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Regional Implementation Plan for Measures to Conserve Pacific Lamprey (*Entosphenus tridentatus*), California – North Central Coast Regional Management Unit

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Table of Contents

List of Figures

List of Tables

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Acronym List

BLM	Bureau of Land Management
CA	California
CalTrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
ESA	Endangered Species Act
ESRI	Environmental Systems Research Institute
HUC	Hydrologic Unit Code (USGS)
Km	Kilometer
NOAA	National Oceanographic and Atmospheric Administration
PG&E	Pacific Gas and Electric Company
PLCI	Pacific Lamprey Conservation Initiative
RM	River Mile
RMU	Regional Management Unit
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
WQ	Water Quality

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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).

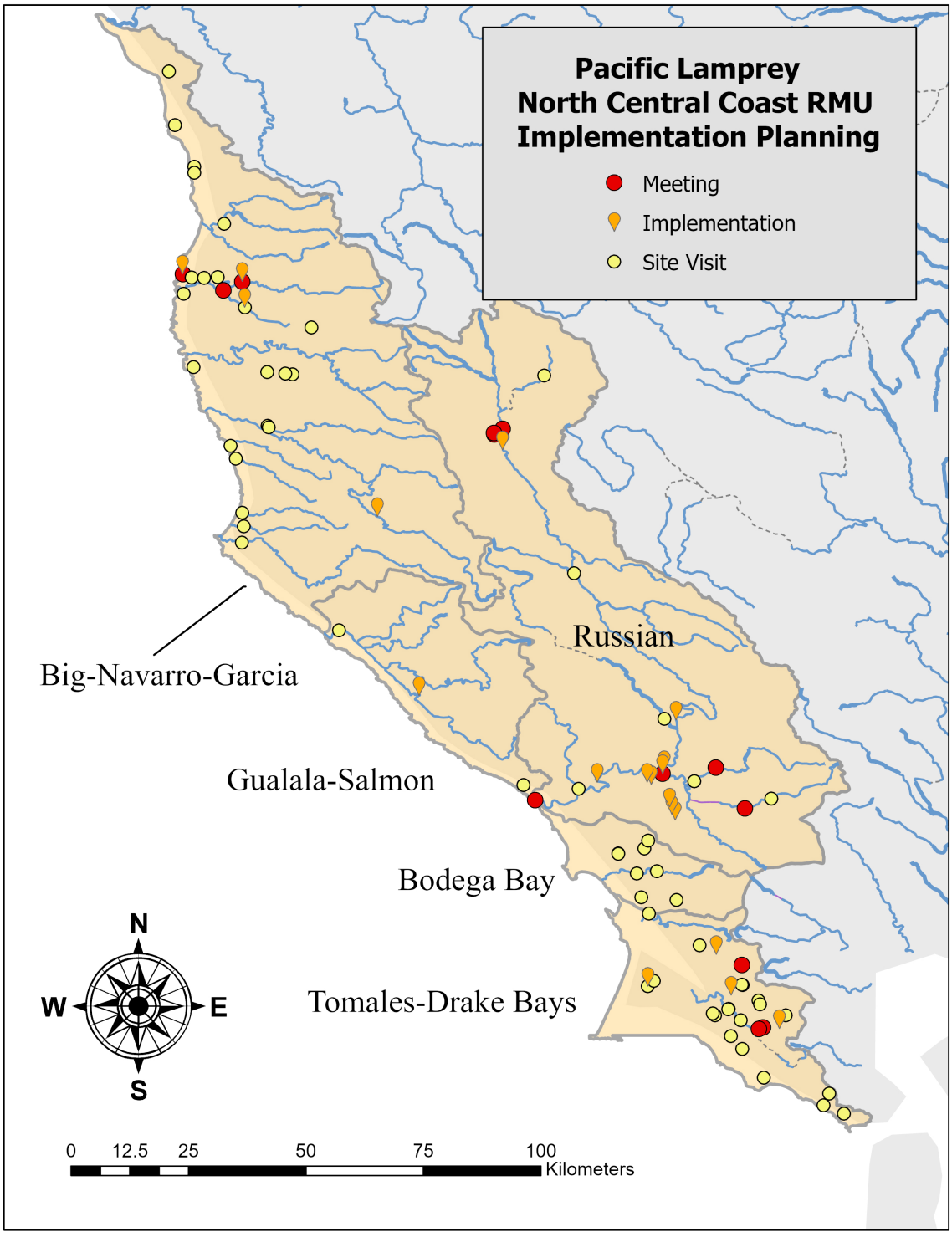

Figure 2. Map of stakeholder discussions, workshops and site visits which informed the development of the North Central Coast implementation plan.

North Central Coast RMU - Status and distribution of Pacific Lamprey

The North Central Coast Subregion includes all coastal drainages from Punta Gorda in the north to the Golden Gate in the south, including the southern half of the Northern California Coast and the outer coast portion of the San Francisco Bay USGS accounting units (Figure 3). It includes five watersheds (4th field HUCS), ranging from 402 - 3,849 km^2 (Table 1). The subregion occupies the Coast Range and Southern and Central Californian Chaparral / Oak Woodlands ecoregions. The population status and distribution of Pacific Lamprey in the North Central Coast RMU are reviewed below and in Table 1 (adapted from 2012 Assessment with current information).

Historical Range Extent

Pacific Lamprey are assumed to have been historically widely distributed and abundant in the North Central Coast drainages, based on historical records, current distribution, available habitat and lack of natural barriers. Smaller coastal drainages entering directing into the ocean were probably not occupied in historical times and may be avoided by Pacific Lamprey (see below).

Current Occupancy

Lamprey currently occupy most anadromous habitat in the subregion north of the Golden Gate, except perhaps the higher gradient reaches of smaller tributaries and smaller coastal streams flowing directly to sea. The primary constraint on their current distribution in occupied drainages are a few large dams (Reid and Goodman 2012). Smaller coastal streams (< 50 km^2 drainage area) in northern California are generally not occupied, and there is evidence that there may be a natural tendency of lamprey to avoid smaller drainages that directly enter the sea (Reid and Goodman 2016). This may have been the case prior to the 1960's as well (Shapovalov and Taft 1954).

Ratio of Current Occupancy to Historical Range Extent

On the whole, the North Central Coast has seen relatively little loss of historical distribution by obstruction of passage. Dams block < 10% of historical habitat.

Population Size

Population size (adults) in the subregion, similar to all other areas, is poorly understood and not formally monitored. Video monitoring of adults in the Russian River has been initiated at Wohler Dam. a seasonal inflatable diversion dam (2000-2015); however, timing of observations, incomplete coverage of potential passage routes, changes in protocol and seasonality result in highly variable effectiveness. The maximum count was 580 adults in 2007 and represents a very conservative minimum population size estimate (Sonoma County Water Agency, unpub. data). Aside from these counts, there is no formal monitoring of lampreys in the subregion, and these estimates represent a very rough minimum count. The only relative certainty is that populations have declined substantially.

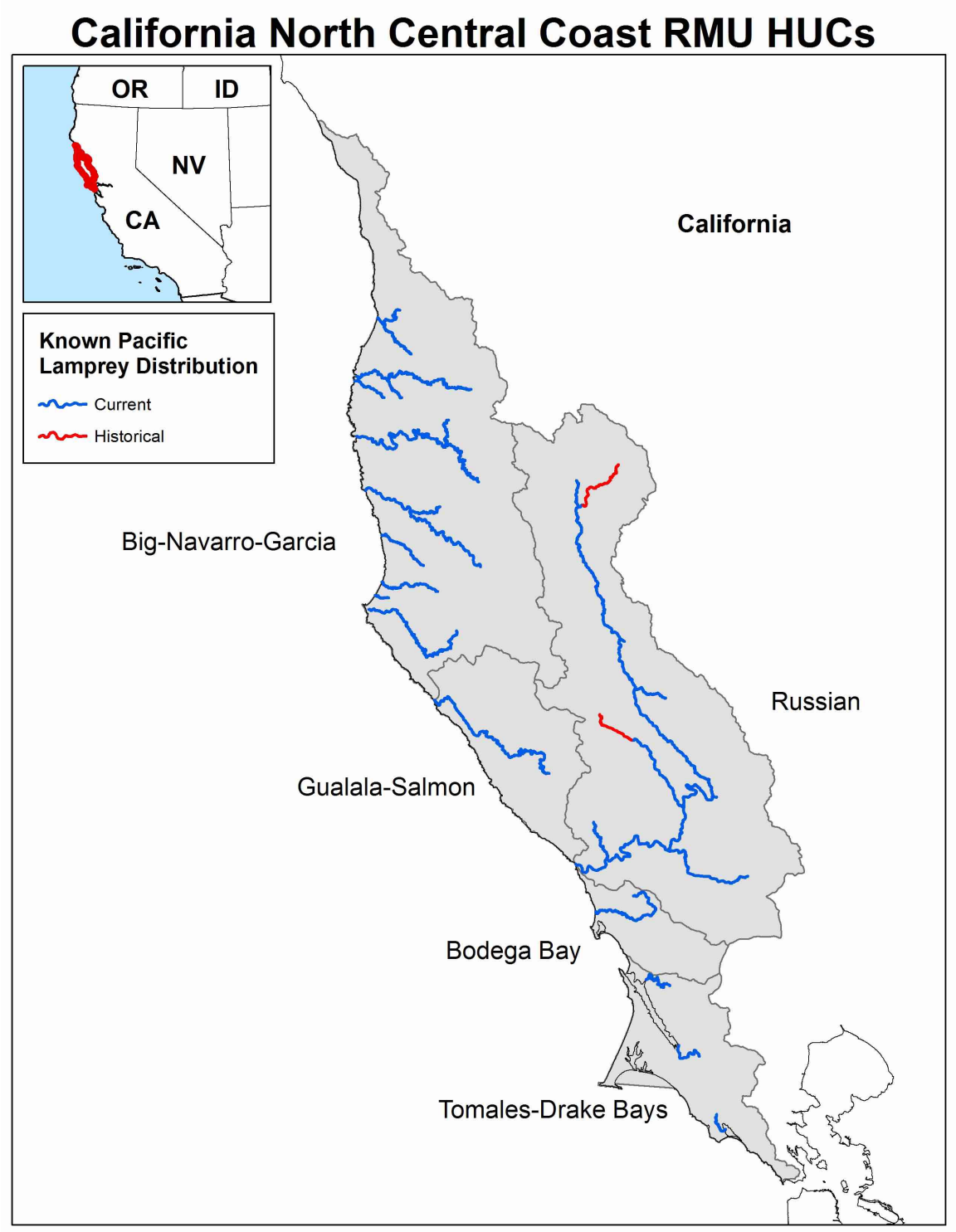

Figure 3. North Central Coast Regional Management Unit (RMU) and its watersheds (4th field HUCs), with current and historical distribution of Pacific Lamprey in 4th order and higher streams (Reid and Goodman 2017).

Table 1. Conservation Status Ranks and Population demographics in the 4th Field watersheds (HUC) in the CA North Central Coast Region. Note that historical and current occupancies are linear stream distances (4th order and above), reflecting improved distribution data since the 2012 Assessment. 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)
Big-Navarro-Garcia	S2	375	375	1	Unknown	50 - 70%
Gualala-Salmon	S2	70	70	1	Unknown	50 - 70%
Russian	S2	348	312	0.9	250-1000	50 - 70%
Bodega Bay	S2	36	36	1	Unknown	50 - 70%
Tomales-Drake Bays	S2	37	37	1	Unknown	50 - 70%

Short Term Trend

Declines in occupied HUCs north of the Golden Gate may be similar to those in the North Coast RMU and Oregon Coast at Winchester Dam on the North Fork Umpqua River (Goodman and Reid 2012; USFWS 2019). However, the lack of monitoring of adult migrations makes any quantification of population trends impossible.

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.

North Central Coast RMU - Threats and Limiting Factors to Pacific Lamprey

Threats and limiting factors to Pacific Lamprey in the North Central Coast RMU are provided in Table 2 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 North Central Coast RMU were dewatering and to a limited extent passage in two HUCs. Most threats were ranked at low to moderate, with no severe threats in any HUCs.

Table 2. NatureServe risk ranks, maximum threat level and principal threat rankings for Pacific Lamprey within the North Central Coast 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**	**Max. Threat**	**Passage**	**Dewatering /Flow**	**Stream Degradation**	**WQ**	**Predation**
Big-Navarro-Garcia	S3	D	2 - 2	2 - 2	1 - 1	4 - 2	2 - 1
Gualala-Salmon	S2	C	2 - 2	2 - 2	2 - 2	4 - 2	2 - 1
Russian	S3	C	4 - 2	3 - 3	2 - 2	4 - 2	3 - 2
Bodega Bay	S2	D	2 - 2	2 - 3	2 - 2	4 - 2	2 - 1
Tomales-Drake Bays	S2	C	3 - 4	2 - 3	1 - 1	4 - 2	2 - 1

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

Major barriers to passage were found in only two HUCs (Russian and Tomales-Drake Bay) and did not affect large portions of suitable habitat in the watersheds. In the Russian River two large dams have blocked substantial reaches: on the East Fork Russian River (Coyote Valley Dam, Lake Mendocino) and on Dry Creek (Warm Springs Dam, Sonoma Lake). However, in both cases upstream habitat may have been seasonally limited in the past due to dry late summer conditions. The East Fork Russian River now receives continuous flow from the Potter Valley Diversion (Cape Horn Dam on the Eel River). Releases from Sonoma Lake provide summer flow in the reaches of Dry Creek below the dam. The Wohler Dam lower in the system has a new fishway. A number of summer dams form additional barriers on the mainstem Russian River, likely blocking or impeding movement of adults from May through September.

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

Dewatering of streams (anthropogenic), resulting in reduced summer flows, was ranked as low in scope (often small-scale unregistered diversions) and moderate in severity in all but the Russian and Gualala rivers, where the scope was broader due

to more extensive agriculture (e.g. viticulture) and groundwater pumping has become more common. In the Russian River alone there are over 150 surface diversions and pumps (Passage Assessment Database, CalFish.org, 2014). Elsewhere, surface diversions and small pumps were typically in smaller streams and exacerbated naturally arid summer conditions.

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

Stream degradation was generally ranked as low, except in the Gualala-Salmon HUC, where instream gravel mining impacted the mainstem rivers. Numerous restoration projects have been completed or are planned for the RMU to address the effects of historical logging practices. The primary concern is that they incorporate the needs of lampreys, in particular with regard to 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, but low in severity throughout the RMU. The principal concern is in the Russian River, where low flows, high nutrient levels and warm temperatures have resulted in algal blooms, including toxic microcystin algae. Low flows, isolated pools and desiccation in the mainstem Gualala are also producing high water temperatures and low oxygen levels in summer refuge pools used by both adults and ammocoetes.

Predation

Predation was not considered a threat in most coastal streams. In the Russian River non-native predatory fishes are common in the mainstem and reservoirs (incl. basses, sunfishes, Striped Bass 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 are only present in the Russian River, where they 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 and bird predation in central coastal streams has not been assessed. A principal area of pinniped and bird predation appears to be the mouth of the Russian River. Predation threats were ranked as Unknown, although they are proposed for assessment.

North Central Coast 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 North Central Coast RMU and its component HUCs, thereby promoting the conservation and management of the species range-wide. A summary of the plan is provided below, with details available in the Implementation Database (Appendix C).

General Conservation Needs within the North Central Coast RMU

Within the North Central Coast RMU there are some general conservation needs that pertain to all HUCs. 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 North Central Coast 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., USBR, CalTrans, CDFW, Pacificorp, PG&E, and USFWS) to ensure lamprey consideration 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.

A specific regional focus is also proposed for increasing awareness of adverse impacts caused by surface diversions, groundwater pumping, summer dams, and nutrient inputs in the North Central Coast RMU. Unregulated water withdrawals reduce flows in or even fully dry up both mainstems and smaller tributaries. Even short-term loss of surface flow is lethal to over-summering adults and resident ammocoete populations, resulting in the local loss of up to seven year classes. Higher temperatures caused by lower flows and increased nutrient loading promoting algal blooms in mainstem rivers further degrade habitat used by over-summering adults and ammocoetes, who cannot tolerate anoxic conditions in the sediment or water column.

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 during their 5–7 year instream development are highly dependent on the habitat provided by fine sediments. 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 blooms on sediment conditions, and mitigation measures for use during in-water projects to reduce mortality of ammocoetes.

Adult holding habitat: Many adult lamprey hold over during the summer/winter and spawn the following spring. Observations of dead adults in summer months, outside the expected spawning period, indicate that high water temperatures and low dissolved oxygen (DO) may seriously impact adult survival during the holding period. Research is proposed to determine thermal and DO tolerances for adult lamprey during summer holding period.

Due to our currently 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 censusing and assessment of emigration timing for macropthalmia, are recommended for each occupied HUC. Although these surveys are common to all HUCs, they are specified individually for each in the database due to differences in threat level, stakeholders and project development, and to facilitate progress monitoring within 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 North Central Coast HUCs. Details are available in the Implementation Database.

Big-Navarro-Garcia

This HUC includes a series of small to medium-sized drainages ($\leq$ 818 km^2) along the coast from the Eel River to the Gualala. Twelve drainages are occupied by Pacific Lamprey, including: Bear (217 km^2), Mattole (768 km^2), Usal (71 km^2), Ten Mile (310 km^2), Noyo (294 km^2), Hare (25 km^2), Big (469 km^2), Navarro (818 km^2), Elk (73 km^2), Alder (78 km^2), Brush (53 km^2), Garcia (297 km^2). The remaining drainages are all < 50 km^2 (Reid and Goodman, in prep.).

The primary concerns in the HUC are relatively minor passage issues and continued habitat restoration, incorporating lamprey into design and outcome goals. Of the occupied drainages, only the Noyo and Navarro have passage issues in their mainstems and/or lower reaches of principal tributaries. Pudding Creek is unoccupied and no historical records exist, however a dam in the estuary with a step-pool fish ladder may be hampering adults from entering the drainage (Figure 4).

Figure 4. Dam and fish ladder in the estuary of Pudding Creek. This location was used to provide water to a neighboring lumber mill that is no longer in operation. It now serves as a fish population monitoring facility. No records of Pacific Lamprey exist for Pudding Creek and they do not currently occupy the drainage. Improving passage at the fish ladder may improve the potential for future colonization.

Gualala-Salmon

This HUC includes the entire Gualala River drainage (774 km^2) and a series of small drainages along the coast down to the Russian River, all but one with drainages < 10 km^2 (Russian Gulch, 29 km^2), and none apparently occupied by Pacific Lamprey (Reid and Goodman 2016).

The primary concerns in the HUC are ensuring water management that prevents seasonal channel desiccation in the mainstems, understanding its effects on lampreys and assessing the effects of in-channel gravel mining in the drainage (Figure 5).

Figure 5. An isolated pool on the Gualala River. It is uncertain how summer low streamflow conditions affect Pacific Lamprey populations in the North Central Coast (Photo credit Nathan Rich, Kashia Band of the Pomo Indians).

Russian River

This HUC includes the entire Russian River drainage (3,844 km^2). Its principle tributaries are Austin, Green Valley, Mark West (incl. Santa Rosa), Dry, Maacama, and East Fork.

The primary concerns in the HUC are maintaining passage, flow and water quality in the mainstem Russian River and the lower reaches of its principle tributaries. Applied research needs include assessments of predation at the mouth, management of the sand bar opening, timing of movements, behavior at summer dams, adult holding and spawning areas, and adult population monitoring (Figure 6). The Mirabel Dam fishway was recently improved by the Sonoma County Water Agency and the fish ladder desigs incorporates Pacific Lamprey passage needs, although it has not been tested.

Figure 6. Summer Dam at Vacation Beach on the Russian River near Guerneville. This is one of several summer dams established annually in the Russian River to provide recreational opportunities (and bathing). The effects of these dams on Pacific Lamprey are uncertain and under investigation.

Bodega Bay

This small HUC includes the coast from the Russian River to Tomales Bay and contains only three relatively small drainages suitable for Pacific Lamprey: Salmon Creek (90 km^2), Estero Americano (100 km^2), and Estero San Antonio (139 km^2). All have relatively dry summer conditions in their small watersheds, and potential habitat is limited to the lower mainstems. Of these only Salmon Creek has historical records of Pacific Lamprey and is currently occupied (Reid and Goodman 2016).

The primary concern in the HUC is insuring water management that prevents seasonal channel desiccation in the mainstems.

Tomales-Drakes Bay

This HUC includes tributaries to Tomales Bay and a series of small drainages along the coast from Tomales Point to the Golden Gate. These small coastal streams, all < 25 km^2 in drainage area, are not known to support lamprey populations, with the exception of Pine Gulch Creek in Bolinas Lagoon. Pine Gulch Creek contains a resident population of Pacific Brook Lamprey, *Lampetra c.f. pacifica*, and 1-2 adult Pacific Lamprey have occasionally been reported in the stream (NPS pers. comm. 2015); however, there is currently no established population of Pacific Lamprey ammocoetes (Reid and Goodman 2016). Tomales Bay contains two principal tributaries utilized by Pacific Lamprey, Walker (205 km^2) and Lagunitas (282 km^2) creeks.

The primary concerns in the HUC are assessment and resolution of any potential passage constraints in the two principal drainages (Walker and Lagunitas), continued habitat restoration, incorporating lamprey into design and outcome goals, and flow management that prevents seasonal channel desiccation and addresses outmigration cues for macrophthalmia. Additional actions include determining timing of adult in-migration and macropthalmia emigration, as well as adult holding habitat in Lagunitas Creek. Continued monitoring of Pine Gulch Creek is recommended to ensure suitable habitat conditions for the resident brook lamprey population and better understand the use of the creek by Pacific Lamprey.

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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:	Point Reyes	7 Jul 2011
	Lagunitas	7 Jul 2011
Lamprey Summit:	Portland OR	20 Jun 2012
2015 Implementation planning:	Lagunitas	9 Sep 2015
	Stewarts Point	22 Sep 2015
	Jenner	22 Sep 2015
	Santa Rosa	23 Sep 2015
	Fort Bragg	24 Sep 2015
Workshops:		
	Ukiah	16 May 2018
Stakeholder Discussions:		
CDFG	Ukiah	13 Jun 2017
Sonoma County Water, CDFG	Mirabelle fish ladder	15 May 2018
Multiple	Ukiah	16 May 2018
Landowner - Hemphill, Boy Scouts	Noyo River	19 Jul 2018
Sonoma County Water	Santa Rosa	21 Mar 2019

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. Implementation tasks and needs - North Coast

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 - North Central Coast. Listed items include tasks and needs that are general to the state, as well as specific to individual HUC's within the North Central Coast 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 salmonid 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
NORTH CENTRAL COAST					
All HUCS	Dewatering/ Flow	Dewatering	Increase awareness of adverse impacts caused by small-scale diversions and nutrient inflows throughout the region and promote more responsible use of water.	Coord.	Ongoing
All HUCS	Population	Spawning	Determine migration timing, spawning locations and timing in principal streams.	Research	Underway
Big-Navarro-Garcia	Passage	Culverts	Map and assess culverts in principal streams and tributaries and evaluate available lamprey habitat upstream.	Survey/ Assess.	-
Big-Navarro-Garcia	Passage	Dams, small	Assess and retrofit the Pudding Creek weir for lamprey passage and to allow monitoring for presence of in-migrating adult P. Pudding Creek is not apparently not occupied by PL at this time.	Instream	-
Big-Navarro-Garcia	Passage	Dams, small	Assess and retrofit the Noyo Egg Collection Facility for lamprey passage.	Instream	Planned
Big-Navarro-Garcia	Population	Distribution	Carry out distribution surveys to determine upstream extent in coastal streams within the HUC4 with consideration of current limits of anadromy.	Survey	-
Bodega Bay	Passage	Culverts	Map and assess culverts in principal streams within the HUC and evaluate available lamprey habitat upstream.	Survey/ Assess.	-
Gualala-Salmon	Dewatering/ Flow	Dewatering	Assess groundwater extraction effects on surface stream flow and lamprey habitat/populations.	Assess.	-
Gualala-Salmon	Dewatering/ Flow	Dewatering	Increase awareness of adverse impacts caused by small-scale diversions and nutrient inflows throughout the North Central coast region and promote more responsible use of water.	Coord.	Ongoing
Gualala-Salmon	Passage	Culverts	Map and assess culverts in principal tributaries of the Gualala River and evaluate available lamprey habitat upstream.	Survey/ Assess.	-
Gualala-Salmon	Population	Distribution	Carry out distribution surveys to determine upstream extent in coastal streams within the HUC4 with consideration of current limits of anadromy.	Survey	Completed
Gualala-Salmon	Stream Degradation	Restoration	Restoration of natural channel morphology in mainstem Gualala River.	Instream	-

HUC	Threat Category	Subcategory	Action Description	Type	Status
Gualala-Salmon	Water Quality	Survey	Assess mainstem to determine areas where WQ may be substantially affecting adult holding &/or ammocoete rearing habitat.	Survey/ Assess.	-
Russian	Dewatering/ Flow	Dewatering	Assess groundwater extraction effects on surface stream flow and lamprey habitat/populations.	Assess.	-
Russian	Dewatering/ Flow	Dewatering	Assess impact of water diversions on summer flow and WQ in mainstem Russian River.	Assess.	-
Russian	Dewatering/ Flow	Dewatering	Increase awareness of adverse impacts caused by small-scale diversions and nutrient inflows throughout the North Central coast region and promote more responsible use of water.	Coord.	Ongoing
Russian	Dewatering/ Flow	Flow management	Assess role of Sonoma Lake reservoir releases in maintaining suitable downstream habitat and incorporate PL into management strategies.	Assess.	-
Russian	Other	Lack of awareness	Hold a public lamprey conservation workshop to promote lamprey conservation in the Russian River Basin.	Coord.	Underway
Russian	Passage	Culverts	Map and assess culverts in principal tributaries of the Russian River and evaluate available lamprey habitat upstream.	Survey/ Assess.	-
Russian	Passage	Dams, small	Assess passage constraints for lampreys on Santa Rosa and Matanza creeks and develop adaptive improvements, if necessary.	Assess.	-
Russian	Passage	Dams, small	Assess passage constraints for lampreys at summer dams in the mainstem Russian River and develop adaptive improvements.	Assess.	Completed
Russian	Passage	Diversions	Assess entrainment at Potter Valley diversion.	Assess.	-
Russian	Passage	Diversions	Map, assess and prioritize principal diversions for downstream passage, entrainment and dewatering of downstream reaches.	Survey/ Assess.	-
Russian	Passage	Fish Ladders	Make modifications to the Healdsburg Veterans Park Summer Dam to improve lamprey passage as necessary, depending on results of assessment.	Instream	Completed
Russian	Passage	Fish Ladders	Assess passage constraints for lampreys at the Vacation Beach Summer Dam and develop improvements.	Instream	Completed
Russian	Passage	Fish Ladders	Assess passage constraints for lampreys in the new Wohler fish ladder design and develop	Assess.	Underway

HUC	Threat Category	Subcategory	Action Description	Type	Status
			adaptive improvements, if necessary.		
Russian	Passage	Fish Ladders	Assess passage constraints for lampreys at the Johnson Beach Summer Dam and develop improvements.	Instream	Underway
Russian	Population	Distribution	Use telemetry to determine migration behavior and areas utilized by over-summering adult Pacific Lamprey within the Russian River and tribs	Research	-
Russian	Population	Distribution	Carry out distribution surveys to determine upstream extent in the mainstem Russian River and its principal tributaries.	Survey	-
Russian	Population	Monitoring	Assess the potential to use pinnipeds and birds of prey to monitor lampreys at the mouth of the Russian River.	Instream	-
Russian	Population	Monitoring	Develop a monitoring program and adapt facilities to census lampreys at the Healdsburg Veterans Park fish ladder.	Instream	-
Russian	Population	Monitoring	Refine monitoring program for lampreys at the Wohler fishway.	Instream	Underway
Russian	Predation	Pinnipeds	Assess impact of pinnipeds on adult lamprey in the mouth of the Russian River.	Assess.	-
Russian	Water Quality	Assessment	Assess impact of eutrophication and associated algal blooms on ammocoetes in the Russian River.	Survey/ Assess.	-
Russian	Water Quality	Survey	Assess mainstem to determine areas where WQ may be substantially affecting adult holding and/or ammocoete rearing habitat.	Survey/ Assess.	-
Tomales-Drake Bays	Passage	Culverts	Map and assess culverts in principal streams within the HUC and evaluate available lamprey habitat upstream.	Survey/ Assess.	-
Tomales-Drake Bays	Passage	Culverts	Map and assess culverts in principal streams within the HUC and evaluate available lamprey habitat upstream.	Survey/ Assess.	-
Tomales-Drake Bays	Passage	Fish Ladders	Make modifications to the Roy's Pools fish ladder or incorporate them into any new design to improve lamprey passage as necessary.	Instream	Completed
Tomales-Drake Bays	Population	Monitoring	Incorporate Pacific Lamprey into local fish monitoring programs to determine frequency of use by Pacific Lamprey.	Instream	Ongoing