investigate ammocoete responses to fluctuating hydrographs.	Research	Ongoing
Statewide	Other	Dredging	Assess dredging impacts to lampreys in California, focusing on the lower Sacramento and San Joaquin rivers.	Assess.	Underway
Statewide	Other	Habitat	Investigate the role of beavers in lamprey life history.	Research	Ongoing
Statewide	Other	Lack of awareness	Provide outreach, training and local education to stakeholders, resource managers and community members.	Coord.	Ongoing
Statewide	Other	Lack of Coordination	Establish Lamprey Working Groups, including active stakeholders.	Coord.	Ongoing
Statewide	Passage	Culverts	Determine how lampreys move through culverts and what culvert characteristics limit passage.	Research	Completed
Statewide	Passage	Culverts	Develop passage criteria for assessments in California Fish Passage Database (PAD).	Research	Completed
Statewide	Passage	Dams, small	Develop design criteria for instream structures encountered by adult lampreys.	Research	Ongoing
Statewide	Passage	Entrainment	Determine entrainment risk from small-scale (<4") unscreened pumping stations.	Research	-
Statewide	Passage	Entrainment	Develop downstream passage/screening criteria for ammocoetes and out-migrating juveniles.	Research	Ongoing
Statewide	Passage	Entrainment	Assess potential risks of entrainment and mitigation strategies for ammocoetes and out-migrating juveniles.	Research	Ongoing
Statewide	Passage	Fish Ladders	Coordinate with other passage stakeholders to insure lamprey consideration in existing passage structures, as well as current and future projects.	Coord.	Ongoing
Statewide	Passage	General	Review PAD to provide new/modified field that are informative for lampreys.	Assess.	Completed
Statewide	Passage	General	Hold a Lamprey Passage Workshop to educate stakeholders on lamprey issues and promote sharing of experience, solutions and perspective.	Coord.	Completed

HUC	Threat Category	Subcategory	Action Description	Type	Status
Statewide	Population	Biology	Examine the role ammocoetes play in in-stream concentration of *E. coli*.	Research	Completed
Statewide	Population	Biology	Evaluate the swimming capability of adult Pacific Lamprey.	Research	Completed
Statewide	Population	Biology	Examine the outmigration of macropthalmia to better understand timing and behavior, especially with relation to environmental cues.	Research	Completed
Statewide	Population	Biology	Examine the role ammocoetes play in stream food webs.	Research	Completed
Statewide	Population	Biology	Determine whether there are individual/population differences in maturity state and timing of in-migrating adult Pacific Lamprey.	Research	Ongoing
Statewide	Population	Distribution	Determine the probably historical range of Pacific Lamprey in California, based on tribal information, post-contact historical records, scientific collections, environmental constraints and natural barriers, as well as evidence from the current distribution.	Research	Completed
Statewide	Population	Distribution	Develop standard methods for ammocoete presence/absence surveys and assess probabilities of detection.	Research	Completed
Statewide	Stream Degradation	Education	Develop ammocoete mitigation measures for use in inwater projects to reduce mortality of ammocoetes.	Research	Ongoing
Statewide	Stream Degradation	Restoration	Assess use and design features from samonid restoration for improvements for lamprey ammocoetes in local restoration projects.	Assess.	-
Statewide	Stream Degradation	Sediment	Determine sediment habitat needs of ammocoetes	Research	Ongoing
Statewide	Stream Degradation	Sediment	Investigate ammocoete habitat needs and ecology.	Research	Ongoing
Statewide	Water Quality	Assessment	Determine impact of eutrophication and associated algal blooms on ammocoetes.	Research	-
Statewide	Water Quality	Assessment	Determine thermal and DO tolerances for adult lamprey during summer holding period.	Research	-
Statewide	Water Quality	Assessment	Determine effects of low DO on ammocoetes in fine-grained depositional rearing habitats.	Research	Ongoing
Statewide	Water Quality	Assessment	Determine effects of temperature on ammocoetes and potential impact of climate change on distribution of Pacific Lamprey	Research	Ongoing
California Coastal	Population	Distribution	Assess historical and current use of small coastal drainages by Pacific Lamprey and explore	Assess.	Completed

HUC	Threat Category	Subcategory	Action Description	Type	Status
			limiting factors that determine distribution.		
California Coastal	Predation	Pinnipeds	Assess impact of pinnipeds on adult lamprey in river mouths	Assess.	Underway
SAN FRANCISCO BAY					
All HUCS	Other	Lack of awareness	Hold a lamprey biology/conservation workshop in the San Francisco Bay area.	Coord.	-
All HUCS	Population	Spawning	Determine migration timing, spawning locations and spawning timing in principal streams.	Research	Underway
All HUCS	Predation	Fishing	Assess the potential threat to lampreys of fishing by the homeless and others.	Assess.	-
Alameda	Passage	Dams, small	Assess passage constraints for lampreys at diversion upstream of Upper Inflatable Dam and develop adaptive improvements, if necessary.	Assess.	-
Alameda	Passage	Dams, small	Assess passage constraints for lampreys at the Lower Inflatable Dam apron develop adaptive improvements, if necessary.	Assess.	Completed
Alameda	Passage	Dams, small	Assess new fish ladder design for lampreys and develop adaptive improvements, if necessary.	Assess.	Underway
Alameda	Passage	Dams, small	Assess passage constraints for lampreys at Upper Inflatable Dam and develop adaptive improvements, if necessary.	Assess.	Underway
Alameda	Passage	Dams, small	Assess passage constraints for lampreys at the pillow dam on Alameda Creek and develop adaptive improvements, if necessary, or remove.	Instream	Underway
Alameda	Passage	Diversions	Assess impact of gravel mine ponds in Alameda Creek for upstream/downstream passage, entrainment and dewatering of nearby reaches.	Survey/ Assess.	-
Alameda	Population	Distribution	Carry out distribution surveys to evaluate presence/absence in the Alameda drainage.	Survey	Completed
Alameda	Population	Distribution	Evaluate habitat and carry out distribution surveys to evaluate presence/absence and habitat suitability in the Arroyo de la Laguna drainage.	Survey	Ongoing
Alameda	Population	Monitoring	Develop a monitoring program and adapt facilities to census lampreys at the Bart Weir fish ladder.	Instream	-
Coyote	Passage	Culverts	Assess and develop solution for passage at the Singleton Road culverts and evaluate value of upstream habitat	Assess.	-

HUC	Threat Category	Subcategory	Action Description	Type	Status
Coyote	Passage	Dams, large	Evaluate removal of the Searsville Dam from the standpoint of lamprey populations.	Assess.	-
Coyote	Passage	Dams, small	Assess passage constraints for lampreys at the Metcalf Diversion and fish ladder; develop adaptive improvements, if necessary.	Assess.	-
Coyote	Passage	Dams, small	Assess passage constraints for lampreys at the Alamitos Percolation Dam and fish ladder; develop adaptive improvements, if necessary.	Assess.	-
Coyote	Passage	Dams, small	Survey fish passage constraints on Coyote Creek (mainstem), below Anderson Dam.	Survey/ Assess.	-
Coyote	Passage	Dams, small	Survey fish passage constraints in the Guadalupe drainage, incl. Guadalupe, Los Gatos and Alamitos mainstems.	Survey/ Assess.	-
Coyote	Passage	Diversions	Investigate and assess habitat suitability and impacts of percolation pond system upstream of Silver Creek Valley Road to Anderson Dam.	Assess.	-
Coyote	Population	Distribution	Carry out distribution surveys to determine upstream extent in streams within the Coyote Creek drainage with consideration of seasonality and access.	Survey	Completed
Coyote	Population	Distribution	Carry out distribution surveys to determine upstream extent in streams within the Guadalupe drainage with consideration of seasonality and access.	Survey	Completed
Coyote	Population	Distribution	Carry out distribution surveys to evaluate presence/absence in the San Francisquito drainage, including above and below Searsville Dam.	Survey	Completed
Coyote	Population	Monitoring	Assess an appropriate site, develop a monitoring program and adapt facilities to census lampreys on Coyote Creek (e.g. Metcalf Diversion and fish ladder).	Instream	-
Coyote	Population	Monitoring	Assess an appropriate site, develop a monitoring program and adapt facilities to census lampreys on the Guadalupe River (e.g. Alamitos Percolation Dam).	Instream	-
Coyote	Water Quality	Assessment	Assess mainstem water management to determine areas where WQ or adverse sediment conditions may be substantially affecting adult holding and/or ammocoete rearing habitat.	Assess.	-
Coyote	Water Quality	Assessment	Assess mainstem water management to determine areas where WQ or adverse sediment conditions may be substantially	Assess.	-

HUC	Threat Category	Subcategory	Action Description	Type	Status
			affecting adult holding and/or ammocoete rearing habitat.		
San Pablo Bay	Dewatering/ Flow	Dewatering	Assess seasonal flow, WQ and habitat permanence in the mainstem Napa River as it relates to ammocoete and adult holding needs.	Assess.	-
San Pablo Bay	Dewatering/ Flow	Dewatering	Assess seasonal flow, WQ and habitat permanence in the mainstem Sonoma River as it relates to ammocoete and adult holding needs.	Assess.	-
San Pablo Bay	Passage	Culverts	Survey Napa River upstream of Greenwood Road to assess effectiveness of project and recolonization by Pacific Lamprey.	Assess.	-
San Pablo Bay	Passage	Culverts	Assess the Dunbar Rd. culvert for lamprey passage and upstream habitat for suitability. Make recommendations if necessary.	Assess.	Completed
San Pablo Bay	Passage	Culverts	Remove/replace Greenwood culvert	Instream	Completed
San Pablo Bay	Passage	Dams, small	Assess the Suttenfield dam and mainstem Sonoma for lamprey passage. Make recommendations if necessary.	Assess.	Completed
San Pablo Bay	Passage	Dams, small	Assess potential PL habitat above Conn Dam and potential for providing passage over dam.	Assess.	Proposed
San Pablo Bay	Population	Distribution	Carry out distribution surveys to determine upstream extent in the Sonoma drainage with consideration of seasonality and access.	Survey	Completed
San Pablo Bay	Population	Distribution	Survey Napa Creek for its full lower reaches and assess for lamprey habitat to determine causal factors if still unoccupied.	Survey/ Assess.	Funded 2022 ?
San Pablo Bay	Population	Habitat suitability	Assess potential PL habitat in Napa Creek, survey for ammocoetes, and assess potential causes, if absent.	Assess.	Proposed
Suisun Bay	Dewatering/ Flow	Dewatering	Assess seasonal flow, WQ and habitat permanence in the mainstem of Walnut Creek as it relates to ammocoete and adult holding needs.	Assess.	-
Suisun Bay	Passage	Dams, small	Assess passage constraints for lampreys at the Bancroft Road drop structure and develop adaptive improvements, if necessary.	Assess.	-
Suisun Bay	Passage	Dams, small	Assess passage constraints for lampreys at the San Ramon drop structure and develop adaptive improvements, if necessary.	Assess.	-

HUC	Threat Category	Subcategory	Action Description	Type	Status
Suisun Bay	Passage	Dams, small	Assess passage constraints for lampreys at the tunnel area and develop adaptive improvements, if necessary.	Assess.	-
Suisun Bay	Passage	Dams, small	Assess passage constraints for lampreys at the Willow Pass Road drop structure and develop adaptive improvements, if necessary.	Assess.	-
Suisun Bay	Passage	Fish Ladders	Assess passage constraints for lampreys at the fish ladder and develop adaptive improvements, if necessary.	Assess.	-
Suisun Bay	Passage	Fish Ladders	Assess passage constraints for lampreys at the fish ladders and develop adaptive improvements, if necessary.	Assess.	-
Suisun Bay	Population	Distribution	Carry out distribution surveys to determine upstream extent in Suisun and Green Valley creeks with consideration of seasonality and access.	Survey	Ongoing
Suisun Bay	Population	Distribution	Carry out distribution surveys to determine upstream extent in streams within the Walnut Creek drainage with consideration of seasonality and access.	Survey	Ongoing