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

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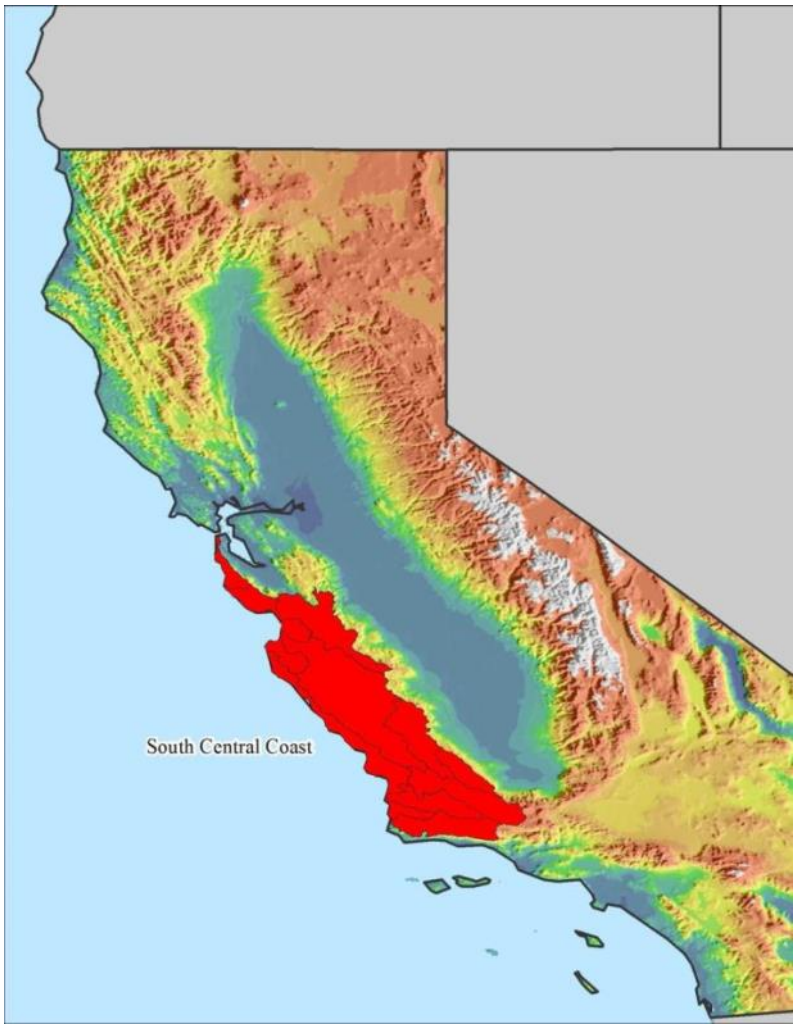

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Acronym List

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
NOAA	National Oceanographic and Atmospheric Administration
P.G.&E	Pacific Gas and Electric Company
PLCI	Pacific Lamprey Conservation Initiative
RM	River Mile
RMU	Regional Management Unit
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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Introduction

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

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

It is the USFWS's strategy to improve the status of lampreys by proactively engaging in a concerted conservation effort. This collaborative effort, through the development and implementation of the Pacific Lamprey Conservation Initiative (PLCI) initiated in 2004, will facilitate opportunities to address threats, restore habitat, increase our

knowledge of Pacific Lamprey, and improve their distribution and abundance in the United States portion of their range. The approach of the PLCI is to use the best scientific and empirical information available to assess current issues affecting the viability of Pacific Lamprey throughout its range in the western United States, to resolve knowledge gaps that limit our ability to conserve the species and to identify the specific conditions that must be addressed in order to conserve both regional and local populations. This document reviews risks identified 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 subregional plans will be incorporated into a regional plan for the whole of California and coordinated with implementation efforts in other regions.

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. 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 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 experience, conservation concerns and suggestions for information needs and conservation actions (see Figure 2 and Appendix A for stakeholder meetings and workshops). Outreach and information gathering included 17 stakeholder meetings or workshops and included 46 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

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

Prioritization of conservation actions is facilitated through the implementation database by inclusion of separate factors that may guide selection of individual projects. Priorities will be influenced by such factors as the specific needs of Pacific

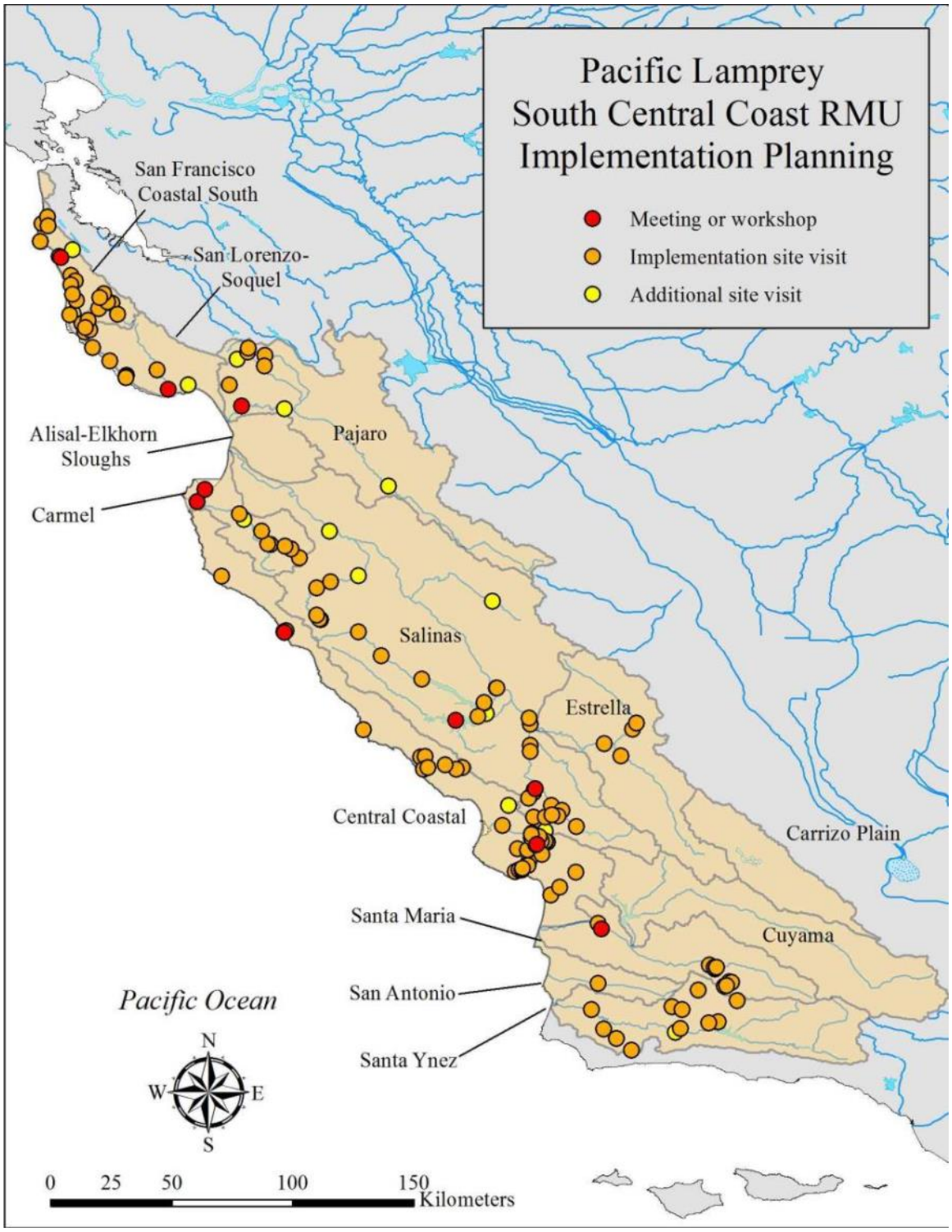

Figure 2. Map of stakeholder meetings, workshops, and site visits which informed the development of the South Central Coast implementation plan.

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.

South Central Coast RMU - Status and distribution of Pacific Lamprey

The South Central Coast Regional Management Unit (RMU) includes all coastal drainages from the Golden Gate Bridge to Point Conception, including the coastal portion of the San Francisco Bay and most of the Central California Coastal USGS accounting units (Figure 3). It includes 13 watersheds (4th field HUCS), ranging from 574 - 8,519 km^2 (Table 1). The subregion occupies the Coast Range and Southern and Central Californian Chaparral / Oak Woodlands ecoregions. The population status and distribution of Pacific Lamprey in the South Central Coast RMU are reviewed below and in Table 1 (adapted from 2012 Assessment with current information).

Historical Range Extent

Pacific Lamprey are assumed to have been widely distributed historically and abundant in the South Central Coast drainages, based on historical records, current distribution, available habitat and lack of natural barriers. Abundances may have been naturally lower in some of the arid southern HUCs (i.e., Estrella, Santa Maria, Cuyama, San Antonio, and Santa Ynez), but we have no accurate records of population abundance before recent declines.

Current Occupancy

Lamprey currently occupy most anadromous habitat in the subregion north of Big Sur, except perhaps the higher gradient reaches of smaller tributaries and smaller coastal streams flowing directly to sea. However, recent surveys indicate that lampreys have disappeared from all coastal streams south of the Big Sur River (Reid and Goodman 2012; unpub. data). Furthermore, even occupied drainages have had major habitat loss by impassable dams and desiccation of habitat by reservoir management, diversions, and groundwater pumping (see Threats below).

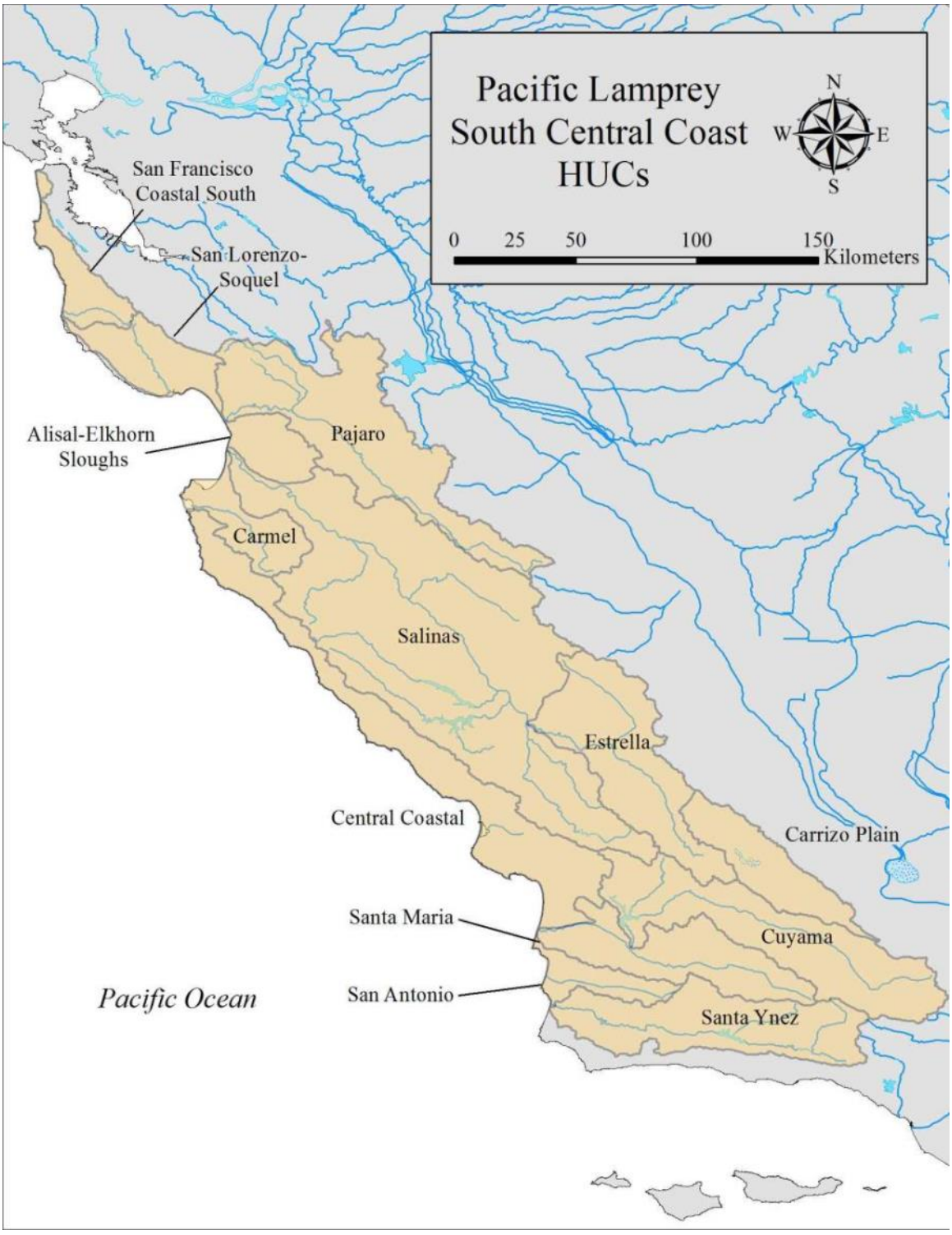

Figure 3. Map of the South Central Coast Regional Management Unit (RMU) and its watersheds (4th field HUCs).

Table 1. Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the South Central Coast RMU**.** Unoccupied HUCs are included for reference - historically non-anadromous HUCs are indicated by "N/A", and drainages (HUCs) isolated by impassable dams, desiccated, or thought to be unoccupied based on recent surveys are indicated as Extinct? NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure. [from Goodman and Reid 2012]. Unkn. indicates unknown.

S. CENTRAL COAST		Distribution				Max. Threats		
Watershed	HUC	Max. Historical (km^2)	Ratio Current/ Historical	Population Size (#)	Short-Term % Decline	Scope	Severity	Risk Rank
S.F. Coastal South	18050006	662	0.75	Unkn.	Unkn.	Mod.	Mod.	S2
San Lorenzo-Soquel	18060001	937	0.75	Unkn.	Unkn.	Mod.	Mod.	S2
Pajaro	18060002	3,354	0.75	Unkn.	30 - 50%	Mod.	Mod.	S3
Carrizo Plain	18060003	N/A	-	-	-	-	-	-
Salinas	18060005	8,519	0.25	Unkn.	Unkn.	Mod.	Mod.	S2
Estrella (trib. Salinas)	18060004	2,466	0.001	Extinct?	-	High	High	SH
Alisal-Elkhorn Sloughs	18060011	613	0.75	Unkn.	Unkn.	High	High	S2
Carmel	18060012	832	0.50	Unkn.	Unkn.	Mod.	Mod.	S2
Central Coastal	18060006	2,815	0.10	< 250	70 - 99%	High	High	S1
Cuyama (trib. S.M.)	18060007	2,956	0.001	Extinct?	70 - 99%	High	High	SH
Santa Maria	18060008	1,764	0.001	Extinct?	70 - 99%	High	High	SH
San Antonio	18060009	574	0.001	Extinct?	70 - 99%	High	High	SH
Santa Ynez	18060010	2,334	0.001	Extinct?	70 - 99%	High	High	SH

Many of the smaller coastal streams (< 100km drainage area) in California are not currently occupied, and there is evidence that there may be a natural tendency of lamprey to avoid smaller drainages that directly enter the sea (Reid and Goodman 2015; unpub. data). This may have been the case prior to the 1950s as well (Shapovalov and Taft 1954), and is currently being explored by the authors.

Ratio of Current Occupancy to Historical Range Extent

As a result of extensive range contraction in the south, streambed desiccation, and elimination of upstream habitat by impassable dams, the ratio of current to historical habitat has been substantially reduced by 25 to 90% in all occupied HUCs and five of twelve HUCs do not currently contain viable populations.

Population Size

Population size (adults) in the RMU, similarly to all other areas, is poorly understood and not monitored. The only relative certainty is that five HUCs no longer contain viable populations.

Short Term Trend

Recent surveys and lack of incidental observations along the coast south of Monterrey have documented the complete loss of populations recorded in the 1970s and, more recently, the loss of the San Luis Obispo population at some time between 2005 and 2011 (Goodman and Reid 2012; unpub. data). Declines in occupied HUCs north of Big Sur may be similar to those in the North Coast RMU and Oregon Coast at Winchester Dam on the North Fork Umpqua River (Goodman and Reid 2012). However, the lack of monitoring of adult migrations makes any quantification of population trends impossible.

NatureServe Risk Ranks

NatureServe risk ranks varied from imperiled to vulnerable (S2-S3) north of Big Sur, with the Central Coastal HUC ranked Critically Imperiled (S1) due to the rapid loss of populations and other threats. Populations in all HUCs are subject to metapopulation declines caused by regional threats outside the watershed. See discussion of threats below.

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

Threats and limiting factors to Pacific Lamprey in the South Central Coast RMU are provided in Table 2 for the principal five threats, also discussed below. The remaining threat categories were either of low risk throughout the RMU or were not considered in this assessment as a whole due to lack of information (see discussion under Goodman and Reid 2012, Chap. 4 - California Regional Summary: Small Population Size, Disease, Lack of Awareness, Ocean Conditions, and Climate Change). Populations in all HUCs are subject to metapopulation declines caused by regional threats outside the watershed.

Pacific Lamprey have apparently disappeared from all South Central Coast drainages south of Big Sur at this time. Therefore, those HUCs were assessed for threats that would prevent lampreys from recolonizing or affect populations were they to become reestablished. The principal threats to lampreys along the South Central Coast were passage, dewatering of streams, natural aridity, and flow management that results in flow events that trigger emigration of macrophthalmia not reaching the ocean or providing insufficient flow to open the river mouth for in-migrating adults. In only three HUCs was passage not considered a major threat, but in these dewatering and low flow conditions restricted access to much of the drainage. Poor water/habitat quality, primarily associated with higher temperatures and low or seasonal flows,

Table 2. Principal threat rankings, maximum threat level, and NatureServe risk ranks for Pacific Lamprey within the South Central Coast RMU. See map, Figure 3. Historically non-anadromous HUCs are indicated by "N/A" and included for reference. 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. WQ= water quality.

			Individual Threats (Scope - Severity)				
Watershed	**Risk Rank**	**Max. Threat**	**Passage**	**Dewater /Flow**	**Stream Degradation**	**WQ**	**Predation**
San Francisco Coastal South	S2	C	3 - 3	2 - 2	2 - 2	2 - 2	2 - 1
San Lorenzo-Soquel	S2	C	3 - 3	2 - 3	2 - 2	3 - 2	2 - 1
Pajaro	S3	C	3 - 3	3 - 3	2 - 2	4 - 2	2 - 1
Carrizo Plain	NA	-	-	-	-	-	-
Salinas	S2	C	3 - 3	3 - 3	2 - 2	4 - 2	2 - 1
Estrella (trib - Salinas)	SH	A	1 - 1	4 - 4	2 - 2	4 - 2	1 - 1
Alisal-Elkhorn Sloughs	S2	A	2 - 2	4 - 4	3 - 4	4 - 4	2 - 1
Carmel	S2	C	3 - 3	3 - 3	2 - 2	4 - 2	2 - 1
Central Coastal	S1	A	3 - 3	2 - 4	2 - 2	4 - 2	2 - 1
Cuyama (trib - Santa Maria)	SH	A	4 - 4	4 - 4	2 - 2	4 - 2	2 - 1
Santa Maria	SH	A	1 - 2	3 - 3	2 - 2	4 - 3	2 - 1
San Antonio	SH	A	4 - 4	3 - 3	2 - 2	3 - 2	2 - 1
Santa Ynez	SH	A	4 - 4	4 - 4	2 - 2	4 - 2	2 - 1

was also a concern in two HUCs. The absence of resident lamprey populations in the southern streams also present a barrier to future recolonization due to the absence of ammocoete pheromones to attract migrating adults into the drainage, while low adult numbers reduce the probability of encounter with potential mates if an adult does enter the drainage.

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

Passage was ranked as a major threat in four HUCs containing major dams or passage barriers that block nearly all suitable habitat in the drainages (ranked 4-4) and in four HUCs containing major dams that block a substantial portion of suitable habitat in the drainages (ranked 3-3). Two HUCs just south of the Golden Gate (San Francisco Coastal South and San Lorenzo-Soquel) had a number of smaller passage barriers (e.g., culverts and weirs) that restricted passage in a substantial portion of suitable habitat in the drainages (also ranked 3-3). Otherwise, passage concerns in remaining watersheds are generally limited to culverts and smaller diversions on tributaries and were ranked low in scope. Passage not considered a major threat in only three HUCs.

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

The southern portion of the central coast, south of Santa Cruz is naturally arid and the extensive use of water for agricultural and urban purposes in most HUCs further exacerbates adverse conditions in local streams. In the Salinas and Carmel rivers, the former by far the largest drainage basin in this subregion, high permeability of the sandy lower reaches combined with heavy agricultural groundwater pumping results in periods where the river channel has long dry reaches. These dewatered reaches limit access by adults to upstream spawning habitat and periodically cause mass mortalities of emigrating juveniles when flows, even during periodic storm events, do not reach the sea. In the Big Sur River, groundwater pumping in the lowest reach contributes to seasonal desiccation of the low gradient, rearing reach below Highway One. Reservoir management and agricultural use of water in the Pajaro, Salinas, Carmel, Cuyama (Santa Maria tributary), and Santa Ynez also severely reduce the available perennial upstream habitat for rearing ammocoetes.

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

Many South Central Coast streams are highly impacted by agriculture and water management. Nevertheless, there remains considerable habitat in most HUCs that would be relatively suitable for lampreys, and stream habitat degradation was generally not considered a major threat in this subregion.

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

South Central Coast includes major agricultural and moderate to minor urban areas, and as such, has water quality issues with contaminants, although the effects on local lamprey populations has not been evaluated. However, higher water temperatures, low flow conditions, eutrophication, high algal density, and associated dissolved oxygen problems, especially in sediments occupied by ammocoetes, were ranked as a major threat in Alisal-Elkhorn Slough and as low to moderate threats elsewhere.

Predation

Non-native predatory fishes are present in some HUCs, but were not considered a major threat to lamprey populations. Sacramento Pikeminnow, *Ptychocheilus grandis*, (native to the Pajaro and Salinas drainages) have become established in Chorro and Los Osos creeks, the two principal tributaries to Morro Bay (Central Coast HUC). Large pikeminnow are piscivorous and are known to consume juvenile lampreys (Nakamoto and Harvey 2003). However, the impact of predation by pikeminnow on local lamprey populations is not known and may be ameliorated by downstream migration during periods of high flow and turbidity (Goodman et al. 2015, in prep.). The two species are sympatric throughout much of the region, and the effect on Morro Bay populations is not known, particularly as neither creek is currently occupied by lampreys. Seals and sea lions are known to feed on migrating runs of adult lampreys near the mouths of rivers (Klamath and Rogue). However, the

nature or severity of pinniped predation in southern streams has not been assessed. Predation threats were ranked as Unknown, although they are proposed for assessment.

Small Effective Population Size

Small effective population size was ranked as a substantial threat (high scope and severity) in populations south of Big Sur (Central Coastal HUC) due to the apparent absence, or extremely low abundance, of ammocoetes in all southern HUCs. Absence of ammocoete pheromones reduces or eliminates attraction of migrating adult Pacific Lamprey into the drainage (see Chap. 2 Biology), hindering reestablishment of the population. Extremely low adult numbers also reduce the probability of encounter with potential mates if an adult does enter the drainage.

South Central Coast RMU – Implementation Plan

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

General Conservation Needs within the South Central Coast RMU

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

Coordination

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

A specific regional focus is proposed for coordination with other passage stakeholders (e.g., USBR, CalTrans, CDFW, Pacificorp, P.G.&E, and USFWS) to ensure lamprey consideration in existing passage structures, as well as current and future projects. Passage obstruction has been identified as one of the primary threats to Pacific Lamprey region-wide, isolating over 40% of potential anadromous habitat and eliminating the ecological role of Pacific Lamprey in reaches above barriers.

Furthermore, active passage programs/projects focusing on salmonids often ignore the needs of, or actively block, lampreys due to their design and/or management.

A specific regional focus is also proposed for increasing awareness of adverse impacts caused by surface diversions, groundwater pumping, and nutrient inputs in the South Central Coast RMU. Unregulated water withdrawals reduce flows in or even fully dry up both mainstems and smaller tributaries. Even a short term loss of surface flow is lethal to ammocoete populations, resulting in the local loss of up to seven year classes. Higher temperatures caused by lower flows and increased nutrient loading promoting algal blooms in mainstem rivers further degrade habitat used by over-summering adults and ammocoetes, who cannot tolerate anoxic sediments. In some South Central Coast drainages (e.g., Salinas and Carmel rivers), loss of surface flow prevents emigrating juveniles from reaching the ocean and results in major mortality events. Reduced winter flows also reduce or delay the time the river mouth is open to the sea, affecting in-migrating adults and emigrating macrophthalmia.

General research needs

Passage: Although passage obstruction is identified as a primary threat to Pacific Lamprey region-wide, there is limited information on how lampreys move past barriers or how to design instream structures to facilitate lamprey passage. Therefore, a number of basic research goals will investigate and develop designs or management approaches for passage at culverts, low-head dams or weirs, and fish ladders. Other projects include investigation of entrainment risk from small-scale (<4") unscreened pumping stations and development of downstream passage/screening criteria for ammocoetes and emigrating juveniles.

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

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

Due to our currently limited understanding of the specific distribution and population dynamics of Pacific Lamprey, distributional surveys of ammocoetes, adult spawning

areas, and over-wintering habitat, as well as adult population censusing and assessment of emigration timing for macropthalmia, are recommended for each occupied HUC. Although these surveys are common to all HUCs, they are specified individually for each in the database due to differences in threat level, stakeholders and project development, and to facilitate progress monitoring within HUCs.

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

Below are brief summaries of principal implementation needs and proposed projects in each of the South Central Coast HUCs. Details are available in the Implementation Database.

San Francisco Coastal South

This HUC includes a series of small drainages along the coast south of the Golden Gate to Pescadero Point. Only three drainages have historic or current records of Pacific Lamprey: Pescadero (211 km^2), San Gregorio (135 km^2), and Pilarcitas (75 km^2), with Pescadero, the largest, and also the only drainage currently with a substantial population of Pacific Lamprey (Reid et al. 2012).

The primary concerns in the HUC are identification and resolution of any potential passage constraints in the three principal drainages, as well as determination of causal factors for limited populations or apparent absence, respectively, in the San Gregorio and Pilarcitas drainages. Additional actions are for monitoring the Pescadero population and determining timing of adult immigration and macropthalmia emigration (Figure 4).

San Lorenzo-Soquel

This HUC includes a series of small drainages along the coast from Pescadero Point south to the Pajaro River. It is probable that, at most, three drainages are large enough to attract Pacific Lamprey: San Lorenzo (378 km^2), Soquel (128 km^2), and Aptos (72 km^2). Pacific Lamprey were encountered in recent surveys of the San Lorenzo River and Soquel Creek (Goodman and Reid unpub. data); there are no current or historical records of lamprey in Aptos Creek (Shapovalov and Taft 1954).

The primary concerns in the HUC are identification and resolution of any potential passage constraints in the three principal drainages. Additional actions are for monitoring the San Lorenzo population and determining timing of adult in-migration and emigration of macropthalmia.

Figure 4. Pescadero Creek, at Memorial County Park weir. This site could be modified to monitor population trends and restoration effects. Photo October 2012.

Pajaro

The Pajaro River drainage is a relatively large HUC, including the Pajaro and its most extensive tributary the San Benito River. However, the majority of perennial flow is in the lower mainstem and tributaries draining the southern Santa Cruz mountains (Corralitos, Uvas, and Llagas creeks being the largest). Both Uvas and Llagas creeks have large impassable dams in the upper reaches (Figure 5). The San Benito and eastern tributaries of the Diablo Range are generally minor or seasonal streams and are not especially suitable for Pacific Lamprey. Although the San Benito does contain a resident brook lamprey (*Lampetra* c.f. *pacifica*), there are no records of Pacific Lamprey.

The mainstem Pajaro is heavily impacted by agriculture. Therefore, principal concerns for the mainstem Pajaro are associated with WQ and its effects on ammocoete rearing and adult holding habitats. In the two dammed tributaries (Uvas and Llagas creeks), proposed actions involve potential passage opportunities and flow management issues downstream of the dams. Additional actions for the mainstem and major tributaries include survey assessments of smaller passage barriers and distribution.

Figure 5. Uvas Dam on the Uvas Creek a tributary to the Pajaro River. Uvas dam blocks passage to historical habitats and should be evaluated for potential to provide passage and incorporate Pacific Lamprey into streamflow management decision-making. The photo is looking downstream from the top of the reservoir overflow channel. Photo taken in August 2013.

Salinas

The Salinas River, including the Estella sub-basin (see below), is the second largest coastal drainage in California. The basin is generally arid. However, the Salinas valley and coastal plain support one of the country's major agricultural areas, as well as the Salinas urban area and numerous smaller towns. The natural aridity of the

basin and considerable agricultural and urban demands cause the mainstem river to dry up along much of its length. Flow is heavily managed in the system, with major water storage dams on the upper Salinas and two of three major tributaries (Nacimiento and San Antonio rivers). The third principal tributary, Arroyo Seco, is undammed but has groundwater extraction demands for agriculture in the lower reaches where it generally goes dry in the late summer. Water stored in the dams is used to recharge the groundwater basin in the lower valley, and many flow events

never reach the mouth, leaving a dry reach and stranding emigrating macropthalmia (Figure 6).

The principal concerns in the Salinas are flow management below the dams and in the mainstem, as well as passage into the upper basin. Proposed actions include development of improved flow management, inclusion of lamprey migration periods (in-migrating adults and emigrating macropthalmia) into flow decision-making, and mitigation measures to prevent mortality events driven by insufficiency and timing of flows. Additional actions include removal of the dams in the upper Salinas mainstem, survey of the populations below the two tributary dams, and monitoring of the undammed Arroyo Seco population, determining timing of adult in-migration, spawning, and emigration of macropthalmia.

Estrella (tributary to Salinas)

The Estrella River is a major eastern tributary drainage to the Salinas. However, at this time, and probably historically, the sand-dominated mainstem and its tributaries are intermittent and generally dry (Figure 7). There are no historical records of lamprey in the HUC, and it could not currently support lampreys without major changes to its flow characteristics.

The principal recommended action at this time is assessment of possible causes of current and possible historic channel dewatering in the Estrella River mainstem to determine whether establishment of permanent flow is feasible.

Figure 6. Pacific Lamprey macropthalmia stranded in the mainstem Salinas River during their migration toward the Pacific Ocean (photo courtesy of California Department of Fish and Wildlife). Mass mortality events highlight the need to incorporate lamprey into streamflow management decision-making. Photo taken in March 2012.

Figure 7. The mainstem Estrella River a tributary to the Salinas River. The Estrella currently lacks perennial streamflow and is therefore not suitable for Pacific Lamprey. Photo taken in March 2013.

Carmel

The Carmel River is the southernmost substantial drainage currently occupied by Pacific Lamprey - the only known population to the south is in the Big Sur River. The lower drainage is agricultural and urbanized, with associated water demands that are generally fulfilled by groundwater pumping. The mainstem Carmel is blocked by two major dams (San Clemente and San Pedro) at RM 18 and RM 25, respectively (Figure 8). The San Clemente Dam is in the process of being removed. Most Carmel tributaries, with the exception of San Clemente Creek, are probably too small, high gradient or seasonal to provide substantial habitat, but most have not been surveyed for lampreys.

The principal concerns in the Carmel are mainstem passage and flow management. In the lower river flow events are often insufficient to reach the mouth, resulting in mass mortalities of emigrating macropthalmia. Proposed actions are focused on the mainstem. In the upper reaches, they include removal of the dams and monitoring of recolonization in the upper drainage. In the lower reaches, proposed actions include development of improved flow management, inclusion of lamprey movement periods into flow decision-making, and mitigation measures to prevent mortality events driven by insufficiency and timing of flows.

Figure 8. San Clemente Dam on the Carmel River. Passage above the dam will provide an additional 7 miles of mainstem habitat, an implementation action that is currently underway (Photo curtesy of the San Clemente Dam removal project).

Central Coastal

This HUC includes a series of relatively small drainages ($\leq$ 396 km^2) along the coast south of the Carmel River to the Santa Maria River. Six drainages have historic or current records of Pacific Lamprey. The only current population is in the Big Sur River (151 km^2) (Figure 9). San Luis Obispo, the second largest drainage (225 km^2), is the only additional drainage with a substantial population of Pacific Lamprey documented in the last decade. Pacific Lamprey are no longer present in the drainage (Reid et al. 2012) (). Historical records from the 1970s, or earlier, document lampreys in Little Sur River (107 km^2), Big Creek (58 km^2), San Carpoforo (92 km^2), and Arroyo de la Cruz (112 km^2).

Figure 9. Pacific Lamprey habitat in the relatively pristine Big Sur River. Although Pacific Lamprey recently occupied streams as far south as Mexico, their range has contracted, with the Big Sur now representing the southern limit of their current distribution. Photo taken in June 2004.

The primary concerns in the HUC are groundwater pumping in the Big Sur (Figure 10), identification and resolution of any potential passage constraints in the principal drainages to allow for successful recolonization, as well as determination of causal factors for the loss of historical populations along this section of the coast (Figure 11). A suite of actions is proposed for the reintroduction of Pacific Lamprey into the San Luis Obispo drainage and monitoring of the population to gain information for potential reintroductions in other drainages. Additional actions proposed are for monitoring the Big Sur population and determining timing of adult in-migration, spawning, and macropthalmia emigration.

Figure 10. Well pump on lower Big Sur River. Groundwater pumping is increasing desiccation of crucial low gradient rearing habitat below Highway 1.

Cuyama (tributary to Santa Maria)

The Cuyama River is a tributary to the Sisquoc-Santa Maria River. At this time most of the drainage is blocked by the Cuyama Dam about 8 miles upstream from its confluence with the Sisquoc River, where the two join to form the Santa Maria. The reservoir is part of the Santa Maria Project and is used primarily to store water for subsequent release to refill the Santa Maria Valley ground-water reservoir. No historical records exist for lamprey in the Cuyama Drainage, and they are not currently present below the dam. The principal recommended action at this time is an assessment and survey to evaluate suitability and feasibility of the drainage for Pacific Lamprey, both above and below the dam.

Santa Maria

The Santa Maria River is formed by the confluence of the Sisquoc and Cuyama rivers and extends for 40 km before reaching the Pacific Ocean. The Santa Maria is frequently dry under current management, acting only as a migration corridor to the Sisquoc during storm flow events. The Sisquoc River lies primarily in the Los Padres National Forest and is unimpeded above the forest boundary (Figure 12). The drainage is naturally arid, with the lower reaches impacted by groundwater pumping and may contain perennial reaches only during wet years. The other principal constraint on lamprey usage is access from the sea along the Santa Maria corridor. Initial surveys of reported trout habitat in the upper reaches of tributaries

Figure 11. The Marre Tidal Weir at the San Luis Obispo Creek estuary. The weir was modified in 2006 to provide improved passage for coastal Rainbow Trout. Unfortunately, the design likely excluded Pacific Lamprey and may have extirpated the population. Photo taken in March 2012.

(e.g., Manzana Creek) indicates that the tributary habitat is generally too high gradient, seasonal, and lacking in fines to support lampreys, resulting in prioritization of the Sisquoc mainstem habitat which, when perennial, offers suitable habitat. There are no historical records of lamprey from the Santa Maria system, although its size suggests that it would have supported lampreys in the past, prior to major flow alterations.

The principal concern in the Santa Maria - Sisquoc is mainstem flow management to provide access to in-migrating adults and prevent stranding of emigrating

San Antonio

The San Antonio is the smallest HUC in this RMU and lies between the Santa Maria and Santa Ynez basins. No historical or current records exist for Pacific Lamprey in the HUC.

The principal recommended action at this time is a survey to evaluate suitability of the drainages for Pacific Lamprey and possible presence, as well as an assessment of

Figure 12. Surveying for Pacific Lamprey in isolated perennial pools, Sisquoc River.

possible mainstem passage barriers, including the frequency at which the mouth is typically open.

Santa Ynez

The Santa Ynez River is the southernmost major drainage above Point Conception. It is now blocked by a series of dams that are primarily used to supply municipal communities along the coast and local agriculture. The lowest in the system is the Bradbury Dam at RM 49. Below the dam, the principal constraints on lamprey usage are access from the sea along the mainstem corridor due to limited flow and restricted perennial habitat for rearing, although the perennial reaches below the dam appear to offer suitable habitat. Pacific Lamprey historically used the river, and adults were reported at the base of Cachuma Dam (constructed in 1950) at least as late as 1978.

The principal concern in the Santa Ynez at this time is mainstem flow management below the dam to provide access to in-migrating adults and prevent stranding of emigrating macropthalmia, should a population become reestablished, as well as expanding available rearing habitat in the lower river. Proposed actions are focused on the mainstem and include understanding current and historical flow management, inclusion of lamprey movement periods into flow decision-making, and mitigation measures to prevent mortality events driven by insufficiency and timing of flows. Additional actions include survey and monitoring of suitable habitat for ammocoetes below the dam, as well as assessments of potential passage over the Bradbury Dam and habitat suitability surveys above the dam.

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Appendices

Appendix A. Stakeholder implementation meetings and workshops

Meeting Type	Location	Date
Risk assessment	Sacramento	Sept. 1-2, 2009
	San Luis Obispo	May 18, 2011
	Monterey	Jul. 6, 2011
	Santa Cruz	Jul. 7, 2011
Implementation plan	San Luis Obispo	Mar. 28, 2012
	Atascadero	Mar. 29, 2012
	Nacimiento	Sept. 13, 2012
	Half Moon Bay	Oct. 11, 2012
	San Francisco	Oct. 12, 2012
	Big Creek	Jun. 1, 2012
	Ventura	Sept. 11, 2012
	San Luis Obispo	Aug. 7, 2013
	Santa Maria	Aug. 17, 2013
	San Luis Obispo	Jul. 14, 2014
	Carmel	Jul. 17, 2014
	Wilsonville	Jul. 17, 2014
Lamprey summit	Portland	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 - South Central Coast.

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

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