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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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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, guided by 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 by Goodman and Reid (2012) and introduces implementation actions to aid in conservation of the species. Neither document represents analyses required by the Endangered Species Act to determine if a species is warranted for listing as threatened or endangered.

The 2012 Assessment and Template for Conservation Measures in California (Goodman and Reid 2012) includes introductory chapters describing the overall assessment and conservation strategy of the PLCI, general biology of and threats to Pacific Lamprey, and methods. Successive chapters focus on Pacific Lamprey in the California Region as a whole and in seven specific geographic subregions (Regional Management Units - RMUs) 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

In this stage of the PLCI, we use the combined results of viability and threats assessments in the 2012 California Assessment to develop implementation plans for each of seven RMUs (Figure 1); identifying conservation efforts, knowledge gaps, and key implementation projects that will reduce threats 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 California Assessment, collaborative input from partners and stakeholders, and drainage specific needs 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 will reduce threats to Pacific Lamprey within each of California's seven RMUs and their component HUC watersheds, thereby promoting the conservation and management of Pacific Lamprey both locally and range-wide through collaborative solutions. They are intended to provide a tool for managers and conservation biologists to guide conservation efforts, prioritize projects, and monitor progress.

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

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 years 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 and recovery of a keystone species integral to the health and ecological function of western rivers. Both the Conservation Assessment and this Implementation Plan are intended as living documents that will be updated as we develop new information and understanding of lamprey conservation status and as implementation progresses.

Implementation Planning – Methods

The initial phase of this implementation planning was to assess population status and identify threats within individual 4th field Hydrologic Unit Code watersheds (HUCs) through the 2012 California Assessment process (Goodman and Reid 2012). 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 California Assessment are summarized herein, but the Assessment itself contains 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 methods. 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 Goodman and Reid (2012).

Collaborative stakeholder meetings and site visits were held for each HUC to seek out local knowledge, conservation concerns and suggestions for information needs and conservation actions (see Figure 2 and Appendix A for stakeholder meetings and

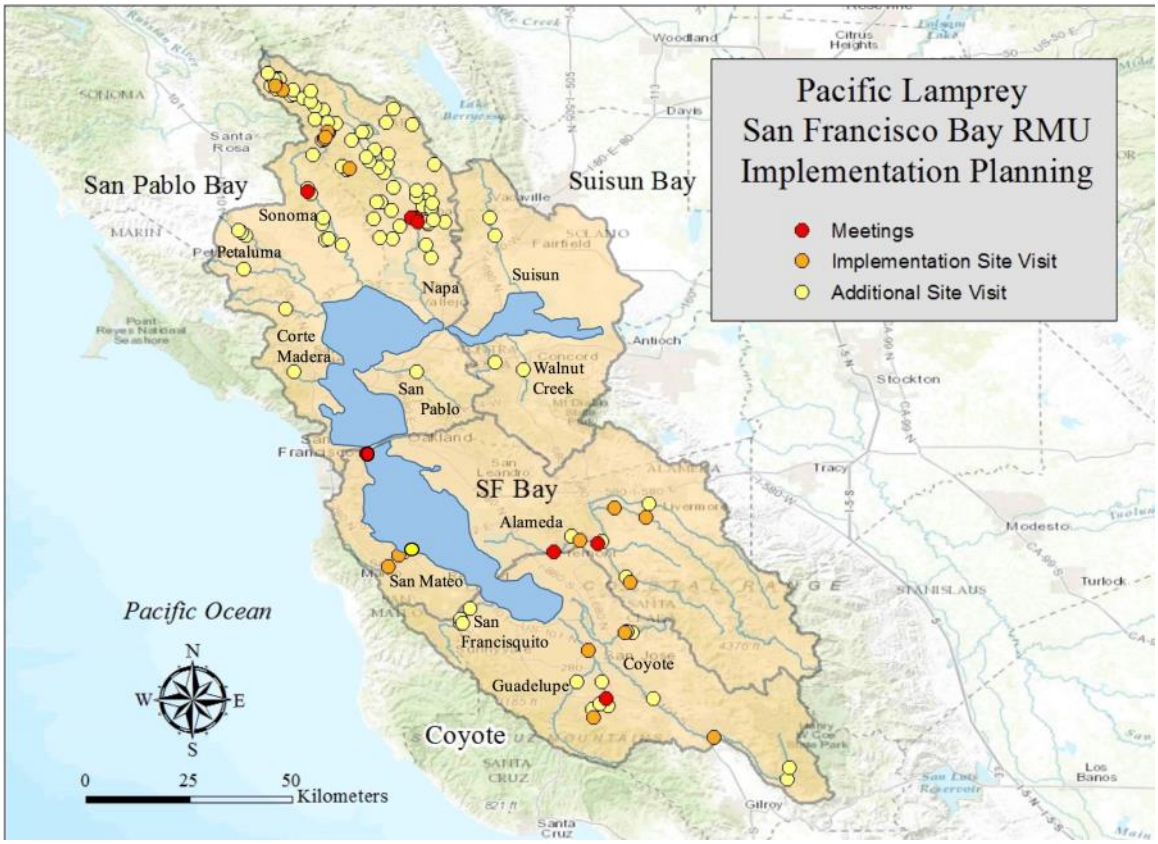

Figure 2. Map of stakeholder meetings, workshops, and site visits that informed the development of the San Francisco Bay implementation plan.

workshops). Outreach and information gathering included 7 stakeholder meetings or workshops and included 32 different stakeholders. Stakeholder meetings 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 California threat assessment and drew upon various sources of information. For each recognized threat, actions were developed to specifically address that threat, or 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 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
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

Prioritization of conservation actions is facilitated through the implementation database by inclusion of separate factors that may guide selection of individual projects (See Appendix B for specific fields and details of the database structure). 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 recovery biologists to address the specific needs of Pacific Lamprey, guide conservation efforts, prioritize projects, and monitor progress. See Appendix C for contact information.

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, Reid and Goodman, in manuscript). A similar pattern was

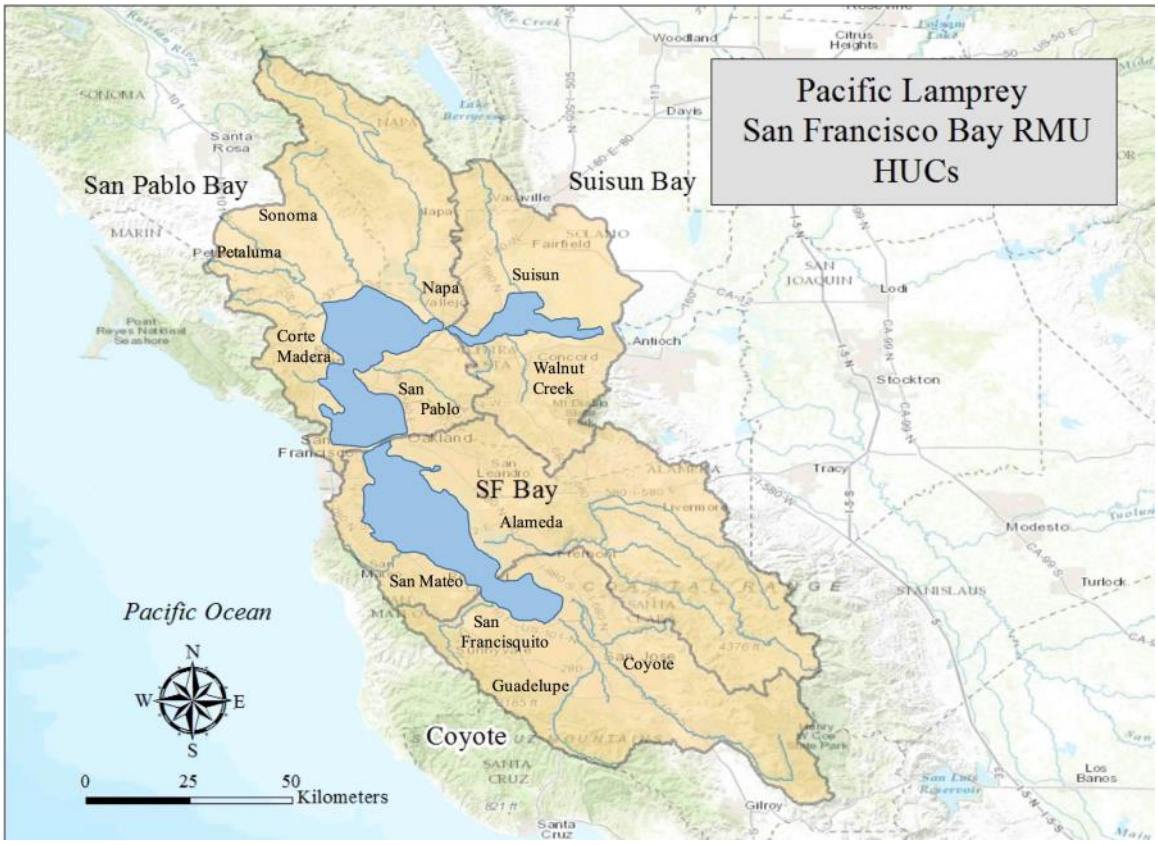

Figure 3. Map of the San Francisco Bay Regional Management Unit (RMU) and its watersheds (4th field HUCs). Drainages mentioned in the text and tables are labeled.

found along the California coast, where 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. The evidence suggests that there is little, if any, use of smaller coastal drainages (< 25 km^2) that directly enter the sea (Reid and Goodman 2016). 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).

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, Reid and Goodman 2016).

Table 2. Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the San Francisco Bay RMU. 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 Goodman and Reid 2012, updated to current understanding. A revised Status and Threat Assessment is expected in 2018.

SAN FRANCISCO BAY		**Distribution**				**Max. Threats**		
Watershed	**HUC**	**Maximum Historical (km^2)**	**Ratio Current/ Historical**	**Population Size (#)**	**Short-Term % Decline**	**Scope**	**Severity**	**Risk Rank**
Suisun Bay (Pacheco)	18050001	599	0.37	Unknown	Unknown	Mod.	Mod.	S2
San Pablo (Napa/Sonoma)	18050002	1,399	0.75	Unknown	Unknown	Mod.	Mod.	S3
Coyote (Coyote/Guadalupe)	18050003	1,690	0.25	Unknown	Unknown	High	Mod.	S2
San Francisco (Alameda)	18050004	1,693	0.37	Unknown	Unknown	High	Mod.	S2

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.

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 planning and 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

Table 3. Principal threat rankings, maximum threat level, and NatureServe risk ranks for Pacific Lamprey within the San Francisco Bay RMU. See map, Figure 3. Individual threat rankings for Scope and Severity: 1 to 4, Insignificant to High; U = Unknown. NatureServe ranks (Natureserve 2009): SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure. Maximum threat ranks: X, Extinct due to dams (prior to 1985); and A to H, substantial and imminent threat to unthreatened. Adapted from Goodman and Reid 2012, updated to current understanding. A revised Status and Threat Assessment is expected in 2018.

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

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.

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 insuring groundwater management that prevents seasonal channel desiccation and possible water quality issues in the mainstems and lower reaches of principal tributaries; passage issues are relatively limited in the 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).

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).

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 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.

Literature Cited

Goodman, D. H., and S. B. Reid. 2012. Pacific Lamprey (*Entosphenus tridentatus*) Assessment and Template for Conservation Measures in California. U.S. Fish and Wildlife Service, Arcata, California. 128 pp. Online at http://www.fws.gov/Arcata/fisheries/reports/technical/PLCI_CA_Assessment_Final.pdf.

Goodman, D.H. and S.B. Reid. 2017. Climbing above the competition: innovative approaches and recommendations for improving Pacific Lamprey passage at fishways. Ecological Engineering 107: 224–232.

Goodman, D.H., S.B. Reid, N.A. Som and W.R. Poytress. 2015. The punctuated seaward migration of Pacific Lamprey (*Entosphenus tridentatus*): environmental cues and implications for streamflow management. Canadian Journal of Fisheries and Aquatic Sciences 72(12): 1817-1828, 10.1139/cjfas-2015-0063.

Hubbs, C.L. 1925. The life cycle and growth of lampreys. Pap. Mich. Acad. Sci. 4:587-603.

Leidy, R.A. 2007. Ecology, assemblage structure, distribution, and status of fishes in streams tributary to the San Francisco Estuary, California. San Francisco Estuary Institute, Contrib. No. 530.

NatureServe. 2009. NatureServe conservation status assessment: rank calculator version 2.0. NatureServe, Arlington, Virginia. Online at www.NatureServe.org/explorer/ranking.htm.

Nawa, R. K., J. E. Vaile, P. Lind, T. M. K. Nadananda, T. McKay, C. Elkins, B. Bakke, J. Miller, W. Wood, K. Beardslee, and D. Wales. 2003. A petition for rules to list: Pacific lamprey (*Lampetra tridentata*); river lamprey (*Lampetra ayresi*); western brook lamprey (*Lampetra richardsoni*); and Kern brook lamprey (*Lampetra hubbsi*) as threatened or endangered under the Endangered Species Act. January 23, 2003.

Reid, S. B. and D. H. Goodman. 2015. Detectability of Pacific Lamprey Occupancy in Western Drainages: Implications for Distribution Surveys. Transactions of the American Fisheries Society. Transactions of the American Fisheries Society. In press (accepted 18 November 2014).

Shapovalov, L. and A. C. Taft. 1954. The life histories of the Steelhead Rainbow Trout (*Salmo gairdneri gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game, Fish Bulletin No. 98.

USFWS (U.S. Fish and Wildlife Service). 2004. 90-Day finding on a petition to list three species of lamprey as threatened or endangered. Federal Register: December 27, 2004 (Volume 69, Number 2) Proposed Rules pages 77158-77167.

Guadalupe-Coyote Resource Conservation District (GCRCD). 2005. Petition by Guadalupe-Coyote Resource Conservation District to remove and prevent homeless encampments on the Guadalupe River, Coyote Creek, and tributaries thereto. Petition before the City of San Jose, Santa Clara Valley Water District

and California Department of Fish and Game, in the matter of homeless encampments for: Guadalupe and Coyote creeks (Santa Clara County), January 11, 2005.

Appendices

Appendix A. Stakeholder implementation meetings and workshops

Meeting Type	Location	Date
Threat Assessment	Napa	July 6, 2011
Implementation plan	Fremont, Alameda Creek	May 10, 2016
	San Jose, Coyote/Guadalupe rivers	August 11, 2016
	Napa RCD, Napa River	August 8, 2016
	Napa Library, Napa River	December 14, 2016
	Glen Ellen, Sonoma Creek	December 16, 2016
Lamprey summit	Portland, OR	Jun. 20-21, 2012

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

<u>Status</u>

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 and task list 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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