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

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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
Km	Kilometer
MCZ	Museum Comparative Zoology (Harvard) - Ichthyological collection
NF	National Forest
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
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
YCFCWC	Yolo County Flood Control & Water Conservation District

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**Regional Implementation Plan For Measures To Conserve Pacific Lamprey
(*Entosphenus Tridentatus*), California - Sacramento Regional Management Unit**

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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 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 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 risks 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. Ultimately, the various RMU plans will be incorporated into a



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

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 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. Already, many of the proposed implementation projects have been initiated or are well underway.

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 RMUs, 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 experience, conservation concerns and suggestions for information needs and conservation actions (see Figure 2 and Appendix A for stakeholder meetings and

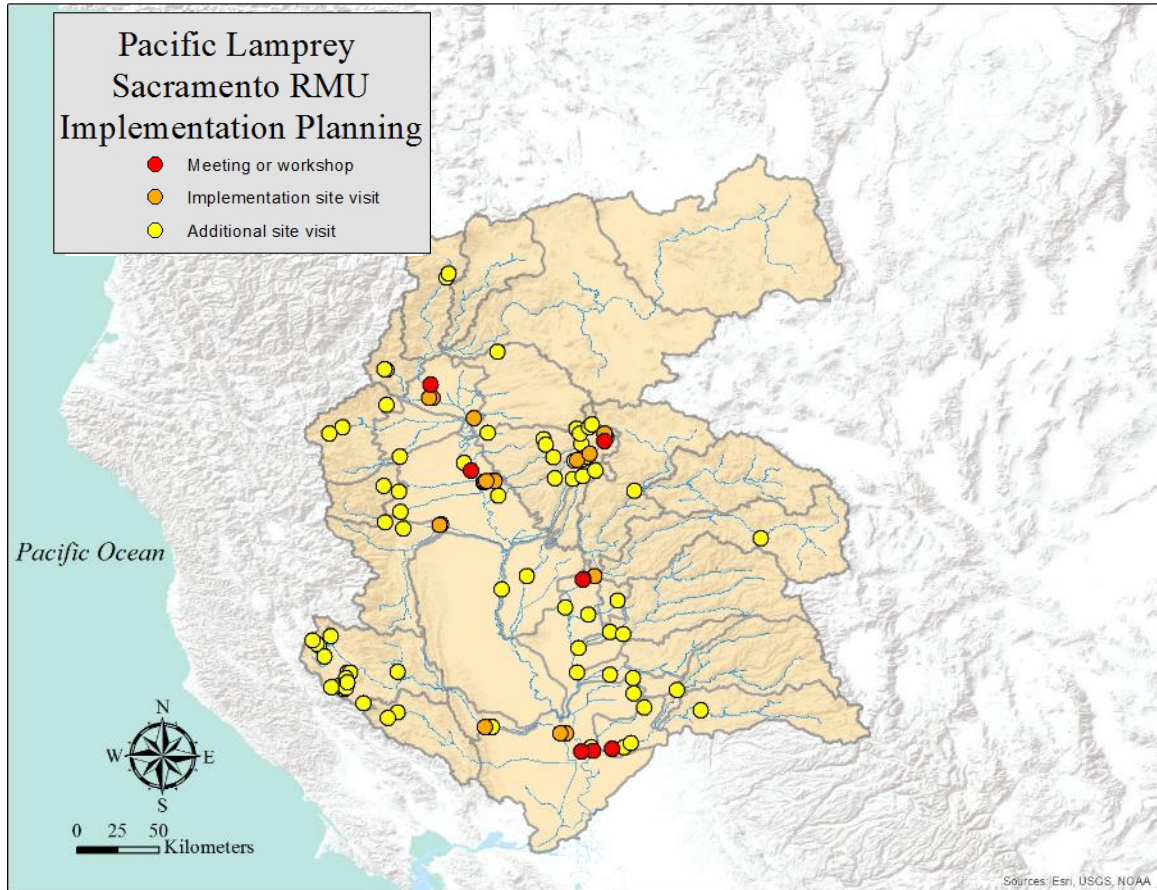


Figure 2. Map of stakeholder meetings, workshops, and site visits which informed the development of the Sacramento implementation plan.

workshops). Outreach and information gathering included 7 stakeholder meetings or workshops and included over 20 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.



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

Sacramento RMU - Status and Distribution of Pacific Lamprey

The Sacramento RMU includes the mainstem Sacramento River and all of its tributaries downstream to the confluence with the San Joaquin River, including the Upper and Lower Sacramento USGS accounting units (Figure 3). It includes 34 watersheds (4th field HUCs), ranging from 96–7,041 km² (Table 1). The RMU extends from the San Francisco Bay inland through California's Central Valley, east into the Sierra Nevada Mountains, northwards to Mount Shasta, and inland to the arid Goose Lake Basin (currently endorheic and not shown in tables) and western slope of the Warner Mountains. It occupies the Central California Chaparral / Oak Woodlands, Central California Valley, Sierra Nevada, Klamath Mountains, Cascade, and Eastern Cascade, slopes and foothills ecoregions. Due to differences in hydrology, habitat and threats, we have grouped the HUCs within the RMU into three sub-groupings: Upper Sacramento, East Foothills and Sierras, West Valley and Coast Range. Population status and distribution of Pacific Lamprey in the Sacramento 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 widely distributed and abundant historically in the Sacramento RMU, based on current and historical records, available habitat and the absence of natural barriers. The principal uncertainty is how far upstream the species extended into the upper Pit River (above Fall River), given a lack of records. However, for the purpose of this assessment we follow Reid and Goodman (2017) and assume that Pacific Lamprey were able to utilize all habitats with anadromous access. This is based on evidence that anadromous salmonids made it upriver at least as far as Fall River in the past (Yoshiyama et al. 1998); the widespread presence of the closely related Pit-Klamath Brook Lamprey, *Entosphenus lethophagus*, throughout the Pit Basin; the presence of high quality salmonid habitat in the Warner Mountains; and the absence of natural barriers.

A second uncertainty is the extent to which Pacific Lamprey extended into the upstream reaches of the Sierra Nevada. However, we were able to obtain vouchered historical specimens from prior to the construction of the impassable dams and confirm the presence of Pacific Lamprey in the upper Sacramento near Mt. Shasta (2,330 ft) and in the upper McCloud (2,749 ft), Feather (4,254 ft) and Yuba drainages. The Feather River specimens confirmed that lamprey could pass well above large waterfalls typical of the Sierras, many of which represented barriers to anadromous salmonids, thereby further extending their access to habitat in the upper Sierras (see Reid and Goodman 2017).

Current Occupancy

Pacific Lamprey currently only occupy habitat in the Sacramento RMU downstream of impassable dams, primarily on the valley floor and foothills. The lower reaches of most west-side streams are seasonally dry or have low, warm streamflow during a portion of the year and probably do not provide rearing habitat for ammocoetes, but they can function as migration corridors for both upstream migrating adults and downstream migrating juveniles. The principal accessible higher elevation streams are in the Mill-Big Chico HUC, which flow off the southwest slopes of Mt. Lassen and generally still maintain substantial runs of anadromous salmonids (Reid and Goodman 2017, in prep.).

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

Table 1. Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the Sacramento RMU. NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure. Adapted from Goodman and Reid 2012. A revised Status and Threat Assessment is expected in 2018.

SACRAMENTO		Distribution			Max. Threats			Risk Rank
Watershed	HUC	Max. Hist. (km ²)	Current/ Hist.	Population Size (#)	Short-term Decline (%)	Scope	Severity	
<u>Upper Sacramento:</u>								
Upper Pit	18020002	6,752	0	Extinct	-	-	-	SX
Lower Pit	18020003	7,041	0	Extinct	-	-	-	SX
McCloud	18020004	1,774	0	Extinct	-	-	-	SX
Sacramento headwaters	18020005	1,561	0	Extinct	-	-	-	SX
Sacramento - Upper Clear	18020112	703	0.1	Unknown	Unknown	High	Mod	S1
<u>East Foothills and Sierras:</u>								
Upper Cow - Battle	18020118	2,169	0.9	250-1000	Unknown	Mod.	Mod.	S2
Lower Cow - Lower Clear	18020101	1,098	1	Unknown	Unknown	High	Low	S3
Mill - Big Chico	18020119	2,343	0.9	Unknown	Unknown	High	Low	S3
Butte - Upper	18020120	522	0.37	Unknown	Unknown	Mod.	Mod	S2
Butte - Lower	18020105	1,552	1	Unknown	Unknown	High	Low	S3
Feather - North Fork	18020121	3,129	0	Extinct	-	-	-	SX
Feather - N.F. East Branch	18020122	2,658	0	Extinct	-	-	-	SX
Feather - Middle Fork	18020123	3,519	0	Extinct	-	-	-	SX
Feather - Lower	18020106	1,792	0.9	Unknown	Unknown	Mod.	Mod	S3
Honcut headwaters	18020124	287	1	Unknown	Unknown	High	Low	S2
Yuba - Upper	18020125	3,395	0.1	Unknown	Unknown	High	Mod	S1
Yuba - Lower	18020107	96	1	Unknown	Unknown	High	Low	S2
Bear - Upper	18020126	940	0	Extinct	-	-	-	SX
Bear - Lower	18020108	271	1	Unknown	Unknown	High	Low	S2
Upper Coon - Upper Auburn	18020127	223	0.75	Unknown	Unknown	Mod.	Mod	S2
American - North Fork	18020128	2,616	0	Extinct	-	-	-	SX
American - South Fork	18020129	2,213	0	Extinct	-	-	-	SX
American - Lower	18020111	776	0.9	Unknown	Unknown	Mod.	Mod	S2
<u>West Valley and Coast Range:</u>								
Cottonwood headwaters	18020113	1,571	0.9	Unknown	Unknown	High	Low	S3
Cottonwood - Lower	18020102	861	0.9	Unknown	Unknown	Mod.	Mod	S2
Upper Elder - Upper Thomes	18020114	856	1	Unknown	Unknown	High	Low	S3
Sacramento - Lower Thomes	18020103	2,982	0.5	Unknown	Unknown	Mod.	Mod	S2
Stony - Upper	18020115	1,929	0	Extinct	-	-	-	SX
Sacramento - Stone Corral	18020104	4,801	0.25	Unknown	Unknown	Mod.	Mod	S2
Cache - Upper	18020116	2,467	0.75	Unknown	Unknown	Mod.	Mod	S3
Cache - Lower	18020110	487	0.37	Unknown	Unknown	High	High	S1
Putah - Upper	18020117	1,476	0	Extinct	-	-	-	SX
Sacramento - Lower	18020109	4,565	0.9	Unknown	Unknown	Mod.	Mod	S3

Ratio of Current Occupancy to Historical Range Extent

The presence of large impassable dams around the rim of the Sacramento has severely limited the current range of anadromous lamprey (ca. 70% decrease in total historical habitat in the RMU), and much of the area lost is from the higher gradient foothill and mountain reaches that provide good water quality and spawning habitat. Nearly all habitat in the upper Sacramento HUCs has been blocked by dams, while eight of 18 HUCs in the eastern foothills and Sierra drainages have been fully or essentially blocked (60% decrease in historical habitat), and two HUCs in higher reaches of the Coast Ranges have been lost to dams (15% decrease in historical habitat).

Population Size

Population size (adults) in the RMU, similarly to all other areas, is poorly understood and not formally monitored. However, video monitoring has been undertaken in Battle Creek (Upper Cow-Battle Creek HUC) since 2009, with an average count of 395 adults and ranging from 60 in 2015 to 1457 in 2017 (R.J. Bottaro USFWS pers. com.). There is also a video monitoring facility on the lower Yuba River. These observations are limited by diurnal use patterns, seasonal monitoring that may miss lamprey migrations, turbidity issues at high flow, and the possibility that lampreys use routes other than those being monitored. Nevertheless, they provide lower limits for population size in this stream. (Goodman and Reid 2012, Reid and Goodman 2016).

Short Term Trend

Declines within occupied HUCs in the Sacramento RMU may be similar to those in other Californian RMU's, as well as throughout the species' range (Goodman and Reid 2012). However, the lack of monitoring of adult migrations makes any quantification of population trends impossible. There are video monitoring stations at the Battle Creek and lower Yuba fish ladders, but their effectiveness for lampreys has not been assessed. We are aware of no recent changes in distribution.

NatureServe Risk Ranks

NatureServe risk ranks varied from critically imperiled (3 HUCs) to vulnerable (S1-S3), or completely extirpated by dams (12 HUCs). See discussion of threats below.

Sacramento RMU - Threats and Limiting Factors to Pacific Lamprey

Threats and limiting factors to Pacific Lamprey in the Sacramento 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.

Beyond the historical elimination of much of the lamprey habitat in the Sacramento by impassable dams, the primary threats to currently occupied HUCs were smaller passage constraints and dewatering or flow management. A major uncertainty is the effects of the large water diversions at the Tracy Pumping Facility (USBR) and Clifton Court Forebay Diversion Facility (CDFW) in the lower San Joaquin delta, which potentially impact passage for large numbers of downstream migrating juvenile lamprey from the Sacramento drainages (Goodman et al. 2016). Assessment of entrainment and passage effects at these facilities is currently underway and is dependent on screening efficiency, diversion timing, flow management in the complicated Central Valley water system, and downstream migration timing for juvenile lampreys. A second uncertainty is the threat of predation by Striped Bass, *Morone saxatilis*, in the lower river reaches that serve as major migratory corridors for both adults and outmigrating juvenile lamprey.

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

The presence of large impassable dams along the rim of the Sacramento Valley has severely limited the current range of anadromous lamprey (ca. 70% decrease in total historical habitat), and much of the area lost is from the higher gradient foothill and mountain reaches that provide good water quality, spawning and rearing habitat. Nearly all habitat in the upper Sacramento HUCs has been blocked by dams, while eight out of 18 HUCs in the eastern foothills and Sierran drainages have been fully or essentially blocked (60% decrease in historical habitat), and two HUCs in higher reaches of the Coast Ranges have been completely lost to dams (15% decrease in historical habitat). Medium-sized diversion dams on some creeks (e.g. Battle, Cache, upper Coon and Putah creeks) also obstruct passage and may be suitable for reestablishment of passage. However, within occupied habitat, most mainstem rivers remain accessible up to the large dams, and other passage issues (e.g. culverts and smaller weirs) were generally ranked as a low threat in most occupied HUCs. At this time we do not feel that passage above the larger storage dams is feasible, primarily due to challenges in providing outmigration opportunities to juvenile lampreys heading downstream.

A special case for passage issues (ranked as 3 or 4-U for the three lower mainstem Sacramento HUCs) is entrainment at the Tracy Pumping Facility (USBR) and Clifton Forebay Diversion Facility (CDFG) in the lower San Joaquin, which potentially impacts passage for large numbers of downstream migrating juveniles from both the San Joaquin and Sacramento drainages. Assessment of entrainment and passage effects at these facilities is currently underway (Goodman et al. 2016) and is dependent on screening efficiency, diversion timing, flow management in the complicated Central Valley water system, and downstream migration timing for juvenile lampreys.

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

Streamflow is highly manipulated in the Sacramento system. Threats due to flow management were generally ranked low in the upper reaches of occupied streams and moderate in the lower reaches. Threats were ranked higher in the west-side streams due to dewatering and diversion of lower reaches, where channels are usually dry or have low, warm flow in the summer and fall. Water storage reservoirs, including Shasta Reservoir on the mainstem Sacramento, also reduce available flow and artificially manage winter and spring flow events, reducing flow events that are crucial for outmigration of macrophthmia (Goodman et al. 2015). Manipulation of flow in the lower Sacramento by the major pumping projects in the delta may also have substantial effects on orientation of migrating lampreys (adults and juveniles).

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

While the Sacramento system is highly modified, the actual threat of stream and floodplain degradation to lampreys was rated as insignificant to low in most occupied HUCs, with the notable exceptions of some west-side valley bottom reaches with gravel mining impacts and dredging in the lower Sacramento.

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

The Sacramento system, as a major agricultural and urban area, has numerous water quality issues with contaminants; however, the effects on local lamprey populations has not been evaluated. Threats due to water quality were generally ranked as widespread but low in severity. Threats due to higher water temperatures caused by low flow conditions were generally captured under dewatering and flow management.

Predation

Non-native predatory fishes are common in the Sacramento Valley and foothill streams. Nevertheless, while there is certainly predation on larval and juvenile lampreys by introduced centrarchids (bass and sunfish) and catfishes, they have occupied the system since the late 1800's and were generally not considered to be a major threat to lamprey populations. In the lower reaches and delta of the Sacramento River itself, introduced Striped Bass are now abundant and represent a potential threat to lampreys. Striped Bass are large predators, capable of feeding on all stages of lampreys, including adults. They occupy the primary migration routes for adults moving upstream to spawn and juveniles outmigrating to the sea. However, the extent of predation on lampreys by Striped Bass and the actual threat this represents to the population are unresolved. Movement patterns expressed by Striped Bass generally overlap with nocturnal activity patterns of lampreys and downstream migration during periods of high flow and turbidity.

Table 2. Principal threat rankings, maximum threat level, and NatureServe risk ranks for Pacific Lamprey within the Sacramento 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. A revised Status and Threat Assessment is expected in 2018.

Watershed	Individual Threats (Scope - Severity)						
	Risk Rank	Maximum Threat	Passage	Dewatering /Flow	Stream Degradation	Water Quality	Predation
<u>Upper Sacramento:</u>							
Upper Pit	SX	X	X	-	-	-	-
Lower Pit	SX	X	X	-	-	-	-
McCloud	SX	X	X	-	-	-	-
Sacramento headwaters	SX	X	X	-	-	-	-
Sacramento - Upper Clear	S1	B	3-4	1-1	3-2	4-2	2-1
<u>East Foothills and Sierras:</u>							
Upper Cow - Battle	S2	C	3-3	3-2	1-1	4-2	2-1
Lower Cow - Lower Clear	S3	D	3-2	2-3	2-2	4-2	3-1
Mill - Big Chico	S3	D	2-2	3-2	1-1	4-2	3-1
Butte - Upper	S2	C	3-3	2-2	1-1	4-2	2-1
Butte - Lower	S3	D	3-2	2-3	2-2	4-2	3-1
Feather - North Fork	SX	X	X	-	-	-	-
Feather - N - F - East Branch	SX	X	X	-	-	-	-
Feather - Middle Fork	SX	X	X	-	-	-	-
Feather - Lower	S3	C	3-2	3-3	2-2	4-2	3-1
Honcut headwaters	S2	D	1-2	2-2	1-1	4-2	2-1
Yuba - Upper	S1	B	4-3	2-2	1-1	4-2	2-1
Yuba - Lower	S2	D	3-2	2-3	2-2	4-2	3-1
Bear - Upper	SX	X	X	-	-	-	-
Bear - Lower	S2	D	3-2	2-3	2-2	4-2	3-1
Upper Coon - Auburn	S2	C	3-3	2-2	1-1	4-2	2-1
American - North Fork	SX	X	X	-	-	-	-
American - South Fork	SX	X	X	-	-	-	-
American - Lower	S2	C	3-3	2-3	2-2	4-2	3-1
<u>West Valley and Coast Range:</u>							
Cottonwood headwaters	S3	D	1-2	2-3	1-1	4-2	2-1
Cottonwood - Lower	S2	C	2-2	3-3	2-2	4-2	3-1
Upper Elder - Upper Thomes	S3	D	2-2	2-3	1-1	4-2	2-1
Sacramento - Lower Thomes	S2	C	3 - U	3-3	3-3	4-2	3-1
Stony - Upper	SX	X	X	-	-	-	-
Sacramento - Stone Corral	S2	C	3 - U	3-3	2-2	4-2	3-1
Cache - Upper	S3	C	3-3	2-3	1-1	4-2	2-1
Cache - Lower	S1	A	3-3	4-4	3-3	4-2	3-1
Putah - Upper	SX	X	X	-	-	-	-
Sacramento - Lower	S3	C	4 - U	3-2	3-3	4-2	4 - U

Sacramento 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 Sacramento 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 Sacramento RMU

There are some general conservation needs that pertain to all HUCs within the Sacramento 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 Sacramento 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. CalTrans, CDFW, USFS, USBR, Tribes, local municipalities, landowners, irrigation districts 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, basic research is needed to better describe 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 is needed to guide management actions intended 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 prior to 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 in the implementation plan database 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 macrophthalmia 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 Sacramento HUCs. Details are available in the Implementation Database.

Sacramento - Mainstem

We have separated out the mainstem Sacramento from its tributaries (see below) although the lower reaches of some tributaries are included in "Sacramento" HUCs (e.g. Lower Thomes, Lower Putah).

The primary concerns in the mainstem Sacramento are flow management as part of its use in regional water management (e.g. Yolo Bypass, Delta Cross Channel), as well as operations of the large water diversions in the delta, which are capable of diverting over 100% of the entire flow of the mainstem with associated high levels of entrainment loss due to ineffective screening (Figure 4) (Goodman et al. 2016). Potential entrainment of ammocoetes or macrothemia by numerous large and small diversions and pumps is also a concern that needs to be further assessed.

Proposed implementation projects focus on 1) understanding and addressing issues caused by operations and design features at the Delta pumping facilities, 2) determining the impact and potential diversion of outmigrating macrothemia thru the Delta Cross Channel during pumping operations at the Delta pumps, 3) assessment of potential entrainment risk at the numerous small- to medium-scale pumping facilities along the river, 4) assessment of potential entrainment or stranding of all life stages of lampreys in the Yolo Bypass. A further possibility is to use the upper Sacramento drainage (above Keswick and Shasta dams) as a test for the feasibility of providing passage over large dams and addressing the needs for outmigrating macrothemia.



Figure 4. Entrainment at the Tracy Pumping Facility (USBR) and Clifton Court Forebay Diversion Facility (CDFW) in the lower San Joaquin potentially impact passage for large numbers of downstream migrating juveniles from both the San Joaquin and Sacramento drainages.

American - Lower

The lower American River provides 22 mi of accessible habitat below Nimbus Dam. The primary concern in the HUC is the lack of fine sediments suitable for ammocoete rearing in the upper reaches of the HUC due to settling and removal by upstream dams. At this time, the only specific implementation project proposed is to assess rearing habitat suitability and ammocoete distribution in the American River below Nimbus Dam to mouth and provide guidance for lampreys in the management of bedload.

Upper Coon - Auburn Ravine

The lower reaches of these minor tributaries of the Sacramento are included in the Lower Sacramento HUC. The distribution and potential issues with lampreys in these drainages are not well known. However, Pacific Lamprey do reach at least upstream of Lincoln in Auburn Ravine. No specific implementation projects are proposed for these drainages at this time, although general surveys of distribution, habitat conditions and potential passage challenges would be useful. They will also benefit from projects focused on broader RMU issues, such as entrainment in both small diversions and the large Delta facilities, metapopulation dynamics, non-native predators, as well as continued outreach and inclusion of Pacific Lamprey in management planning.

Bear

The lower Bear River provides 18 mi of habitat below Camp Far West Dam. No specific implementation projects are proposed for Bear River at this time, although general surveys of distribution and habitat conditions would be useful. The Bear River will also benefit from projects focused on broader RMU issues, such as entrainment in both small diversions and the large Delta facilities, metapopulation dynamics, non-native predators, as well as continued outreach and inclusion of Pacific Lamprey in management planning.

Yuba

The lower Yuba River provides 24 mi of habitat below Englebright Dam. However, 13 mi are obstructed by the Daguerre Point Dam at rm 11. The principal implementation projects for the lower Yuba are ensuring passage at Daguerre Dam and evaluation of rearing habitat availability caused by sediment removal at the upstream dams and legacy mining impacts resulting in lack of fines. The primary concern in the HUC is limited fine sediments suitable for ammocoete rearing, especially at the higher end of the reach. The Yuba will also benefit from projects focused on broader RMU issues, such as entrainment in both small diversions and the large Delta facilities, metapopulation dynamics, non-native predators, as well as continued outreach and inclusion of Pacific Lamprey in management planning.

Feather - Lower

The lower Feather HUC contains the lower 67 miles of the Feather River up to the Fish Barrier Dam below Oroville Dam (Figure 5). No specific implementation

projects are proposed for lower Feather River or the Honcut drainage at this time. The Feather River will also benefit from projects focused on broader RMU issues, such as entrainment in both small diversions and the large Delta facilities, metapopulation dynamics, as well as continued outreach and inclusion of Pacific Lamprey in management planning. The hatchery facility at Oroville provides an excellent outreach and educational opportunity.

Butte

The primary concern in the Butte HUCs is ensuring passage through smaller instream structures up to Centerville Dam, especially White Mallard Weir. Passage over or removal of Centerville Dam is also under consideration, which would open the upper drainage to lampreys.



Figure 5. Fish Barrier Dam below Oroville Dam on the Feather River adjacent to the Feather River hatchery.

Mill - Deer - Big Chico

The Mill-Big Chico HUC includes three relatively large eastern tributaries of the Sacramento: Mill, Deer and Big Chico creeks. These drainages are not blocked by the large storage dams present on many Sierran streams and generally still have relatively natural flow regimes above the valley floor. The primary concerns in the HUC are with smaller instream structures, some of which have been designed to incorporate lamprey passage needs (Figure 6). Proposed implementation projects focus on passage assessments, improvements and monitoring of upstream distribution.

Upper and Lower Cow - Lower Clear

The Upper and Lower Cow - Lower Clear HUCs include a number of smaller Sacramento tributaries entering the mainstem below Shasta Dam. These include: Antelope, Paynes, Battle, Cow and Clear creeks. Only Clear Creek is blocked by a large dam (rm 18). The primary concerns in the HUCs are with smaller instream structures (Figure 7). Proposed implementation projects focus on passage assessments, improvements and monitoring of upstream distribution. Two facilities are also proposed for enhancement as adult lamprey monitoring stations, on Battle Creek at the Coleman hatchery and on lower Clear Creek.



Figure 6. Ward Weir on lower Mill Creek with new lamprey-friendly fishway structure. Note weirs have rounded tops to provide lamprey climbing routes and are v-shaped to provide low velocity climbing routes at a range of streamflows. However, many other fish passage facilities in the Sacramento RMU do not provide lamprey friendly passage routes.



Figure 7. Sheetpile structure on lower Clear Creek to protect irrigation siphon below streambed. This structure may pose an obstacle to upstream lamprey migration and reduce their ability to reach upstream habitats.

Cottonwood - Elder - Thomes - Stony

The four principal drainages in these HUCs are all western tributaries of the Sacramento: Cottonwood, Elder, Thomes and Stony creeks. They drain the arid eastern slopes of the coast ranges, have low summer flows and are generally seasonal in their lower reaches. Only Stony Creek has a large dam (Black Butte) blocking its upper reaches. The other streams have relatively natural stream flows above the valley floor and are occupied by Pacific Lamprey.

No specific implementation projects are proposed for these drainages at this time, although general surveys of distribution and habitat conditions would be useful. They will also benefit from projects focused on broader RMU issues, such as entrainment at the large Delta facilities, metapopulation dynamics, non-native predators, as well as continued outreach and inclusion of Pacific Lamprey in management planning.

Cache

Cache Creek flows out of Clear Lake and provides connectivity to that basin as well as the North Fork Cache Creek and Bear Creek drainages. The lower reaches of Cache Creek are seasonal and highly modified, but the upstream foothill habitats and potentially Clear Lake itself would provide suitable habitat. Access to upper Cache Creek is blocked by diversion structures in the Yolo Bypass (see mainstem Sacramento), the Cache Creek Settling Basin and Capay dam (Figure 8). Implementation projects for Cache Creek focus on passage through these structures that block the migration corridor into the upper drainage.



Figure 8. Capay Diversion Dam on lower Cache Creek. Capay Dam is one of several passage obstacles blocking Pacific Lamprey from historical habitat in Cache Creek.

Putah

The lower reaches of Putah Creek are included in the Lower Sacramento HUC. Putah Creek itself is blocked about 30 miles upstream from the Sacramento by Monticello Dam and Lake Berryessa. Additional minor structure downstream may impede passage. The primary concerns in the lower stream reaches are passage and water quality due to flow management. It is not clear what routes Pacific Lamprey use to enter Putah Creek. No specific implementation projects are proposed for Putah Creek at this time, although general surveys of distribution, habitat conditions and potential passage challenges or entry routes would be useful. Putah Creek will also benefit from projects focused on broader RMU issues, such as entrainment in both small diversions and the large Delta facilities, metapopulation dynamics, non-native predators, as well as continued outreach and inclusion of Pacific Lamprey in management planning.

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Appendices

Appendix A. Stakeholder implementation meetings and workshops

Meeting Type	Location	Date
Threat Assessment	Sacramento	September 15, 2009
	Tracy	June 9, 2011
	Stockton	June 7, 2011
Implementation plan		May 10, 2016
	BOR, Fresno, Don Portz	8-Aug-17
	CDFW LaGrange	9-Aug-17
	EBMUD, Lodi	10-Aug-17
	USFWS	
Site Visits	CDFW Clifton Fish Screens	19-Jan-12
	BOR Tracy fish screens	20-Dec-15
	Granlee's diversion, Cosumnes	16-Dec-16
	Merced confl., Halls Ferry	8-Aug-17
	Eastside Bypass, culvert site	8-Aug-17
	Mariposa Bypass, at Eastside B	8-Aug-17
	Eastside Bypass, control structure	8-Aug-17
	Sack Dam, Henry Miller I.D.	8-Aug-17
	Mendota Weir	8-Aug-17
	San Mateo Rd. crossing culverts	8-Aug-17
	Skaggs Bridge	8-Aug-17
	Lost Lake Park	8-Aug-17
	Friant Dam	8-Aug-17
	Woodbridge	9-Aug-17
Workshop	Tracy	January 19, 2012
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

Status

Status

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

Work in Progress: Brief description of current work underway or completed

Implementing Entity: Lead entity, and partners

Contact: Primary contact for threat or action

Cost: Approximate (this is difficult)

Funding Source: Current or potential

Funds available: Percent (%) of total cost

Stakeholders: Involved/effected parties - not necessarily implementer or funder

Notes:

Appendix C. Proposed implementation tasks and needs - Sacramento.

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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