Pacific Lamprey (*Entosphenus tridentatus*) Assessment and Template for Conservation Measures in California

Region 8
U.S. Fish and Wildlife Service
Sacramento, California

(August 2012)

DISCLAIMER

The Pacific Lamprey Assessment and Template for Conservation Measures for California was written with the most current information available at the time, gathered at regional stakeholder meetings hosted throughout the California range of Pacific Lamprey in 2009-2012. Any new information will be incorporated into subsequent revisions of the Assessment and into the Regional Implementation Plans.

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ACRONYM AND SYMBOL LIST

BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BPA	Bonneville Power Administration
CBFWA	Columbia Basin Fish and Wildlife Authority
CBWTP	Columbia Basin Water Transactions Program
CDFG	California Department of Fish and Game
CRBLTWG	Columbia River Basin Lamprey Technical Workgroup
CRITFC	Columbia River Inter-Tribal Fish Commission
EPA	Environmental Protection Agency
ESA	U.S. Endangered Species Act
FERC	Federal Energy Regulatory Commission
FY	Fiscal Year
GIS	Geographic Information System
HCP	Habitat Conservation Plans
HUC	Hydrologic Unit Code (USGS)
ID	Identification
ISAB	Independent Scientific Advisory Board
IUCN	International Union for Conservation of Nature
MOA	Memorandum of Agreement
mtDNA	Mitochondrial DNA
Ne	Effective population size
NF	North Fork
NMFS	National Marine Fisheries Service (NOAA)
NOAA	National Oceanographic and Atmospheric Administration
ODFW	Oregon Department of Fish and Wildlife
PLCI	Pacific Lamprey Conservation Initiative
PUD	Public Utility District
RKM	River Kilometer
RM	River Mile
RM&E	Research Monitoring and Evaluation
SIP	Steelhead Intrinsic Potential
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
USACE	United States Army Corp of Engineers
USBR	United States Bureau of Reclamation
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey
WRIA	Water Resource Inventory Area

EXECUTIVE SUMMARY

Results of the California Assessment under the Pacific Lamprey Conservation Initiative

This assessment indicates that Pacific Lamprey populations in California had been extirpated from at least 55% of their historical habitat north of Point Conception by 1985. The primary threat responsible for extirpations was large impassible dams, which excluded migrating adults from access to high quality spawning and rearing habitat in the foothills and higher elevations.

In southern California, recent surveys and review of available information also indicate that no viable populations of Pacific Lamprey currently occupy drainages south of the Big Sur River on the central coast. Some populations have been lost due to drainage-specific threats, however, there is also evidence for a general northward range contraction, perhaps caused by regional metapopulation dynamics.

Most of the remaining occupied California watersheds are rated at ‘imperiled’ or 'vulnerable' in the NatureServe rankings. This result suggests both the urgency for action and opportunities for recovery with implementation of appropriate conservation measures. The principal threats affecting many populations include passage barriers (mainstem and tributary), dewatering or flow management, and water quality/habitat issues associated with high water temperatures, low flow and nutrient loading. Additional threats, generally low to moderate in scope or severity, included stream habitat degradation, possible predation (varying by sub-region), and “small population” effects in the south. Ongoing actions such as distribution and habitat surveys, barrier removals, fish screening, and habitat restoration projects are assisting Pacific Lamprey restoration in all sub-regions. However, due to a focus on salmonid conservation in the region, there is a general lack of awareness or consideration for lamprey requirements in many projects, which can and has led to unintentional adverse effects.

Next steps— In the next stage of this project, we will use the combined results of the viability and threats assessments, as well as ongoing conservation measures, and discussions with stakeholders to develop a regional and watershed-based implementation plan to guide future conservation efforts and implementation projects that we believe should reduce risks to Pacific Lamprey, thereby promoting the conservation of the species range-wide. Continued outreach to stakeholders is crucial component of the implementation planning phase of this project.

Regional summary and overview of Pacific Lamprey Conservation Initiative Process

Although Pacific Lamprey were historically widespread along the west coast of the United States there is an observed decline in abundance and distribution throughout California, Oregon, Washington, and Idaho. Threats to Pacific Lamprey occur in much of the range of the species. The U.S. Fish and Wildlife Service (USFWS) recognizes the need for a comprehensive plan to conserve and restore Pacific Lamprey in collaboration with Native American tribes and other federal, state, and local agencies; and to further lamprey research and conservation actions throughout their native range. The Pacific Lamprey Conservation Initiative is the USFWS's strategy to improve the status of Pacific Lamprey throughout their range in the United States.

The approach of the Pacific Lamprey Conservation Initiative is a three part process: assessment and template for conservation measures (Assessment), conservation agreement, and regional implementation plans. This Assessment identifies critical uncertainties regarding the life history of Pacific Lamprey and improves our scientific understanding of Pacific Lamprey in the ecosystems of the western United States. In addition, the Assessment tracks the current knowledge of Pacific Lamprey habitat requirements; abundance; historical and current distribution; describes threats and factors for decline; and provides the basis for identifying conservation actions, research, monitoring and evaluation needs.

The development of this document relied on voluntary involvement of various federal, state, and local governmental agencies, Native American Tribes, scientific institutions, consultants, non-profit groups, utility companies, private landowners, and many others. The Assessment incorporates other plans and authorities applicable to Pacific Lamprey, and acknowledges that conservation cannot happen without all stakeholders.

To characterize the risk to Pacific Lamprey populations, the USFWS's Western Lampreys Conservation Team is conducting a range-wide assessment using a modified NatureServe ranking approach. The objective in using this assessment tool was to conduct a structured evaluation of existing data with the capability to incorporate and integrate both population data and threat information. This systematic analysis was conducted for discrete geographic groupings in Idaho, Oregon, Washington and California to rank the risk to Pacific Lamprey relative to their vulnerability of extirpation. Data used to rank geographic units included information on population abundance, distribution, population trend, and threats to lamprey. In several geographic areas, little information was available to identify population abundance and trend or to quantify threats to lampreys. In these cases, best professional judgment was used. The relative ranks of risk were calculated and summarized by sub-regional area in California. The risk results were used to identify and prioritize threats to Pacific Lamprey. We collected additional information to identify ongoing and needed conservation actions and research monitoring. The integration of this regional information and the resulting risk analysis will be used to inform the priorities for recommended conservation actions and development of conservation implementation plans.

1. INTRODUCTION

Historically Pacific Lamprey, *Entosphenus tridentatus*, were 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 as food for mammals, fish and birds, nutrient cycling and storage, and as a prey buffer for other species. Recent observations in the reduction of abundance and range of Pacific Lamprey have spurred conservation interest in the species, with increasing attention from tribes, agencies, and others.

In 2003 the 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 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 the 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. Thus, in December 2004, the USFWS determined that listing the Pacific Lamprey was not warranted (69 FR 77158).

It is the U.S. Fish and Wildlife Service's (USFWS) strategy to improve the status of lampreys by proactively engaging in a concerted conservation effort. This collaborative conservation effort, through the development and implementation of the Pacific Lamprey Conservation Initiative (PLCI), 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.

Problem: Rangewide Status of Pacific Lamprey

Pacific Lamprey were historically widespread along the west coast of the United States (Scott and Crossman 1973; Ruiz-Campos and Gonzalez-Guzman 1996), and as they overlap with several Endangered Species Act (ESA) - listed salmonids they may be vulnerable to many of the same threats. In particular, they appear to be declining in numbers due to: reduced quantity and quality of spawning and rearing habitats, passage issues associated hydropower and irrigation diversion such as obstruction, entrainment and mortality, a propensity for high predation risks, and a vulnerability to contaminants due to their life history (Beamish 1980; Beamish and Northcote 1989; Matter et al. 2000; Close et al. 2002; Moyle et al. 2009, Swift and Howard 2009). Although accurate abundance data for Pacific Lamprey are difficult to obtain, observational trends suggest that the current populations are declining from historical numbers in the Columbia River Basin and Pacific Coast streams from Washington to South of Point Conception in California (Figure 1-1; Close 2001; Moser and Close 2003; Luzier et al. 2009, 2011; Moyle et al. 2009; Swift and Howard 2009). In addition, Pacific Lamprey have been extirpated from many river basins (USFWS 2004a).

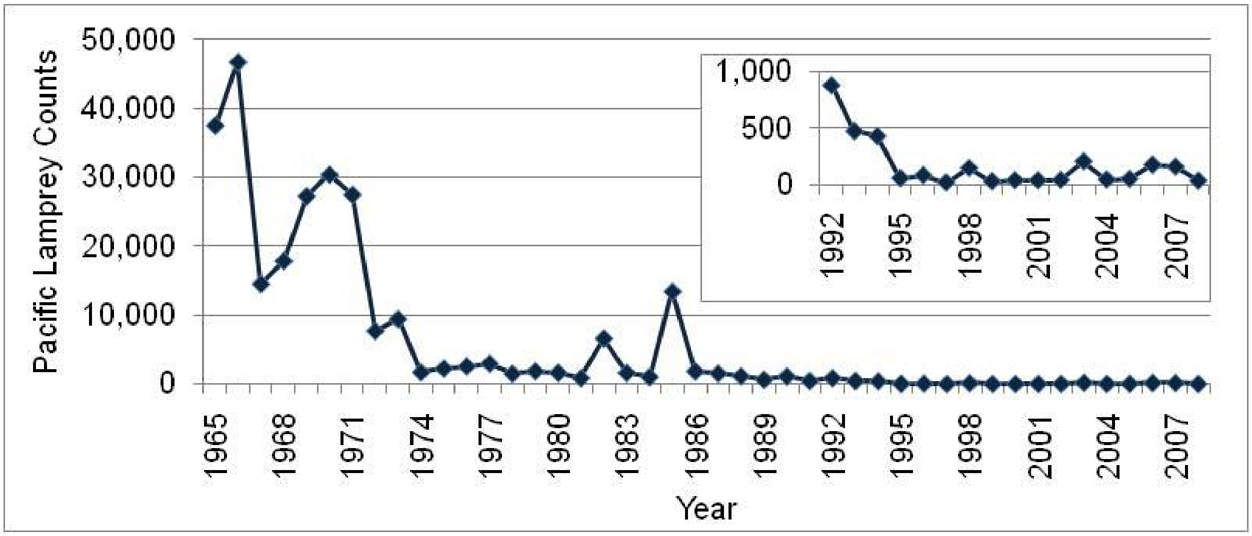


Figure 1-1. Counts of adult Pacific Lamprey between 1965-2008 at Winchester Dam on the Umpqua River, Oregon (data provided by ODFW). Embedded graph displays counts from 1992-2008 using finer vertical scale. [from Lampman 2011]

Description of the Pacific Lamprey Conservation Initiative

The USFWS has been committed to Pacific Lamprey conservation by engaging in activities including, but not limited to: conducting lamprey research, sponsoring and leading the Columbia River Lamprey Technical Workgroup, participating in Lamprey Tribal Summits, funding lamprey conservation actions and research, and partnering with tribes and other agencies to further lamprey research and conservation actions. Pacific Lamprey is a tribal trust species and as such the USFWS recognizes tribal treaty and other rights, interacts with tribes on a government to government basis, and strives to conduct its programs and actions in a manner that protects tribal trust resources, including fish and wildlife resources and their associated habitat.

The Pacific Lamprey Conservation Initiative (PLCI) is the USFWS's strategy to improve the status of Pacific Lamprey by coordinating conservation efforts among states, tribes, federal agencies, and other involved parties. This collaborative conservation effort will facilitate opportunities to address threats, restore habitat, increase our knowledge of Pacific Lamprey, and improve their distribution and abundance.

Purpose of the Pacific Lamprey Conservation Initiative

***Goal*.—**The purpose of the PLCI is to develop implementation plans and to help coordinate the full suite of actions needed to restore and sustain Pacific Lamprey populations throughout their range in the United States.

***Strategy*.—**The USFWS will act as coordinating agency to engage entities willing to participate, coordinate conservation efforts, facilitate increased knowledge about distribution, abundance, population structure, and threats, and work with partners in the development of regional implementation plans for restoring Pacific Lamprey populations. This will be accomplished through a variety of approaches including voluntary participation.

***Partnerships*.—**The development and implementation of the PLCI will be based upon the involvement of various federal, state, tribal, county and city biologists working with representatives of local watersheds, private landowners, industry, and conservation organizations. The PLCI is intended to be compatible with other Pacific Lamprey management plans throughout the species' range. It is intended to be consistent with other management strategies of federal, state and tribal natural resource management agencies and supportive of efforts aimed at the conservation and enhancement of Pacific Lamprey.

***Objectives*.—**The objectives of the PLCI are to:

1. Develop an assessment rangewide and regionally that includes:
    - An enhanced description and tracking of current knowledge of Pacific Lamprey life history, biology, and habitat requirements.
    - Identification of Pacific Lamprey populations, and their current distribution, abundance, and population structure.
    - A rangewide map of historical and current Pacific Lamprey distribution.
    - Description of known threats and reasons for decline.
    - Identification of actions to address known threats.

2. Construct a Conservation Agreement:
    - Developed with overarching agreement with signatories.
    - Linked to Assessment document and regional implementation plans.

3. Develop regional implementation plans:
    - Identify partnerships and participants for implementation.
    - Identify regional strategies and prioritize actions to address threats (that were identified in the regional conservation assessment chapters) and promote restoration and conservation of Pacific Lamprey.
    - Prioritize and implement research, monitoring and evaluation to improve status assessments and the efficacy of conservation measures.
    - Develop restoration goals and population outcomes that will be modified as we learn from research, monitoring and evaluation work (adaptive management approach).
    - Identify potential funding sources and partnerships to address priority actions;
    - Identify potential funding sources and partnerships for research, monitoring and evaluation of projects.
    - Identify priority tasks by region and develop implementation schedules.

Inclusion of Ongoing Conservation Measures

The approach of the Pacific Lamprey Conservation Initiative (PLCI) is to be inclusive of other federal, state, tribal and county conservation measures, with the objective of promoting coordinated efforts throughout the range of Pacific Lamprey. The goal is to have the PLCI be an umbrella under which the conservation and restoration of Pacific Lamprey and associated habitats can be coordinated. The primary method is to initially describe the threats to the long-term survival, which should, if addressed, reverse the decline of the species. It is anticipated that some of the actions, tasks, and threats identified in this document will require further environmental analysis and public review, especially those actions taken by federal agencies. Because a key component of the approach is to be inclusive of ongoing efforts, we have provided a summary of the regulatory history and ongoing conservation measures that directly or

Summary of Approach

The approach of the Pacific Lamprey Conservation Initiative (PLCI) is to use the best scientific and empirical information available to assess the current risk to viability for Pacific Lamprey throughout its range in the western United States and identify the environmental and anthropogenic threats to Pacific Lamprey that must be addressed in order to conserve the species.

Because Pacific Lamprey are widely distributed across a large area, the approach for the California Assessment has been to divide the assessment into sub-regional components. The introductory chapters (Chapters 1-3) describes the overall assessment and conservation strategy of the Pacific Lamprey Conservation Initiative, the general biology of and threats to the species, and our methodology. The successive chapters (Chapters 4-11) focuses on Pacific Lamprey in California as a whole and in specific geographic sub-regions, describing conditions, population status and threats at the watershed level (4th field Hydrologic Unit Code watershed - HUC). We then use the demographic information and identified threats to qualitatively assess the relative risks of extirpation of Pacific Lamprey within each watershed using a NatureServe Assessment Model and summarize the risk information for each sub-region.

In the next stage of this project, we will use the combined results of the viability and threats assessments, and ongoing conservation measures to propose future conservation efforts and implementation projects that we believe would reduce risks to Pacific Lamprey within each sub-region and its component HUCs, thereby promoting the conservation of the species rangewide.

2. BIOLOGY, GEOGRAPHY, THREATS, AND CURRENT RESTORATION ACTIONS OF PACIFIC LAMPREY

Systematics and Taxonomy

The Pacific Lamprey, *Entosphenus tridentatus* (Richardson 1836) is in the class Cephalaspidomorphi, order Petromyzontiformes, and family Petromyzontidae. The species was assigned to the genus *Lampetra* for a period (Hubbs and Potter 1971); however, recent genetic and morphological analyses (Docker et al. 1999, Gill et al. 2003, Lang et al. 2009) have reestablished the validity of the genus *Entosphenus*. Pacific Lamprey is the only anadromous species within the genus, which contains at least six species (Renaud et al. 2009).

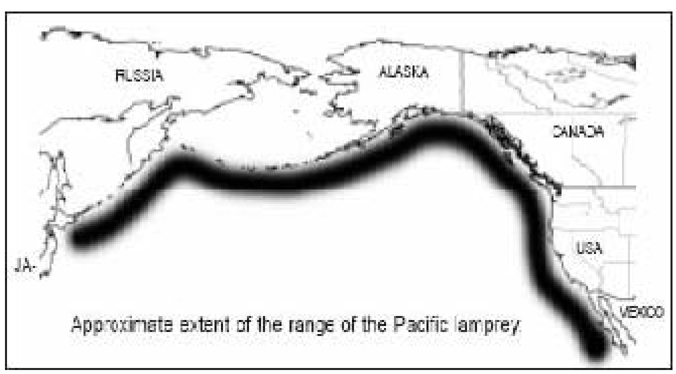
Lamprey species known to occur within the range of Pacific Lamprey in California include: Western Brook Lamprey, *Lampetra richardsoni*; Pacific Brook Lamprey, *L. c.f. pacifica*; Western River Lamprey, *L. ayresii*; Kern Brook Lamprey, *L.* (*E.*) *hubbsi*; Klamath River Lamprey, *Entosphenus similis*; Miller Lake Lamprey, *E. minimus*; and Pit-Klamath Brook Lamprey, *E. lethophagus*.

General Morphological Description

Pacific Lamprey are a relatively large anadromous and parasitic fish reaching over 800 cm in length. Their bodies are elongate, eel-like, more or less cylindrical toward the head, and compressed toward the tail. They do not have swim bladders that allow them to maintain neutral buoyancy and must, therefore, swim constantly or hold fast to objects with their oral disc to maintain position in the water column; swimming mode is anguilliform (Moyle 2002; Mesa et al. 2003). All lampreys have a round sucker-like mouth (oral disc), no scales, and seven gill openings (branchial pores) instead of an operculum. Pacific Lampreys are characterized by the presence of three large teeth (cusps) on the supraoral plate, 2-3 points on each of the four lateral tooth plates and typically 5-6 cusps on the infraoral plate. They have dorsal fins arising far back on the body, and the sexes exhibit dimorphism at maturity. Adults fresh from the sea are generally blue-black to greenish above, silvery to white below. Spawning adults generally become reddish brown but may vary in color (Morrow 1980).

Geographic Distribution

***Historic*.—**Their range in freshwater extends from Hokkaido Island, Japan (Yamazaki et al. 2005); and around the Pacific Rim including Alaska (Vogt 1988), Canada, Washington, Oregon, Idaho (Beamish and Northcote 1989; Moyle et al. 1996; USFWS 2004a; Hamilton et al. 2005); and California to Punta Canoas, Baja California, Mexico (Swift et al. 1993; Ruiz-Campos and Gonzalez-Guzman 1996; Ruiz-Campos et al. 2000; Chase 2001; Renaud 2008). At sea they have been found as far south as the Revillagigedo Archipelago south-east of Cabo San Lucas (Renaud 2008). In North America, their distribution includs major river systems such as the Fraser, Columbia, Klamath-



Trinity, Eel, and Sacramento-San Joaquin rivers, as well as most intervening streams. Pacific Lamprey are the most widely distributed lamprey species on the west coast of North America.

***Current*.—** In Japan, Pacific Lamprey have recently been documented in the Naka River on Honshu Island, as well as other river systems on the Hokkaido Island (Yamazaki et al. 2005). Population status in British Columbia is unranked but may be secure (Renaud et al. 2009); and status is unknown in Alaska. Anecdotal and empirical information suggests that Pacific Lamprey populations have declined or been locally extirpated in parts of California, Oregon, Washington, and Idaho (Close 2001; Moser and Close 2003; Luzier et al. 2009; Moyle et al. 2009; Swift and Howard 2009). In these states, Pacific Lamprey have declined in their distribution along all coastal streams and large rivers, including the Columbia River Basin. They are extirpated in parts of Southern California, above dams and other impassable barriers in coastal streams and larger rivers, and in the upper Snake and Columbia rivers. However, like historical distribution information, current distribution information is extremely limited or simply unavailable.

Life History Characteristics

Compared to what information has been collected about Pacific salmon, there is not much known about the nature of Pacific Lamprey across its range. Much of what is known about the biology and life history of Pacific Lamprey were from early studies done in Canada (Pletcher 1963; Beamish 1980; Richards 1980) and in the Pacific Northwest (Kan 1975; Hammond 1979). In recent years more emphasis has been placed on gathering this information in other parts of their range (Bayer and Seeyle 1999; Chase 2001; Brumo 2006; Gunckel et al. 2006; McGree et al. 2008; Jolley et al. 2010). These studies are useful to characterize its life history. Often what is known about landlocked sea lamprey in the Great Lakes is inferred to apply to anadromous lamprey such as Pacific Lamprey, without justifiable evidence (Clemens et al. 2010). Similarities and differences in the biology as well as key uncertainties between Pacific Lamprey, anadromous Sea Lamprey in North America and the landlocked sea lamprey in the Great Lakes were identified in Clemens et al. (2010), suggesting that further research is needed to more completely describe the biology of each species. A generalized life cycle for Pacific Lamprey is depicted in Figure 2-1, and descriptions of the life stages follow.

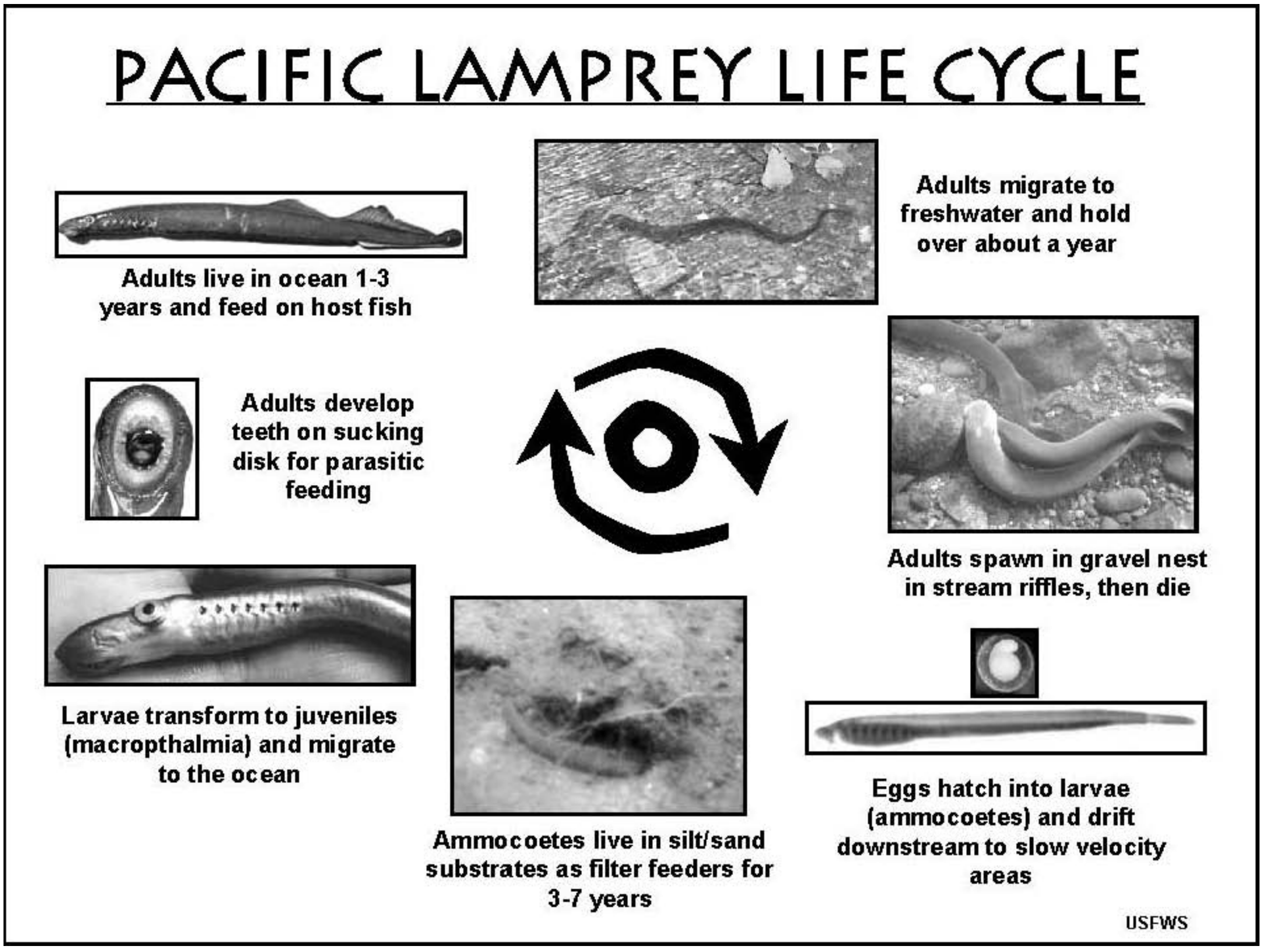


Figure 2-1. General life cycle of Pacific Lamprey, illustrating the duration and morphological characteristics of its life history stages.

***Spawning/Adult*.—** Adult Pacific Lamprey enter freshwater and reside there anywhere from a few months (Bayer and Seelye 1999) to a few years prior to spawning (Whyte et al. 1993; Bayer and Seelye 1999; Fox and Graham 2008; M. Mesa, USGS; S. Gunckel, ODFW; R. Graves, NOAA; Bob Cordie, USACE, personal communication), though spawning generally occurs in the spring following migration into freshwater (Chase 2001). Adults migrate upstream nocturnally (e.g., Potter 1980; Beamish and Levings 1991; Chase 2001) from late fall to spring (Luzier et al. 2006). Regional and size differences may be present in adult migration timing (Pletcher 1963; Kan 1975; Beamish 1980; Moyle et al. 1995; Chase 2001; Kostow 2002). Spawning generally occurs from April to July (Wydoski and Whitney 2003), but regional differences have been observed (Luzier et al. 2009). For example, in the Santa Clara River of southern California, spawning likely begins in January and may continue through April (Chase 2001).

Adult Pacific Lamprey spawn in low gradient stream reaches, in gravel, often at the tailouts of pools and riffles (Mattson 1949; Pletcher 1963; Kan 1975). Velocities over nests generally range from 0.5−1.0 m/s and spawning depths between 30 cm and 4 m (Pletcher 1963; Kan 1975; Gunckel et al. 2006). Nest dimensions are generally between 20−73 cm in diameter and range in depth from 4−8 cm (Kan 1975; Russell et al. 1987; Howard et al. 2005). Spawning habitat has been associated with rearing habitat for ammocoetes (Moser et al. 2007).

Pletcher (1963) described Pacific Lamprey nest construction, summarized here: “A form of low intensity nest construction or "play with stones" was observed first. Both males and females lifted and dropped stones haphazardly without construction of a nest in any one locality. There seemed to be considerable movement within the gravel area before nest construction was started. The male was the instigator of nest construction and contributed to at least 2/3 of the effort. The female helped complete the nest after it was started. Nest construction involved three definite actions on the part of either adult: 1) Rock lifting - most often to downstream edge of nest; 2) Combination of rock lifting and digging; 3) Digging - buccal disk was attached to a rock at the edge of the nest and on its side fish vibrated its tail rapidly to remove sand and small rocks. Digging serves to loosen the bottom and line the bottom of the nest with sand for egg attachment. Nest construction and digging was carried on between spawning acts”. A video of the third action can be seen at http://www.fws.gov/pacific/Fisheries/sphabcon/Lamprey/index.cfm.

Deposition, incubation, and emergence life stages have been documented in a few studies for Pacific Lamprey, and extrapolations from other species have also been made. Female fecundity ranges from 30,000−238,400 eggs (Kan 1975; Close et al. 2002; Wydoski and Whitney 2003). Regional differences in fecundity were found in British Columbia and were related to the distance of upstream migration (Beamish 1980). Death in adults has been observed 3−36 days after spawning (Pletcher 1963; Kan 1975; Beamish 1980).

Many factors affect survival of egg to emergence. Survival to hatching ranges from 50−60% (Close et al. 2002) and appears to be correlated with spawning stock size, water flows during spawning (Brumo 2006), and water temperature (Meeuwig et al. 2005). Although egg predation by Speckled Dace, *Rhinichthys osculus*, has been observed, it occurred only above 14°C and appeared to increase in intensity with increasing water temperature (Brumo 2006). Predation of eggs has not been well documented for other potential predators. Brumo (2006) observed that the period of incubation ranged from 18−49 days and was dependent on water temperature. Yamazaki et al. (2003) found that eggs hatched in 11 days when water temperature was 18°C, while Scott and Crossman (1973) reported hatching in 19 days with a water temperature of 15°C. Yamazaki et al. (2003) documented incubation in Pacific Lamprey, and found the stages of embryological development to be similar between three species of lamprey. Egg size may play a role in the rate of embryological development. In laboratory studies, the effects of temperature on the development of larvae showed zero development at 4.85°C and greatest survival at 18.0°C (Meeuwig et al. 2005). Survival of larvae is optimal over a range of 10−18°C with a sharp decline at 22°C that coincides with an increase in morphological abnormalities (Meeuwig et al. 2005).

Much of what is known about natal homing and lamprey migratory behavior originates from studies of Sea Lamprey. Bergstedt and Seelye (1995) investigated spawning site fidelity in a non-anadromous Sea Lamprey population by mark-recapture studies in Lake Huron. Of the 555 tagged juvenile lamprey, 41 tags were recovered, but none within the stream of origin. This study is presented as evidence for a lack of homing in Sea Lamprey populations. Rather than natal homing, Sea Lamprey may migrate in response to pheromones produced by conspecific larvae. In a study conducted by Robinson et al. (2009), migrating adult Pacific Lamprey were highly sensitive to petromyzonol sulfate (a component of the migratory pheromone) and 3-keto petromyzonol sulfate (a component of the sex pheromone) when first captured. This sensitivity persisted throughout their long migratory and overwinter holding period, before declining to nearly immeasurable levels by the time of spawning. The absolute magnitudes of adult Pacific Lamprey responses to lamprey bile acids were smaller than those of the Sea Lamprey, and unlike the Sea Lamprey, the Pacific Lamprey did not appear to detect taurolithocholic acid 3-sulfate. No sexual dimorphism was noted in olfactory sensitivity. Thus, it appears that Pacific Lamprey are broadly similar to Sea Lamprey in showing sensitivity to the major lamprey bile acids but apparently differ in having a longer period of sensitivity to those acids. Further investigation in the potential utility of bile acid-like pheromones in the restoration of Pacific Lamprey populations may be warranted (see Li et al. 1995; Bjerselius et al. 2000; Yun et al. 2003; Fine et al. 2004).

***Rearing/Ammocoetes*.—**Eggs hatch in graveled upstream areas and newly emerged ammocoetes (larvae) drift downstream to silt areas (Stone and Barndt 2005). Ammocoetes remain in stream and metamorphose in 4−7 years (Beamish 1987). Ammocoetes are filter feeders, diets consisting of detritus, diatoms and algae (Hammond 1979; Potter 1980). Ammocoetes have been observed in Salmon and Steelhead carcasses (R. Lampman, OSU; T. Whitesel, USFWS; A. Brumo, Stillwater Science; personal communication) which could be part of their diet but more likely the ammocoetes are eating microorganisms growing on the carcasses (A. Brumo, Stillwater Science, personal communication). Downstream movement happens year round. Due to poor swimming ability, movement is probably driven by flow conditions and velocities (Moursund 2002). Movement is mostly nocturnal (Beamish and Levings 1991; Moursand et al. 2000; White and Harvey 2003) and correlated with discharge but not temperature (Hammond 1979; Potter 1980; Beamish and Levings 1991; Close et al. 1995).

At larger scales, larvae are most abundant where the stream channel is relatively deep (0.4−0.5 m), gradient is low (<0.5%), and the riparian canopy is open (Torgerson and Close 2004). Pacific Lamprey ammocoetes have been found residing in sediments under 16 m of water in the mainstem Columbia and Willamette rivers (Jolley et al. 2010; Jolley et al. 2011) Ammocoetes rear in areas located near reaches where spawning occurred (Pletcher 1963). At finer scales, larval occurrence corresponds positively with low water velocity, pool habitats, and the availability of suitable burrowing habitat (Roni 2002; Pirtle et al. 2003; Torgersen and Close 2004; Graham and Brun 2005). Ammocoetes of all sizes are known to use slow depositional areas along streambanks and burrow into fine sediments mixed with organic matter and detritus during rearing periods (Pletcher 1963; Lee et al. 1980; Potter 1980; Richards 1980; Torgersen and Close 2004; Graham and Brun 2005; Cochnauer et al. 2006). Ammocoetes have been collected in beaver dams, reservoirs, mussel beds and the hyporheic zone (T. Whitesel, USFWS, personal communication), but it is unknown whether these are preferred habitats for ammocoetes.

***Metamorphosis/Macropthalmia*.—**The stages of metamorphosis have been described for Pacific Lamprey (McGree et al. 2008). McGree et al. (2008) followed ammocoetes through transformation from July to December; however, there may be regional differences in the duration of metamorphosis. Triggers for metamorphosis and the ability to predict it remain unknown. Migrating macropthalmia have been collected in smolt traps and dams year round though more are thought to migrate from late fall to late spring (Close et al. 1995; Kostow 2002). Migration timing has been anecdotally correlated with rain or snow melt, distance from ocean, and elevation.

During metamorphosis, Pacific Lamprey move from fine substrate in low velocity areas to silt covered gravel in moderate current. When fully transformed they are found in gravel or boulder substrate where overlying currents are moderate to strong (Beamish 1980; Potter 1980; Richards and Beamish 1981). During migration, macropthalmia are thought to occupy the lower proportion of the water column (Close et al. 1995; Moursund et al. 2000; White and Harvey 2003). Other studies such as Moursund et al. (2003) found juvenile lamprey distributed throughout the depths of the water column. There is a regional data gap on the habitat needs of macropthalmia based on migration distances. Macropthalmia that migrate greater distances must deal with greater habitat variations. The estuarine and nearshore habitat requirements for macropthalmia are also unknown.

***Ocean Phase/Macropthalmia to Adult*.—**Metamorphosed individuals migrate from parent streams to the Pacific Ocean (Orlov et al. 2008). Onset of parasitic feeding is unknown, although macropthalmia have been observed attached to salmonids in both fresh and varying concentrations of salt water (C. Luzier and G. Silver, USFWS, personal communication), presumably as they were migrating to ocean environments. Adults are parasitic on fishes and smooth skinned marine mammals, attaching and feeding on body fluids and blood. They parasitize a wide variety of ocean fishes, including Pacific salmon, *Oncorhynchus* spp.; flatfish such as, *Pleuronectes* spp. and *Platichthys* spp.; rockfish, *Sebastes* spp.; Pacific Hake *Merluccius productus*; and Walleye Pollock, *Theragra chalcogramma* (USFWS 2004a). It is unknown how hosts are chosen, if there is a preferred host, when they attach, how long they are attached, what stimulates release from a host, or when and where lamprey initiate free swimming migration. The parasitic stage may last 20−40 months (Lee et al. 1980).

Although little is known about ocean distribution rangewide their spatial distribution has been described for the North Pacific where Pacific Lampreys are geographically found in their greatest concentrations in the Bering Sea, Navarin Cape, the Koryak shelf, East Aleutian Islands, and the west coast of the USA (Orlov et al. 2008). Time spent in the marine habitat for adults is thought to be 6 months to 3.5 years (Kan 1975; Beamish 1980; Richards 1980). They have been caught at depths ranging from 90−800 m and at distances greater than 100 km offshore in ocean haul nets (Close et al. 2002; USFWS 2004a; Orlov et al. 2008). Orlov et al. (2008) analyzed trawl surveys and commercial trawling, which were carried out using bottom and variable–depth trawls for regions of the North Pacific for the period 1975– 2007. They found that the overwhelming majority of Pacific Lamprey catches occurred on the shelf and continental slope waters. Results of bottom trawl data showed that about 80% of the Pacific Lamprey were caught at depths of less than 500 m and for pelagic trawls about 83% of all the catches occurred at depths of less than 200 m (Orlov et al. (2008). These results provide evidence that Pacific Lamprey primarily occupy the upper 100 m pelagic zone and were occasionally found at depths of 500 m or greater (Beamish 1980; Orlov et al. 2008). Pacific Lamprey apparently make daily vertical migrations from the ocean bottom into the pelagic zone, presumably to feed (Orlov et al. 2008). The authors' hypothesize that the lamprey vertical movement may be related to the vertical migration of the Alaska Pollock (lamprey's prey), which has characteristic vertical feeding migrations during the day (Orlov et al. 2008). It is unknown what habitat adult lamprey use when between hosts. Adults are preyed upon by sharks, seals and sea lions, fishes and other marine animals during their ocean phase (USFWS 2004a). After feeding and growth, adult lamprey transition from the ocean to fresh water for spawning.

Ecology

Pacific Lamprey are an important part of the ecosystem, contributing to food web dynamics, acting as a buffer for salmon from predators, and contributing important marine nutrients to inherently nutrient-poor watersheds (Close et al. 2002; CRITFC 2008).

Larval Pacific Lamprey can make up a large portion of the biomass in streams where they are abundant, thus making them an important component along with aquatic insects in processing nutrients, nutrient storage, and nutrient cycling (Kan 1975; Close et al. 2002). Larval lampreys process nutrients by filter feeding on detritus, diatoms, and algae suspended above and within the substrate (Hammond 1979; Moore and Mallatt 1980). They are efficient at trapping food; however, they have low food assimilation rates. The material that is undigested by the lamprey is processed into fine particulate matter which is then exported from the system or taken up by other organisms such as filter feeding insects (Merritt et al. 1984). In addition, adult lamprey die after spawning, leaving the marine-derived nutrients in freshwater streams (Beamish 1980).

Pacific Lamprey appear to be a choice food for avian, mammalian, and fish predators, and at times may be preferred over salmon smolts (Close et al.1995; Stansell 2006 cited in CRITFC 2008). Ammocoetes and macrophalmia migrating downstream may buffer salmonids from predation by birds, mammals, and other fishes (Close et al. 2002). For example, lampreys comprised 71% by volume of the diets in California gulls, ringbill gulls, western gulls, and Fosters tern in the mainstem Columbia River during early May (Merrell 1959). Past predation rates on salmon smolts by avian and aquatic predators in the Columbia River basin may have been reduced by historically large numbers of outmigrating lampreys (Close et al. 2002). Also, ammocoetes and macropthalmia become available to predators, including salmonids, during scour events, emergence, and downstream migration.

Adult lamprey returning upstream are an important food for freshwater fishes, birds, and mammals. They may also be an important buffer for migrating adult salmonids from marine mammal predation. Lamprey are relatively easy for marine mammals to catch, have high caloric value, and migrate in schools (Close et al. 1995). Caloric values for lamprey range from 5.92 to 6.34 kcal/g wet weight (Whyte et al. 1993); whereas salmon average 1.26 to 2.87 kcal/g wet weight (Stewart et al. 1983). The most abundant dietary item in seals and sea lions in the Rogue River, Oregon was found to be Pacific Lamprey (Roffe and Mate 1984). Declines of Pacific lamprey may increase marine mammal predation on salmonids.

Population Structure

To date, three genetic studies have evaluated the broad scale population structure of Pacific Lamprey. Goodman et al. (2008) investigated population structure of Pacific Lamprey from Central British Columbia to Southern California through restriction fragment length polymorphism (RFLP) and sequence analysis of the mtDNA. In this study, no significant population structure was identified among populations or regions, indicating a high level of historical gene flow. Higher proportions of drainage-specific or "private" haplotypes were identified in southern regions, but were present in a low number of samples and therefore the implications on Pacific Lamprey population structure are equivocal. Likewise, Lin et al. (2008a) investigated the nuclear genome using amplified fragment length polymorphism (AFLP) analyses among populations from Northern California to Alaska and Japan. This data also suggests significant levels of historic gene flow among populations. The results of these two genetic studies on Pacific Lamprey indicate high levels of historic gene flow identified among collection localities, even those separated by large geographic distances (Northern California to Japan). Docker, Spice and their collaborators also investigated population structure of Pacific Lampreys at 21 locations between British Columbia and Southern California using microsatellite analyses (Docker 2010, Spice et al. 2012). Similar to Goodman et al. (2008), levels of genetic differentiation were low among sites however there was weak indication of regional structure. However, refinement in genetic differentiation techniques in the future may alter this paradigm.

When interpreted on an evolutionary timescale these data indicate a shared evolutionary history and a lack of reproductive isolation. Several components of the available data suggest the possibility of some geographic population structure: 1) higher number of private haplotypes in southern regions; 2) significant differences in AFLP frequencies among collection localities, and 3) weak regional structure in microsatellite data. However, it is clear that Pacific Lampreys are best viewed as regional metapopulations, rather than localized, populations tied to single drainages.

Generalized Threats and Reasons for Decline

Pacific Lamprey face a variety of threats to its various life history stages, and no single threat can be pinpointed as the primary reason for their apparent decline. Recognized threats include artificial barriers to migration, entrainment of migrating juveniles, desiccation of stream habitat or rapid water level changes caused by flow management, poor water quality, predation by native and nonnative species, stream and floodplain degradation, loss of estuarine habitat, decline in prey, ocean conditions, dredging, and dewatering (Jackson et al. 1996; Close et al. 1999; BioAnalysts, Inc. 2000; Close 2000; Nawa et al. 2003).Threat categories considered in this assessment include: 1) Passage, 2) Dewatering and Streamflow Management, 3) Stream and Floodplain Degradation, 4) Water Quality, 5) Harvest, 6) Predation, 7) Translocation, 8) Small Populaion effects, and 9) Disease, as well as Lack of Awareness, Oceanic Conditions, Climate Change. The following is a general discussion of threats considered in this assessment (primarily from Luzier et al. 2011).

***Passage (dams, culverts, water diversions, tide gates, other barriers)*.—**Artificial barriers impact distribution and abundance of Pacific Lamprey by impeding upstream migrations by adult lamprey and downstream movement of ammocoetes and macropthalmia (Close et al. 1995; Vella et al. 1999; Ocker et al. 2001; Lucas et al. 2009). Upstream adult migrations are blocked by dams without suitable passage alternatives or attraction to fish ladder entrances (Moser et al. 2002). Fish ladders and culverts designed to pass salmonids can block lamprey passage, particularly if they have sharp angles that lamprey cannot attach to (Keefer et al. 2010) and high water velocities (Moser et al. 2002; Mesa et al. 2003). Culverts and other low-head structures that have a drop at the outlet are impassable for a variety of reasons including high velocities or distance, insufficient resting areas, and lack of suitable attachment substrate (CRBLTWG 2004). Pacific Lamprey populations persist for only a few years above impassable barriers before becoming locally extirpated (Beamish and Northcote 1989).

Downstream migrating macropthalmia and drifting ammocoetes are often entrained in water diversions or turbine intakes (Moursund et al. 2001; Dauble et al. 2006). Juvenile lampreys have shown high survival through the juvenile salmonid bypass system at Columbia River mainstem dams (Moursund et al. 2002), but the lamprey are often inadvertently collected and transported downstream in barges or trucks with salmonid smolts. It is unknown whether this is detrimental to lamprey (Moser and Russon 2009). However, observations made by a fish technologist on the transportation barge included rapid dewatering and resulting stranding of ammocoetes and macropthalmia, potential predation in the hold, and potential injuries similar to descaling of salmon smolts (M. Barrows, USFWS, personal communication). Due to their size and weak swimming ability (Sutphin and Hueth 2010), ammocoetes and macropthalmia can be impinged on turbine screens (Moursund et al. 2002) and irrigation screens (Ostrand 2004) resulting in injury or death. Irrigation screens can also cause migration delay in macropthalmia as they attach to the screen infrastructure, avoid contact with the screen and take up long residence times (Ostrand 2004). Outmigrant lamprey travel deeper in the water column (no air bladder) compared to salmonids, therefore, traditional spill gates block passage (Moursund et al. 2003).

Passage barriers affect the amount of marine-derived nutrients available to the basin which influence primary productivity of food sources available to ammocoetes. They also affect other threats to lamprey, such as water quality, predation, toxicity, decreased habitat availability, and stream and floodplain degradation.

***Dewatering and StreamFlow Management (reservoirs, water diversions, instream projects)*.—**Rapid fluctuations in reservoir and stream water levels from irrigation diversions, power hydropeaking and instream channel activities strand ammocoetes in the substrate and isolate them from flowing water (J. Brostrom, USFWS; J. Crandall, Wild Fish Conservancy; E. Egbers, WDFW; personal communication; Douglas County PUD 2006 http://relicensing.douglaspud.org/documents/pud_relicensing_documents/downloads/SR/EffectofWaterLevelFluctuations.pdf). Suitable habitat for juvenile lamprey is often at stream margins in areas of low velocity with fine substrate and canopy shading (Claire 2003; Pirtle et al. 2003; Graham and Brun 2005; Torgerson and Close 2004), which are the first areas dewatered when stream flows drop. Juvenile lamprey do not segregate themselves by age (King et al. 2008) so a single event can affect multiple year classes, significantly impacting a local lamprey population. Channel reconstruction or barrier removal projects targeting the restoration of Pacific salmonids can result in rapid and sometimes extensive dewatering of existing channels, stranding juvenile lamprey. Salmonid salvage prior to reconstruction projects has not typically included efforts to rescue ammocoetes which may emerge from the sediment well after salvage/rescue efforts cease and no water remains in the channel.

Nests are often found in low gradient stream reaches, in gravel, and at the tailouts of pools and riffles (Mattson 1949; Pletcher 1963; Kan 1975). These areas are vulnerable when flows drop suddenly, which is common during irrigation season and power hydropeaking. Nests are desiccated when this occurs.

Low flows during summer and fall can impede adult lamprey migration by restricting flow into an exposed, shallow river channel or creating a thermal block. Lamprey movement at all life stages is predominantly nocturnal (Beamish and Levings 1991; Moursund et al. 2000; Chase 2001; White and Harvey 2003); consequently, flow reductions during daylight will inhibit lamprey from moving into more suitable habitat as they will be reluctant to leave a dark, secure area.

***Stream and Floodplain Degradation (channelization, loss of side channel habitat, scouring)*.—**Lamprey spawn (Mattson 1949; Pletcher 1963; Kan 1975), and rear (Pletcher 1963; Potter 1980; Richards 1980; Torgeson and Close 2004; Graham and Brun 2005) in low gradient stream reaches with complex channel structure, pools, and riffles, and adjacent stream margins and side channels with finer sediment and detritus. These features are frequently found in lower gradient areas with wider floodplains, which are popular for development. The loss of these habitats reduces areas for spawning and rearing.

Riparian vegetation is an important component of ammocoete rearing areas. Pirtle et al. (2003) found that ammocoetes were collected where canopy cover was 71.8% on average; however, they were observed over a wide range of cover from 7.5% to 100%. In Idaho, the amount of riparian vegetation and shading was positively correlated with ammocoete abundance (Claire 2003) and loss of these features would likely negatively impact lamprey.

Eggs and ammocoetes from many lamprey species that rear in stream substrates have been impacted by activities that remove silt and fine substrate from the stream such as excavation, mining, or dredging activities (Beamish and Yousan 1987; King et al. 2008). Excavation by heavy equipment can remove high numbers and several age classes of juvenile lamprey (King et al. 2008). Suction dredging has been an effective sampling technique (Bergstedt and Genovese 1994; Steeves et al. 2003; G. Silver, USFWS, personal communication) but not enough is known about its effect on lamprey populations. However, any spoils not filtered, and instead removed from the water, will remove any lamprey within them (King et al. 2008). Dredging activities associated with irrigation screen maintenance can also remove ammocoetes (J. Crandall, Wild Fish Conservancy; and E. Egbers, WDFW, personal communication).

Legacy effects from past practices associated with log drives in rivers are still being observed in several streams in the Pacific Northwest (R. Lampman, OSU, personal communication). The legacy effects on fish habitat include lack of slow water refuges and deep pools, lack of sediment deposition and a more flashy hydraulic system where sediment budget retention rates are low (R. Lampman, OSU, personal communication).

Water Quality (Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source).—Water temperatures of 22°C have been documented to result in mortality or deformation of eggs and early stage ammocoetes under laboratory conditions (Meeuwig et al. 2005). Water temperature of 22°C or higher is often a common occurrence in degraded streams during the early-to-mid-summer period of lamprey spawning and ammocoete development.

Ammocoetes are relatively immobile in the stream substrates and can concentrate in areas of suitable habitat that include many age classes (King et al. 2008) making them susceptible to chemical spills or chemical treatment (e.g. rotenone) targeting other species. Bettaso and Goodman (2010) investigated mercury concentrations of larval lampreys (ammocoetes; *Entosphenus* spp.) and western pearlshell mussels *Margaritifera falcata* in the Trinity River, California to determine whether these two long-lived and sedentary filter feeders show site-specific differences in uptake of this contaminant. Ammocoetes contained levels of mercury 12 to 25 times those of mussels from the same site in Trinity River (Bettaso and Goodman 2010). The Pacific Lamprey ammocoetes were also found to have 70% higher mercury levels in a historically mined area when compared to a non-mined reference reach (Bettaso and Goodman 2008). Their data indicate that ammocoetes may be a preferred organism to sample for mercury contamination and ecological effects compared with mussels in the Trinity River. Other chemicals of concern include PCBs, pesticides and other heavy metals, but the threat of these is not well assessed. Pacific Lamprey adults sampled in the Willamette River had levels of dieldrin, total PCBs and arsenic that were above acceptable tissue concentrations, and as a result consumption guidelines were recommended to Siletz Tribal members (ODHS 2005). More study is needed to determine potential impacts of elevated toxins on Pacific Lamprey.

The effects of low dissolved oxygen levels, eutrophication, or turbidity on natural populations of Pacific Lamprey are unknown.

***Harvest/Overutilization*.—**Pacific Lamprey harvest for food or commercial purposes may present a threat if these activities are concentrated on rivers with low population numbers. Harvest of lamprey can directly reduce the populations, change population structure and alter distribution, thus threatening population viability.

***Predation*.—**Native and non-native fish, marine mammals, and birds prey upon Pacific Lamprey (Close et al. 1995; Moyle 2002) and may pose a threat to lamprey abundance, particularly in altered habitat. As Pacific Lamprey migrate through reservoirs and their associated dams, they may be more susceptible to predation. American mink, birds, raccoons, various fish, and other species feed upon ammocoetes (Semakula and Larkin 1968; Galbreath 1979; Beamish 1980; Wolf and Jones 1989). Adult lamprey are eaten by otters, sea lions, seals, and sturgeon (Roffe and Mate 1984), and northern pike in Alaska (Betsy McCracken, USFWS, personal communication). Concentrations of Stellar sea lions in recent years below Bonneville Dam in the Columbia River have been observed consuming large quantities of Salmon, White Sturgeon *Acipenser transmontanus*, and Pacific Lamprey, although the impact of predation has not been quantified. In the North Umpqua River, blue heron were often observed in areas where tagged adult Pacific Lampreys were holding below the Winchester Dam, and raccoons and mink were observed feeding on larval Pacific Lamprey during the dewatering of the Dam (Ralph Lampman, OSU, personal communication). Native fish species known to prey upon Pacific Lamprey are Northern Pikeminnow, *Ptychocheilus oregonensis,* and Sacramento Pikeminnow, *P. grandis* as well as non-native fishes such as bass, *Micropterus* spp.; sunfish, *Lepomis* spp.; Walleye, *Stizostedion vitreum*; Striped Bass, *Morone saxatilis*; and catfishes, *Ameiurus* and *Ictalurus* spp. have become established over the last century in some rivers in the western U.S.

***Disease*.—**Information pertaining to Pacific Lamprey disease is limited; however, some adults have been collected and the samples analyzed for a spectrum of potential pathogens by the USFWS Lower Columbia River Fish Health Laboratory in the 1990−2003 period (Cochnauer et al. 2006). The pathogen that causes furunculosis, *Aeromonas salmonicida*, has been detected in lamprey in the Columbia River Basin (Cummings et al. 2008) and western Oregon. The causative agent for bacterial kidney disease (BKD), *Renibacterium salmoninarum*, was also found in Pacific Lamprey sampled in the ponds at Entiat National Fish Hatchery in Washington (J. Evered, USFWS, personal communication). The impact of these diseases in lamprey is currently unknown; however, in general, disease may influence lamprey health and reduce their ability to reproduce and survive. Finally, a basic understanding of the pathology of lampreys is lacking. *Aeromonas salmonicida* (the causative agent of furunculosis) and *A. hydrophila* are known to infect adult Pacific Lamprey (Cummings et al. 2008; Clemens et al. 2009; CRBLTWG 2011), and *Renibacterium salmoninarum* has been shown to reside in Sea Lamprey (Faisal et al. 2006) but no infection was found in directly challenged Pacific Lamprey adults (Bell and Traxler 1986). Virtually no information is available on the pathology of larval and juvenile Pacific Lamprey. Future research directed at direct disease challenges of Pacific Lamprey with pathogens of concern (e.g., infectious hematopoietic necrosis virus [IHNV] or BKD) may provide information related to the ability to larval lamprey to serve as vectors of transmission.

***Small Effective Population Size*.—**Effective population size (Ne) is important for assessing conservation and the management of fishes (Rieman and Allendorf 2001). The loss of genetic diversity and the degree of inbreeding within a population is related to the rate of genetic drift that is measured by Ne (Wright 1969). As a result, maintaining populations large enough so that these effects are minimized has become an important goal for ESA-listed species (McElhaney et al. 2000). The potential effects of the various and commonly cited threats to Pacific Lamprey have the potential to lead to reductions in population size (Rieman and McIntyre 1993; Rieman et al. 1997) and therefore in Ne. A significant loss of genetic variation can influence population demographics, dynamics, and ultimately the persistence of populations via inbreeding depression, loss of phenotypic variation and plasticity, and loss of evolutionary potential. Although data on the effective population size is lacking for Pacific Lamprey it is recognized as a critical need (CRBLTWG 2005) for the conservation and enhancement of populations. In this assessment we use adult abundance (N) as a surrogate for Ne, because presently there are no studies that estimate the ratio of Ne:N for Pacific Lamprey.

As Pacific Lamprey adults are attracted to ammocoete pheromones (Fine et al. 2004) as seen in other lamprey species (Li et al. 1995; Bjerselius et al. 2000; Vrieze and Sorensen 2001; Fine et al. 2004), low numbers or a lack of ammocoetes in spawning tributaries may result in reduced attraction of adults. While low numbers of adults in a drainage may substantially decrease the probablity of encounter for spawning.

***Lack of Awareness*.—**A lack of awareness on the distribution of Pacific Lamprey and their preferred habitat use can have negative and unintended impacts to Pacific Lamprey when in-channel activities restoring habitat or passage for other species are implemented. For example, dewatering a stream to replace a culvert may strand ammocoetes, and use of heavy equipment to dig out channels can remove ammocoetes from the channel (Streif 2009; USFWS 2010). To date, Pacific Lamprey have rarely been included in the analysis of impacts of land management activities, such as stream alteration or channel dredging, simply because their presence and distribution is not known. Until recently, Pacific Lamprey were not considered in hydropower operations and relicensing. Identifying and overcoming funding bias and barriers to lamprey-friendly salmon restoration work is needed. Also, the negative impacts of Sea Lamprey from the Great Lakes have given all lamprey species a bad reputation. We are further understanding the role of Pacific Lamprey as an important component of the ecosystem. To combat negative perceptions that many people have toward lamprey, information on the ecological and cultural benefits of native lamprey needs to be disseminated.

***Ocean Conditions*.—**Given that Pacific Lamprey spend up to several years at sea to increase in weight and length prior to returning to freshwater to reproduce, it follows that direct and indirect actions to this environment may significantly influence the population. Actions that greatly effect lamprey, their prey species, or that alter the pelagic or substrate habitats to depths up to 500 meters may alter population demographics (Orlov et al. 2008). Nevertheless, additional research, evaluation and monitoring will be needed to determine how actions are reflected in the population.

***Climate Change*.—**Climate change may exacerbate many of the threats listed above, especially flow, ocean conditions, water quality, diseases, predation, and stream conditions. Across the 20th century, the mean annual air temperature has risen by between 0.3°C and 0.6°C (IPCC 1996), and predictive models forecast continued increases in mean global temperatures (Kerr 1997; McCarty 2001). These increases in global climate temperatures during the 20th century have been linked to threats to species and populations, and it is theorized that these impacts will be accelerated given the current predictive models of future climate change (McCarty 2001). Ultimately, species adapted to current local conditions will face a set of ecosystem changes that can induce changes in the latitudinal and altitudinal range of populations (Brander 2007), collapses of populations that are unable to adapt to changing conditions (Pörtner and Knust 2007), asynchrony of cues necessary for animal migrations (McCarty 2001), and altered timing of biological events that coincide with seasonal changes in food availability (Wiltshire and Manly 2004). Climate change alone may threaten the conservation status of many populations and species (Daufresne and Boet 2007; Pörtner and Farrell 2009).

Other. —There are other factors that may be threats to Pacific Lamprey. Aquatic invasive species are a relatively new occurrence in the range of Pacific Lamprey (USGS 2010), and include New Zealand mudsnails, quagga mussels, zebra mussels, Asian clams, Eurasion water milfoil, water chestnut and others. These species may encroach on available habitat, compete for food sources or affect lamprey in other ways not currently recognized.

3. METHODS

(adapted from Luzier et al. 2011)

General Description of Assessment Development

Western Lamprey Conservation Team (Team) and Steering Committee.— The USFWS formed an internal multi-office team in June 2004 to work on lamprey conservation partly in response to a petition to list four species of lamprey in 2003 and the planning of the first Columbia River Basin Tribal Lamprey Summit. The original mission of the Team was: "Through a variety of internal and external partnerships, we will facilitate the development of an 'on-the-ground' strategy to conserve native lamprey in the Pacific Northwest and California within the next 2 years and beyond. Our strategy will focus on improving our understanding of the life history and distribution of lamprey, restoring and stabilizing lamprey populations, and reducing adverse affects of existing infrastructure on lamprey populations. Our intent is to improve the status of lamprey throughout their range." Eight USFWS biologists from six offices, both Fisheries and Ecological Services, in Oregon, Washington, and Idaho formed the original Team. The current Team is comprised of eight biologists from seven USFWS offices, six Fisheries and one Ecological Services, in Oregon, Washington, Idaho, and California. Contact information for team members can be found on pages iii and iv of the Regional Assessment (Luzier et al. 2011). The primary responsibility of the team is to develop the Plan with the goal of restoring and sustaining Pacific Lamprey populations throughout their historical range by coordinating conservation efforts among states, tribes, federal agencies, and other involved parties.

The approach of the PLCI is a three part process: assessment and template for conservation measures (Assessment); conservation agreement; and implementation plan. The development of this document is based on voluntary involvement of various federal, state, and local governmental agencies, Pacific Rim countries, tribes, scientific institutions, consultants, non-profit groups, utility companies, private landowners and others. A steering committee made up of representatives from these partner organizations was formed in June 2008. Duties of the steering committee include guiding the PLCI development process and review of PLCI products. The first official product of the PLCI was the proceedings from the PLCI Work Session that was held in October 2008 in Portland, Oregon (Luzier et al. 2009, summarized in Luzier et al. 2011).

California Regional Meeting Process.— In September 2009, the Team initially hosted two regional work sessions in California (Arcata and Sacramento). The Arcata session focused on the North Coastal subregion, while the Sacramento session focused on Central and Southern California. The purpose of these meetings was to collect region-specific information on historic and current distribution; estimated abundance; trends in populations; the identification and prioritization of threats to Pacific Lamprey; identification of ongoing conservation actions and needs; and ongoing research, monitoring and evaluation activities and needs. The initial information was gathered at the 3rd field Hydrologic Unit (HUC) level due to the broad areas of coverage, and was intended to help guide future data collection and risk assessments. It is summarized in the Regional Assessment (Luzier et al. 2011).

In 2010 we initiated a more detailed assessment for California with information collected at the 4th Field HUC. The template for collecting information at the 4th Field HUC was designed to consistently record the information collected. Participants in the regional work sessions were also queried about ongoing conservation actions and research in the region as well as needed conservation actions and research, monitoring, and evaluation (RM&E). Information collected at the regional meetings was used to develop this Assessment which includes: assessment of population status, historical and current threats, and relative risk to lamprey persistence by watershed. The next phase of this project will be develop of an implementation plan utilizing the information gathered in Phase 1; prioritization of threats; identification of actions to be taken to improve Pacific Lamprey abundance, distribution and habitat; and identification of research, monitoring and evaluation needs.

Regional and stakeholder workshops (California):

North Coast	
Arcata	09-01-2009
Wietchpec	10-14-2009
Lagunitas	07-07-2011
Point Reyes	07-07-2011
Loleta	03-19-2012
Central Valley / SF Bay	
Sacramento	09-15-2009
Tracy	06-09-2011, 01-19-2012
Stockton	06-07-2011
Napa	07-06-2011
Red Bluff	12-15-2011
South Coast	
Santa Paula	05-17-2011
San Luis Obispo	05-18-2011, 03-28-2012
Malibu	05-19-2011
Monterey	07-06-2011
Santa Cruz	07-07-2011

Background and Context for Methods

Lampreys are among the most poorly studied groups of fishes on the west coast of the United States, despite their diversity (numerous species) and presence in many rivers including coastal streams (Moyle et al. 2009). It has been recognized that a systematic evaluation of lamprey status (Luzier et al. 2009; Moyle et al. 2009), in particular the anadromous form of the species, is lacking. Lamprey are an important dietary and cultural component of the Native American tribes of the west coast of the United States (CRITFC 2008; Petersen Lewis 2009), but have not been historically important to commercial or recreational fisheries of the west coast, likely explaining the paucity of information on abundance and distribution collected by state and federal agencies. Although the USFWS efforts herein reflect primarily freshwater life-stages most likely to be affected by human activity, we recognize and emphasize that future effort and resulting actions should be inclusive of lamprey's marine life-history stage.

This lack of information for anadromous lamprey appears to repeat across the globe. Thiel et al. (2009) identify that more detailed information is urgently needed about the status of European River Lamprey, *Lampetra fluviatilis*, and Sea Lamprey, *Petromyzon marinus*, especially in their estuarine, coastal and offshore marine habitats. For instance, for the southern Baltic Sea, there is no complete description of the past and present distribution or a detailed analysis of the temporal and spatial development of the commercial catches in these areas. Theil et al. (2009) stressed that studies would be important to define conservation requirements for anadromous lampreys in the southern Baltic Sea and as a basis to determine if rebuilding programs for these species are necessary, and where and how they should be implemented. Through a systematic assessment using available information, they identified that restoring habitat connectivity by the removal of barriers or installation of fish passage would restore access to spawning and nursery areas for River Lamprey. Kelly and King (2001) identified that three species of lamprey (Sea, European River, and European Brook *L. planeri*) recorded in Ireland had limited detailed scientific information to assess the distribution, status, habitat use and conservation requirements. Information was largely composed of known spawning locations, with little literature on direct aspects of ecology. However, they reviewed extensive European and North American literature to provide a detailed and comparative account of lamprey ecology, particularly those river life-stages most likely to be affected by human activity, and identified areas where more information is needed to form a basis for decision-making regarding conservation requirements for lamprey species in Ireland.

Lampreys are considered to be endangered in much of Europe (Maitland 2003). European Brook, River, and Sea Lamprey are listed under Annex II of the European Commission Habitats directive (92/33/EEC) and member states are obliged to create special areas of conservation for these lamprey species (Goodwin et al. 2008). During assessments, loss of larval habitat (Kirchhoefer 1996), migration barriers (Igoe et al. 2004; Goodwin et al. 2008) and water quality and habitat issues (Igoe et al. 2004) have been identified as causes for the decline of lamprey species in Europe and Great Britain. In Canada, a lack of information on the distribution and population sizes and trends of the native lamprey species exists (Renaud et al. 2009). They note that most lamprey species status have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and NatureServe conservation rankings have been applied to a number of lamprey species at the national and subnational levels (www.NatureServe.org, Master et al. 2003, Faber-Langendoen et al. 2009; Master et al. 2009). Pacific Lamprey in Canada have not been ranked through NatureServe at the national level, but in British Columbia they have been ranked secure at the subnational level (Renaud et al. 2009).

Moyle et al. (2009) conducted a systematic review using available information for lamprey in California. This approach used criteria that included aspects of lamprey biology, vulnerability to environmental change, and limiting factors; and they found that all species are either declining, in low numbers, or are isolated populations. This assessment extends that work at a more detailed level.

Most of these evaluations related to lamprey conservation around the world have been challenged by the scarcity of information on historic and current distribution, abundance, biology and ecology for anadromous lamprey species. However, a recurring approach to conservation for lamprey populations has been to pool information on populations, and to synthesize information on the biology, ecology, and habitat requirements for lamprey species of interest and other lamprey species. Most of these systematic analyses also focused considerable effort on specifically identifying the threats or limiting factors that are impacting the lamprey populations of concern. Many of the conservation plans and recommendations address threats that have been identified through these systematic evaluations that lacked a preponderance of data on lamprey distribution and abundance. The USFWS and partner agencies have applied similar systematic assessment approaches to evaluate aquatic species status and guide development of conservation plans (Lenstch et al. 2000; USFWS 2008). The USFWS has specifically used NatureServe to evaluate the relative conservation status of Bull Trout at a core area level (USFWS 2005, 2008). This systematic NatureServe approach of assessing an aquatic migratory species' status has been useful in evaluating status with limited information and accepted by the USFWS's partners.

Andelman et al. (2004) conducted a review of protocols for selecting species at risk in the context of viability assessments for the U.S. Forest Service. They reviewed nine published protocols (including NatureServe Ranking, USFWS Listing factors, International Union for Conservation of Nature (IUCN) classification system, and others). They concluded all were useful, but those that explicitly include threats analysis were most useful in determining which species were likely to be adversely affected by proposed management activities. The authors note that the best method for identifying and classifying risk will depend on the management scenarios proposed, the amount of data available, the time frame within which the assessment must be completed, and the scale at which the assessment is to be made (Lehmkuhl et al. 2001). Adelman et al. (2004) concluded the NatureServe Ranks may be the most suitable of the nine existing protocols for identifying species at risk on national forests because of the flexibility of scale, potential for use of existing information, and ability to integrate threats analyses.

Assessment Approach

As systematic approaches have been widely applied for assessing lamprey status (or other aquatic species with limited biological data) and informing conservation, we decided to apply this type of system to guide our conservation planning for Pacific Lamprey. Also, given the direction from our October 2008 workshop to provide step-down conservation guidance at regional levels, we decided to employ an approach that would provide consistency across the range and still accommodate regional needs. Our search for a process that was scientifically supported, well documented and widely used led us to apply the NatureServe Conservation approach to collect a suite of factors to assess the conservation of a species by evaluating the risk of extirpation at discrete geographic groupings. The outcome of researching and recording information on the conservation factors is the assignment of a conservation rank with supporting documentation. By using a consistent approach to gathering data on these factors, we form the backbone of information to be used to assess risk and guide conservation measures.

We used a modification of the NatureServe ranking system (Faber-Langendoen et al. 2009; Master et al. 2009) for discrete geographic units (primarily watersheds at the 4th Field HUC) to rank the risk to Pacific Lamprey relative to their vulnerability of extirpation. Data used to rank

4th Field HUCs consisted of updated information on population abundance, distribution, population trend, and threats to lamprey which were summarized by 4th Field HUC in the Sub-regional Template documents. These relative ranks of risk calculated for each 4th Field HUC were then summarized by regional area.

The Hydrologic Unit Code (HUC) is a system assigning bodies of water into hydrologic units (http://water.usgs.gov/GIS/huc.html). Each hydrologic unit is identified by a unique code consisting of two to eight digits based on the four levels of classification in the hydrologic unit system (region, subregion, accounting unit and cataloging unit). For example, the Shasta River is designated by California Region (18), Klamath-Northern California Coastal Subregion (01), Klamath Accounting Unit (02) and Shasta Cataloging Unit (07); the 4th field HUC would be 18010207.

We conducted a structured evaluation of existing population data and threat information available to us in a variety of formats. We spatially evaluated Pacific Lamprey at discrete watershed units at the 4th Field HUC and larger regional groupings in order to assess overall patterns of risk and to identify any relative strongholds or weak areas for Pacific Lamprey conservation. We reasoned that a successful process would allow us to maximize use of data collected at the watershed levels, where the highest degree of specificity occurs and threats are most appropriately characterized. We then integrated the analysis into larger blocks for assessing risk in the larger conservation context. A strong point of this process was that it could be applied on multiple scales and would therefore be an appropriate tool for quantifying conservation risk of Pacific Lamprey.

Conservation Rank Approach

NatureServe and its member programs and collaborators use a suite of factors to assess the extinction or extirpation (regional extinction) risk of plants, animals, and ecosystems (or "elements" of biodiversity). By researching and recording information on a set of factors, biologists can assign a conservation rank to these elements at both global and regional (i.e., national/subnational) scales. The protocol for assigning a conservation rank is based on scoring an element against ten conservation factors, which are grouped into three categories based on the characteristic of the factor: rarity, trends, and threats. We chose this approach to rank the relative risk of Pacific Lamprey for various watersheds, given the lack of demographic information available across the range. Information for all ten conservation factors is not required to assign a rank. We used a modified suite of factors (seven) to assess the relative risk ranking of Pacific Lamprey by watershed throughout its range. The following seven factors were selected because of our ability to collect the required information for them over the majority of geographic populations.

The set of factors we used to assess Pacific Lamprey conservation status, by category, are:

- **Rarity Category**

1. **Range Extent** (historic distribution) – We used several strategies for obtaining historical distribution estimates throughout the presumed range of Pacific Lamprey. First, we reviewed the published literature and state and federal agency records and

documents to determine if accurate, specific distribution records for Pacific Lamprey exist. Although a few publications do document species occurrence, information is disjointed, incomplete, or absent. We then reviewed museum records for vouchered specimens within California, all specimens outside well-known core areas were personally examined to confirm identification. The historical specimens were particularly useful for establishing the presence and upstream extent of Pacific Lamprey above currently impassable dams. The historic spawning distribution of Steelhead (anadromous rainbow trout, Oncorynchus mykiss) populations was also used as a conservative estimate of the historic habitat available for Pacific Lamprey to spawn because both species use similar spawning habitat. The estimate based on Steelhead distribution is considered conservative because the range extent of Pacific Lamprey may be even larger due to the fact that they are able to scale some natural barriers that block salmonids. In addition to using these surrogate measures of range extent, we used the field experiences of experts (via regional meetings) and specific field surveys by the authors to modify the estimated range extent.

2. **Area of Occupancy** (current distribution) – Current distribution data were provided primarily from experts within the field via regional meetings and specific field surveys by the authors (especially in southern HUCs. Survey data/occurrences specific to Pacific Lamprey were recorded. Incidental data where species identification was not confirmed was noted as such. Additional information was collected from published literature, and state and federal agency records. Very few targeted Pacific Lamprey surveys have been conducted and therefore current distribution data are sparse. In general, based on the experience of the authors and regional field biologists, the current distribution (habitat used at some life-stage) was considered to include all accessible habitat within a HUC downstream of impassable barriers.

3. **Population Size** – Several strategies were used for obtaining current abundance estimates throughout Pacific Lamprey's presumed range. First, we reviewed the published literature and state and federal agency records and documents to determine if accurate, specific abundance records for Pacific Lamprey exist. Although a few publications do document species abundance, information is disjointed, incomplete, or does not exist. Second, we attempted to obtain specific information from experts within the field and tribal representatives via regional meetings and additional discussions. Very few counts of adult lampreys are available in California (discussed in chapters).

4. **Ratio of Area of Occupancy to Range Extent** – The ratio of current to historic distribution was calculated because of the uncertainty of both historical and current distribution for Pacific Lamprey. The addition of ratio lets us factor in the risk associated with rearing and spawning in less spatially diverse areas. The Team placed much greater confidence or certainty on the value of this ratio for each region compared to the estimated values for each of the two factors separately.

- **Trends Category**

5. **Short-term trend** –The trend in population size was estimated over the last 27 years, or about three lamprey generations. Generation time for a species or population is defined as the average age of adults when they reproduce.

- **Threats Category**

6.-7. **Threat Impact** (Scope and Severity are counted as one factor each). Categories of threats are discussed in Chapter 2. Major threat categories that were considered are:

Passage (dams, culverts, water diversions, tide gates, other barriers).
Dewatering and Flow Management (reservoirs, diversions, instream projects).
Stream and Floodplain Degradation (channelization, loss of side habitat, scouring).
Water Quality (Temperature, heavy metals, chemicals, sediment, eutrophication)
Predation.
Harvest/Overutilization.
Small Effective Population Size.
Disease.
Lack of Awareness.
Climate Change.

The values used to rank each of these categories are displayed in Table 3-1.

We did not attempt to collect quantitative information for lack of awareness, ocean conditions, and climate change. Little is known about the effects of these latter metrics on Pacific Lamprey; consequently those metrics were not included in the analysis and will require additional evaluation as more data becomes available.

We made the following changes to the default rank calculator values to better reflect the quality of the information for Pacific Lamprey demographics, trends and threats: 1) changed the weighting of the rarity factors (historic distribution, current distribution, population size and ratio of current to historic distribution) so all equal 1. The information on current distribution for Pacific Lamprey is not adequate to give it double weight. 2) added a new rarity factor, the ratio of current to historic distribution, to decrease the weight of the historic distribution factor. The addition of this ratio lets us factor in the risk associated with rearing and spawning in less spatially diverse areas. This factor was also given a weight of 1, equal to both historic range extent and current distribution. 3) changed the relative weights of the three major categories (Rarity, Trends and Threats) from 0.65, 0.2 and 0.15 to 0.6, 0.1 and 0.3. This change increases the weight for threats from standard NatureServe ranks reflecting the fact that most of our information is on threats and our trend data is severely lacking (Table 3-2). Hence, our adjustments to the weights applied to the ranking factors reflects relative confidence in the data for those factors.

NatureServe has developed the 2009 version of the rank calculator to facilitate the process of assigning conservation status ranks through automation (NatureServe 2009). The updated ranking system and new calculator provide improvements for rank standardization by helping to increase the consistency, objectivity, and transparency of the conservation assessments, and facilitate maintenance of the ranks. A more detailed description of how conservation status ranks are calculated with the 2009 version of the rank calculator can be found in NatureServe 2009, and summary details of the score values used to calculate status ranks can be found in Appendix A.

Information on the conservation factors above was collected from participants at the regional meetings. A rank for each factor was determined by participant input using the NatureServe Rank Key (Table 3-1) and those data were entered into the NatureServe rank. In addition to factors being ranked, the uncertainty for each factor was categorized based on the following scale:

"0" = *No information available*.
"1" = *Best professional judgment based on expansion of data for other species (e.g., Steelhead)*.
"2" = *Largely undocumented but based on extent of habitat, suspected barriers and/or anecdotal information*.
"3" = *Partial adult, juvenile, or nest survey data in one-half or less of the potential spawning and rearing habitat in the watershed*.
"4" = *Partial adult, juvenile, or nest survey data in more than one-half of the potential spawning and rearing habitat in the watershed with some estimate of error*.
"5" = *Comprehensive adult, juvenile, or nest survey data in more than 90% of the watershed incorporating some estimate of error*.

Threat data was also collected by consensus at the regional meetings. The scope and severity of several categories of threats were ranked as high, moderate, low, insignificant or unknown. Within each major category were subcategories (e.g., the passage category had dams, culverts, etc.). Specific information about issues in each threat category or subcategory was recorded (e.g., locations and installation dates of barriers). Additional threats that were applicable to a specific region were added as needed. The scope and severity of the major categories of threats were entered into spreadsheets. The NatureServe rank only accepts one overall ranking for scope and severity so the highest rank recorded for the major threat category was used for the risk assessment calculation.

Once assigned, scores for the individual factors within each of these categories are pooled and the resulting three summary scores are combined to yield an overall numeric score, which is translated into a calculated rank. The risk calculated for these HUCs is from the subnational NatureServe procedure (Masters et al. 2009). NatureServe definitions listed here are for interpreting NatureServe conservation ranks at the subnational (S-rank) levels. The following are the subnational (S) conservation ranks and rank definitions we used:

***SX Presumed Extirpated*.—** Species or ecosystem is believed to be extirpated from the jurisdiction (i.e., nation, or state/province). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered. (= "Regionally Extinct" in IUCN Red List terminology).

***SH Possibly Extirpated*.—** Known from only historical records but still some hope of rediscovery. There is evidence that the species or ecosystem may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include: (1) that a species has not been documented in approximately 20–40 years despite some searching or some evidence of significant habitat loss or degradation; or (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.

***S1 Critically Imperiled*.—** Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction.

***S2 Imperiled*.—** Imperiled in the jurisdiction because of rarity due to very restricted range, very few occurences, steep declines, or other factors making it very vulnerable to extirpation from the jurisdiction.

***S3 Vulnerable*.—** Vulnerable in the jurisdiction due to a restricted range, relatively few occurences, recent and widespread declines, or other factors making it vulnerable to extirpation.

***S4 Apparently Secure*.—** Uncommon but not rare; some cause for long-term concern due to declines or other factors.

***S5 Secure*.—** Common, widespread, and abundant in the jurisdiction.

The application of these calculated rank scores were not used to determine conservation status. The purpose of this assessment was to evaluate relative risk amongst geographic population groupings from population attributes and threats. These relative rankings are then used to systematically guide prioritizing potential conservation measures within a geographic grouping and among geographic groupings in a region. The ranking of secure would have the lowest relative risk and the rank of presumed extirpated would be associated with the highest relative risk.

Regional Group Summaries

Once the ranks were calculated for each geographic unit (approximately 4th Field HUC), the results were summarized by sub-regional grouping. Maps by region were constructed to display the spatial arrangement of risk by watershed. The objective was to provide the range of ranks for the watersheds within a regional grouping, and to consider the spatial arrangement of risk levels for these watersheds. In addition, the maps identified priority threats within these regional groupings that influence the risk rankings.

Table 3-1. NatureServe factors used to assess conservation rank, by category, and applied to Pacific Lamprey.

Rarity 1 Factor Group

Range Extent (Historic Distribution)
Z = Zero (no occurrences believed extant)
A = <100 square km (< about 40 square mi)
B = 100-250 square km (about 40-100 square mi)
C = 250-1,000 square km (about 100-400 square mi)
D = 1,000-5,000 square km (about 400-2,000 square mi)
E = 5000-20,000 square km (about 2,000-8,000 square mi)
F = 20,000-200,000 square km (about 8000-80,000 square mi)
G = 200,000-2,500,000 square km (about 80,000-1,000,000 sq mi)
H = >2,500,000 square km (> 1,000,000 square mi)

Area of Occupancy (Current Distribution)
X = Extinct (no occurrences extant)
Z = Zero (no occurrences believed extant)
A = <0.4 square km (less than about 100 acres)
B = 0.4-4 square km (about 100-1,000 acres)
C = 4-20 square km (about 1,000-5,000 acres)
D = 20-100 square km (about 5,000-25,000 acres)
E = 100-500 square km (about 25,000-125,000 acres)
F = 500-2,000 square km (about 125,000-500,000 acres)
G = 2,000-20,000 square km (about 500,000-5,000,000 acres)
H = >20,000 square km (greater than 5,000,000 acres)

Rarity 2 Factor Group

Population Size
X = Extinct (no occurrences extant)
Z = Zero, no individuals believed extant
A = 1 - 50 individuals
B = 50 - 250 individuals
C = 250 – 1,000 individuals
D = 1,000 – 2,500 individuals
E = 2,500 - 10,000 individuals
F = 10,000 - 100,000 individuals
G = 100,000 - 1,000,000 individuals
H = >1,000,000 individuals

Rarity 3 Factor Group

Ratio of Historic and Current Distribution (Values in percent of historic distribution)
Z = 0.001
A = 0.05
B = 0.1
C = 0.25
D = 0.37
E = 0.5
F = 0.75
G= 0.9
H= 1.0

Trend Factor Group

Short-Term Trend (Past 27 yrs or 3 generations whichever is longer)
A = Severely declining (decline of >70% in population, range, area occupied, and/or # or condition of occurrences)
B = Very rapidly declining (decline of 50-70%)
C = Rapidly declining (decline of 30-50%)
D = Declining (decline of 10-30%)
E = Stable (unchanged or within +/- 10% fluctuation in population, range, area occupied, and/or number or condition of occurrences)
F = Increasing (increase of >10%)

Table 3-1. (continued). NatureServe factors used to assess conservation rank, by category, and applied to Pacific Lamprey.

Threats Factor Group

Threat Scope
High = 71-100% of total population, occurrences, or area affected
Moderate = 31-70% of total population, occurrences, or area affected
Low = 11-30% of total population, occurrences, or area affected
Insignificant = <10% of total population or area affected
Unknown = Scope could not be determined
Threat Severity
High = Near-total destruction of suitable habitat and/or functional loss of Pacific Lamprey from this watershed; (>100 years for recovery)
Moderate = Long-term degradation or reduction of suitable habitat and/or functional loss of Pacific Lamprey from this watershed (50-100 years for recovery)
Low = Reversible degradation of or reduction of habitat and/or measurable reduction of Pacific Lamprey in watershed (2-3 generations for recovery).
Insignificant = Essentially no reduction or degradation due to threats or able to recover quickly from minor temporary loss (within 2 generations)
Unknown = Severity could not be determined

Table 3-2. Weightings for individual factors and factor categories for Pacific Lamprey NatureServe Rank calculator.

Factor Category	Category Weight[a]	Factor	Factor Weight[b]
Rarity	0.6	Range Extent	1.0
		Area of Occupancy	1.0
		Population Size	1.0
		Ratio of Area of Occupancy to Range Extent	1.0
Trend	0.1	Short-term Trend	1.0
Threats	0.3	Threat Impact (scope and severity are separate factors that combine to form impact)	1.0

[a] The category weights are used to calculate overall score from category sub-scores.
[b] Factor weights are used to calculate category sub-score.

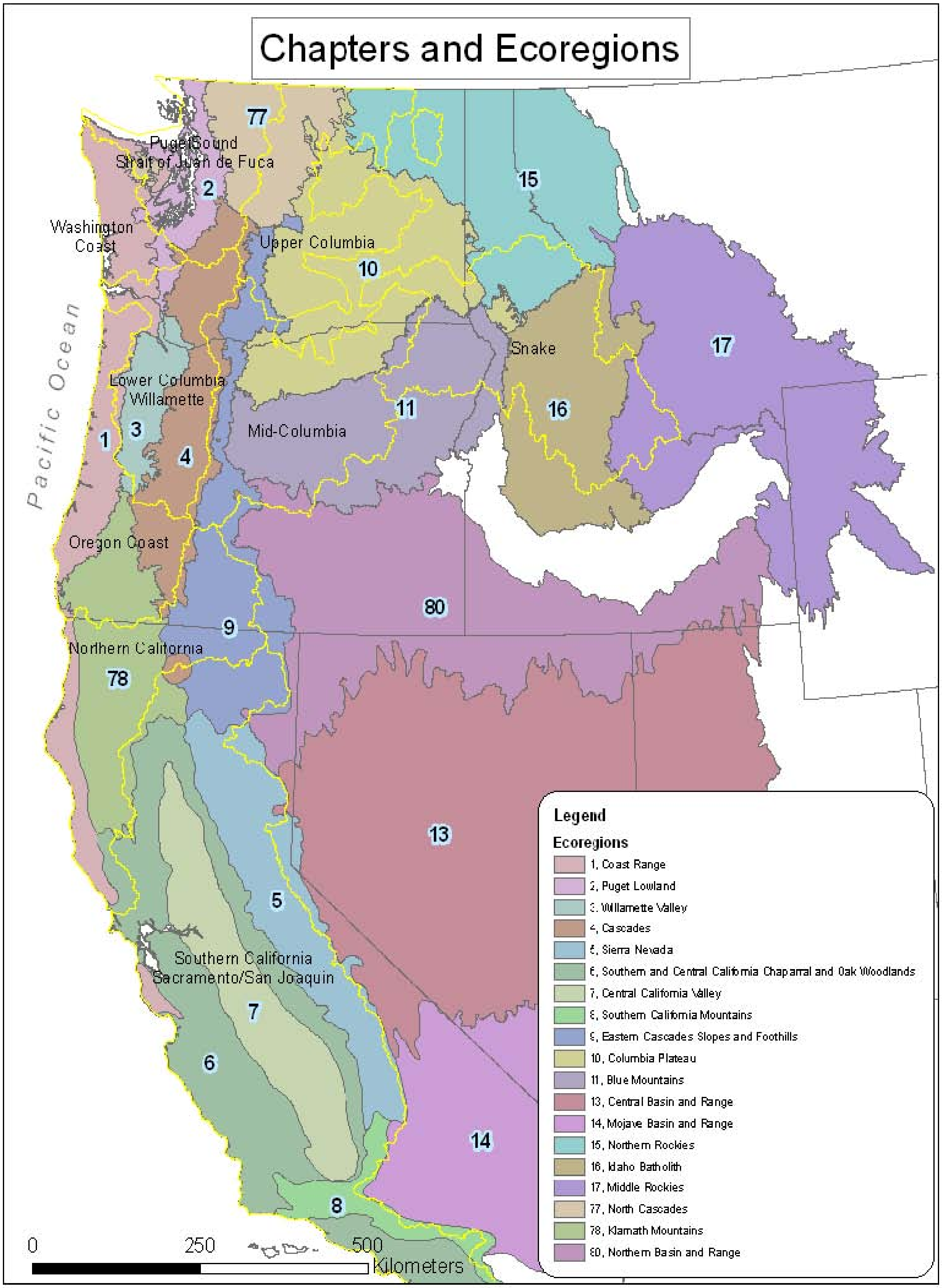


Figure 3-1. Area covered by each Regional Assessment and the EPA Level III Ecoregions.

4. CALIFORNIA REGION - Summary

The California Region within the boundaries of this Assessment is comprised of seven sub-regions: North Coast, North-Central Coast, South-Central Coast, South Coast, Sacramento, San Joaquin, and San Francisco Bay (Figure 4-1). Distribution, population status and threats are summarized below for the entire California Region, followed by assessment of population status and threats within each sub-region and its component 4th Field HUC's.

The ecological and climatic characteristics of areas occupied by Pacific Lamprey vary considerably in California, from cool mountain slopes and moist coastal drainages to arid southern chaparral, representing eight Level III ecoregions (Figure 3.1; Appendix B) described by the Environmental Protection Agency (EPA), including: Coast Range (1), Cascades (4), Klamath Mountains (78), Eastern Cascades Slopes and Foothills (9), Southern and Central California Chaparral and Oak Woodlands (6), Central California Valley (7), Sierra Nevada (5) and Southern California Mountains (8).

Population Status of Pacific Lamprey in the California Region

Population factors were ranked in all watersheds, however there was considerable uncertainty in many watersheds. Uncertainty was due to: a) the paucity of historical and current locality records, due in part to salmonid survey protocols and general lack of attention to lampreys, b) unreliable field identifications in areas where multiple lamprey species are present, including most HUCs except those south of Monterrey Bay, c) lack of targeted surveys for Pacific Lamprey, which require specific methods and timing that often differs from salmonid surveys and d) lack of long-term monitoring programs or counts including lampreys (e.g. at dams or screw-traps). For most HUCs, ranks were based on “best professional judgment” and anecdotal observations by stakeholder participants in local assessments and the authors, with historical collections, counts, surveys and observations used when available (see under specific sub-regions). All individual HUCs were ranked for historical range extent, current occupancy, current population size, and short-term trend. NatureServe status ranks were then calculated for Pacific Lamprey populations within each HUC based on the population rankings and maximum threat rank for the HUC (Figure 4-2).

***Historical Range*.—** For the purposes of this assessment, the historical range of Pacific Lamprey was assumed to have extended throughout most available habitat having anadromous access within a HUC (Figure 4.3). The Tulare Basin and its tributaries in the southern San Joaquin Valley were isolated by drainage of Lake Tulare in the 1800's. Although there is mention of lampreys in Lake Tulare, the southernmost report for anadromous salmonids along the Sierran foothills is for the Kings drainage (Yoshiyama et al. 1996). Therefore, only Lake Tulare and the three northernmost Sierran HUCs (Dry, Kings and Mill, a tributary of the Kings) were treated as historical habitat, absent further information.

Examination of vouchered historical specimens and personal observations showed that Pacific Lamprey move far up larger streams and rivers into the higher elevation reaches when available (Figure 4-3), reaching at least 4300' in the Sierras (Feather River) and headwater reaches of the Sacramento River (vicinity of Mt. Shasta), as well as major coastal rivers (i.e. Trinity, Eel, Russian, Salinas and Santa Clara). Projected Winter Steelhead distribution and barriers to passage were examined in CDFG's CalFish database for evidence of access and major barriers (http://www.calfish.org/Home/tabid/37/Default.aspx); however, vouchered historical Pacific Lamprey in the tributaries of the Sacramento and recent collections above natural barriers to salmonids by the authors indicate that distribution of Pacific Lamprey exceeded that of anadromous salmonids under natural conditions.

***Current Range*.—** The current occupancy of Pacific Lamprey (Figure 4-4) was either largely undocumented, or based on partial surveys for less than one half of the watershed, observations of lamprey redds (nests) seen during salmonid surveys, or anecdotal observations. In few cases were there specific surveys targeting or likely to encounter lampreys. For the purposes of rating, occupancy was treated similarly to Historical Range, in most cases, and lampreys were assumed to occupy all suitable habitat below impassable barriers. This resulted in a conservative estimate of the ratio between current and historical range, dependent primarily on the presence of impassable man-made structures installed since 1900. Principal exceptions to this treatment included the southern San Joaquin/Tulare drainages that had been extirpated by drainage and diversion of the Tulare Basin and its conduits to the San Joaquin, tributaries of the Sacramento without perennial flow in their lower reaches due to diversions (e.g. lower Thomes Creek), the naturally arid Estrella watershed (exacerbated by groundwater pumping), and populations south of Big Sur that have been repeatedly sampled over the last three decades with mostly only scattered individuals (ammocoetes or adults) encountered in a few drainages and no currently viable populations. The only two substantial populations encountered in the southern portion of the range in the last 27 years were in the San Luis Obispo and Santa Clara drainages; however lampreys have not been encountered in these drainages since ca. 2010 (perhaps 2004) and 2006, respectively, in spite of relatively extensive surveying/monitoring.

***Ratio of Current to Historical Range*.—** The ratio of current to historical range varies between complete extirpation and essentially unchanged (0.00-1.00) in the California Region (Figure 4-4). HUCs in the North and North Central Coast sub-regions, with relatively few dams (outside the upper Klamath and Trinity rivers) exhibited a generally higher ratio (0.75–1.0) of the historical range still occupied than in the Sacramento and San Joaquin. In the Sacramento and San Joaquin sib-regions, , which are dominated by large impassable dams located along the Sierran and upper Sacramento foothills, 40% of all HUC's have been completely extirpated by impassable dams, and 25% of the remainder have less than half of the historical habitat currently accessible. This excludes the entire Tulare sub-basin, which was entirely extirpated by drainage of the extensive Lake Tulare in the 1800's. HUCS in the South Coastal and S.F. Bay sub-regions also had relatively low ratios (0.25– 0.90) due to passage barriers from the Carmel River (Point Lobos) northwards. All populations south of the Big Sur River appear to have been functionally extirpated by man-made barriers, desiccation of stream channels, habitat alteration, a possible northward range contraction driven by metapopulation dynamics (unresolved at this time), or a combination of threats.

***Population Size*.—** Population size, defined as the number of adults migrating into a given HUC, ranged from 0 (Extinct) to an estimated range of 1,000-2,500 (Figure 4-5). However, there is very little information available, other than anecdotal sightings, and for that reason most

HUC's were ranked as Unknown, although they apparently contain viable populations of uncertain size, based on the extensive presence of ammocoetes (larvae) in occupied HUC's. Fish passage is not generally provided or, if present (rare), monitored sufficient for lampreys at the larger California dams, so this monitoring opportunity is not available, as it is at the Columbia River and Winchester (Umpqua River, OR) dams. Numeric estimates of population size could only be obtained for a few HUCS. In the North Coast sub-region, tribal fisheries provide a minimum estimate for the number of adults caught moving upstream past collection points, resulting in general estimates for the the Klamath and Eel drainages, augmented by recent catches by CDFG at the Van Arsdale Dam on the upper Eel. Video counters at two smaller fish ladders also provide documentation of adult lampreys on the Russian River and in Battle Creek (tributary to the upper Sacramento). 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 these HUC's. The population in the Central Coastal HUC directly south of Carmel (Point Lobos to Santa Maria River) was estimated at 50-250 adults, based on the presence of lampreys in only the two northernmost streams, both relatively small (Little and Big Sur). Population sizes for HUC's above impassable dams and south of Big Sur were ranked as zero.

***Short Term Trend*.—** Short term trend in local populations was defined as the percentage of decline in the population over the last three generations or approximately 27 years (Figure 4-6). Due to the lack of long-term monitoring of lamprey populations there was no way to quantify these trends, except at the extremes. Impassable dams that extirpated populations in the Central Valley and north of Point Lobos, generally went in prior to 1970 and not in the last 30 years. These populations are ranked as extinct. In southern California, HUC's where lampreys of any life-stage have not been encountered in over 27 years, or only as sporadic individuals, are ranked as believed extinct. While HUC's that have recently contained viable populations (Central Coast, Ventura and Santa Clara) are ranked as severely declining. The severe decline (>70%) of lampreys in the North Coast sub-region is based on tribal observations during low-level subsistence harvest, where lampreys were once relatively common in the 1970-80's and have declined by approximately an order of magnitude.

Figure 4-1. **Map of six California sub-regions used for assessment**. For finer resolution maps of each individual sub-region, with 4th Field HUC's, see separate sub-region sections.

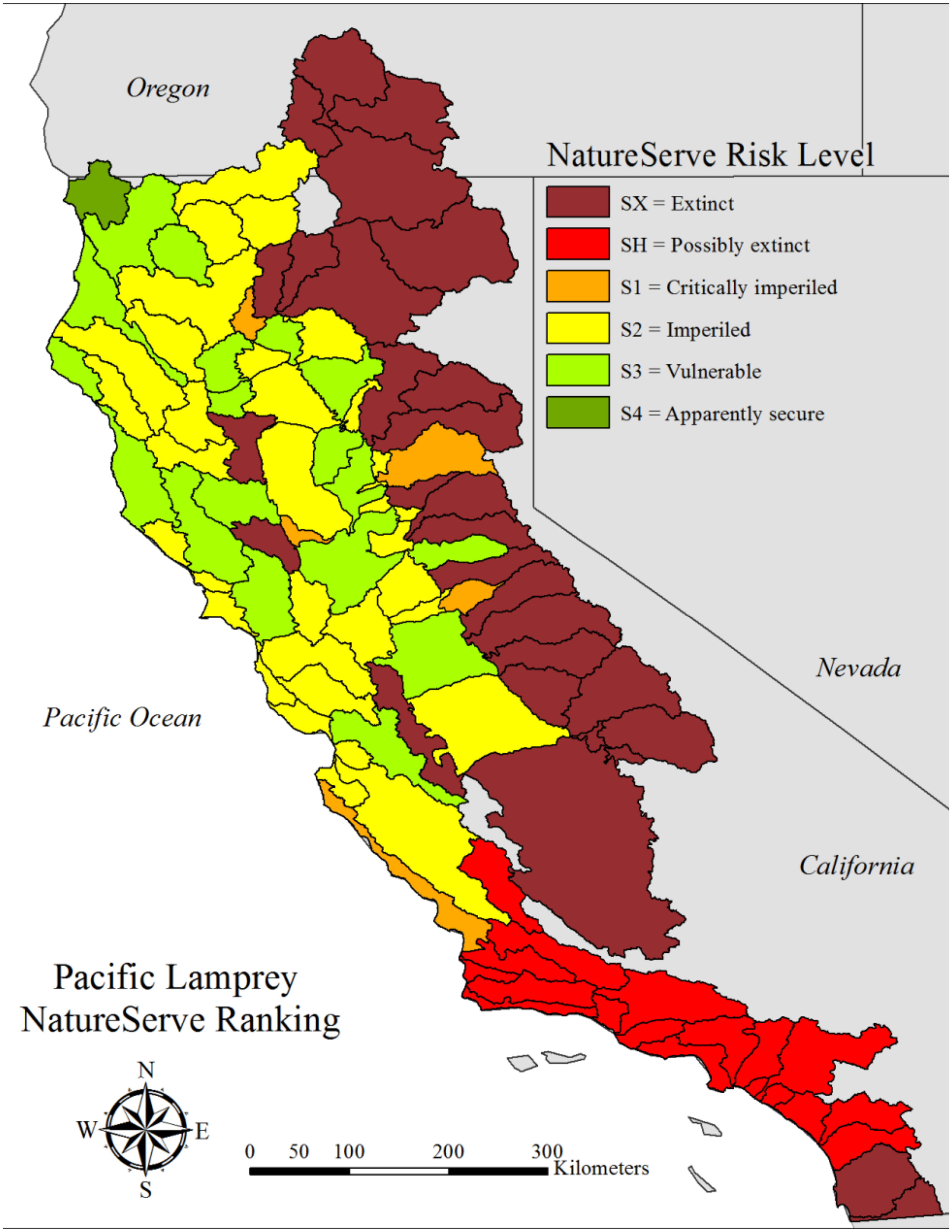


Figure 4-2. **Calculated NatureServe relative risk ranks for Pacific Lamprey in California** (see tables under separate sub-region sections for details).

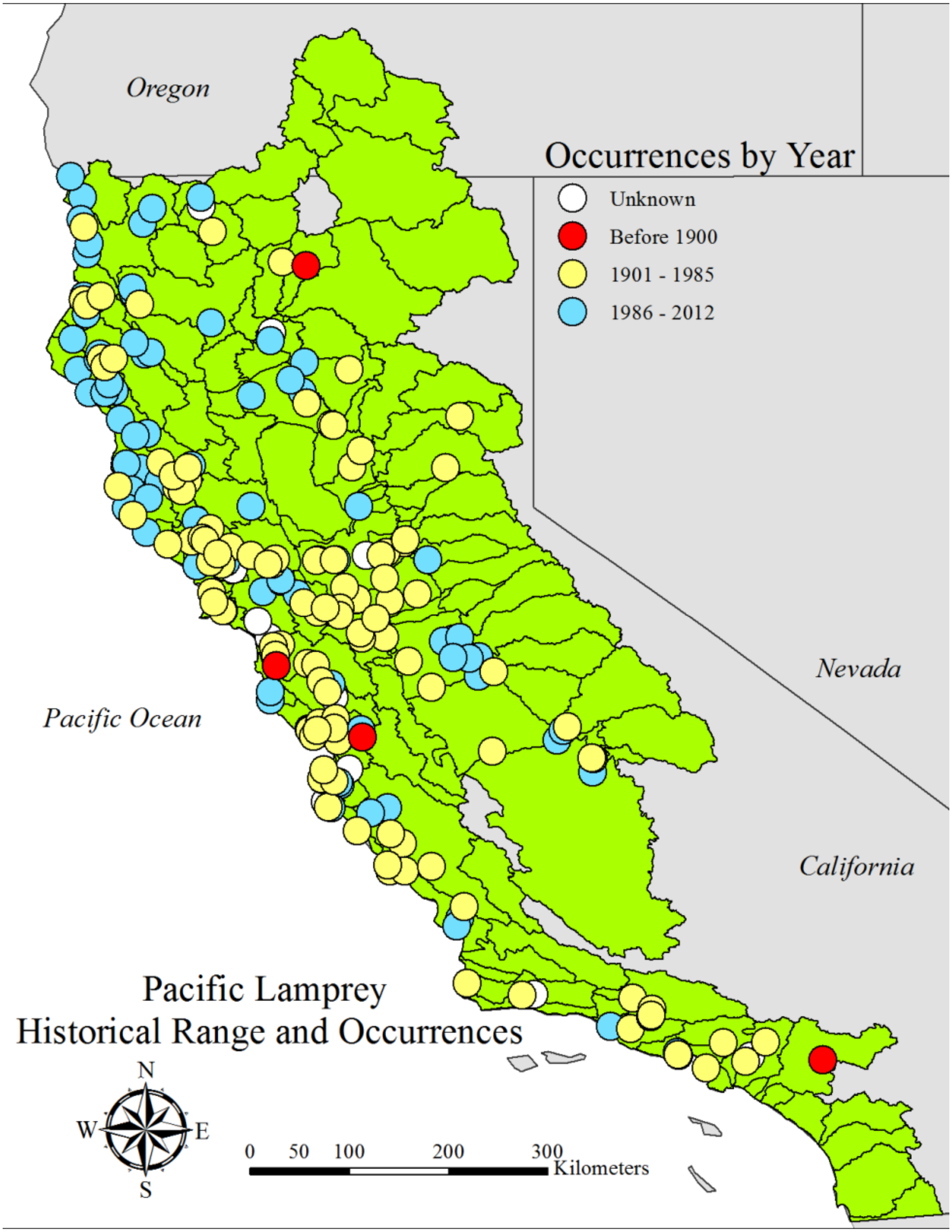


Figure 4-3. **Historical range of Pacific Lamprey in California** at resolution of 4th Field HUC's, with locations of vouchered museum specimens and period of collection.

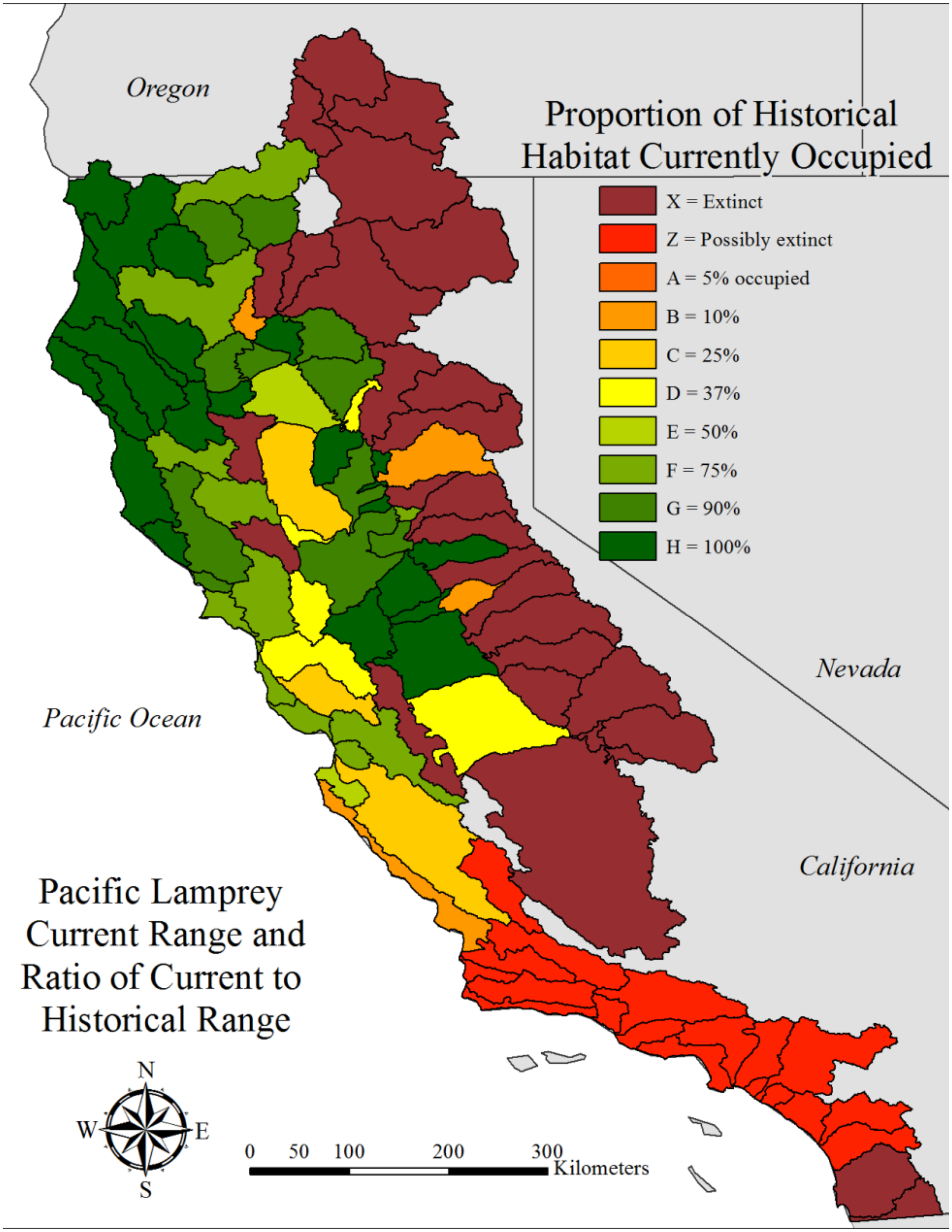


Figure 4-4. **Ratio of current to historical range for Pacific Lamprey in California**. The current range includes all HUC's not ranked Extinct (X) or Believed Extinct (Z), and the southernmost viable population is currently the Big Sur River, just south of Monterrey Bay.

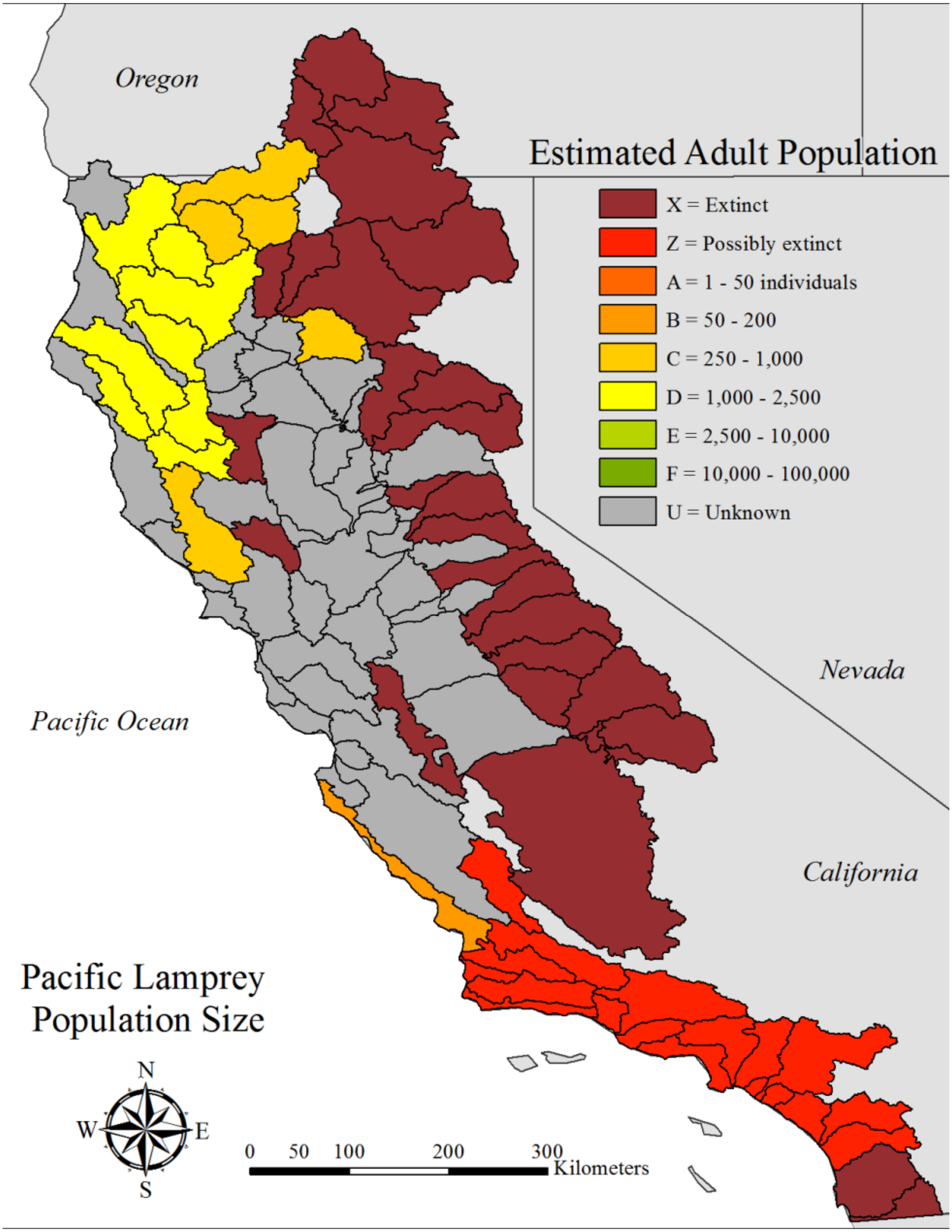


Figure 4-5. **Current population size of Pacific Lamprey in California** at resolution of 4th Field HUC's. Much of the region could not be estimated due to lack of information.

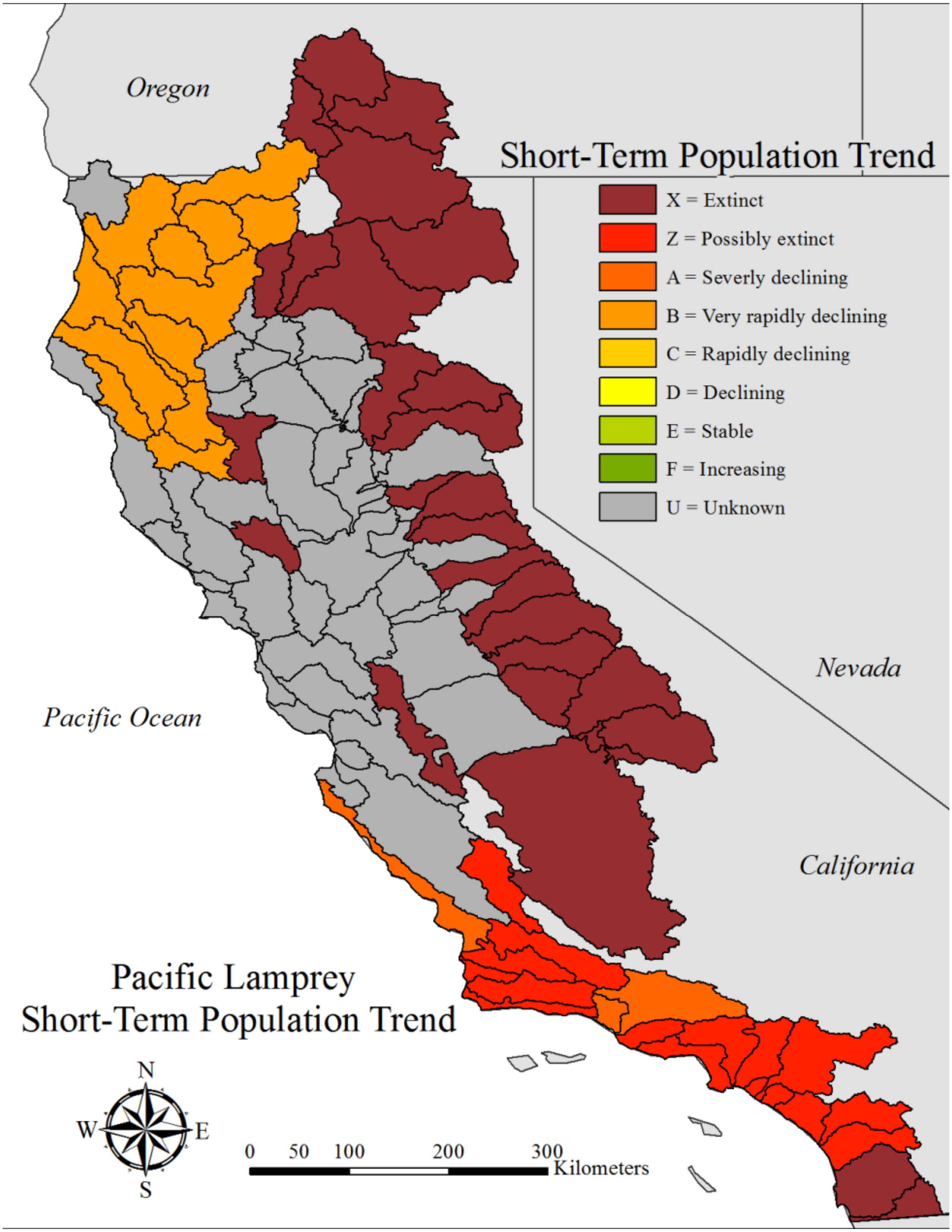


Figure 4-6. **Short term trend in abundance of Pacific Lamprey in California** at resolution of 4th Field HUC's.

Threats and Limiting Factors to Pacific Lamprey in the California Region

All threat categories considered within the California Region are summarized and discussed below. The scope of at least one threat category and/or another was generally widespread within a HUC or else affected a large portion of the population, as would a passage obstruction (Figure 4-7), and the severity of at least one threat was generally moderate to high (Figure 4-8). Principal threats generally fell into one of five categories (Passage, Dewatering, Stream Degradation, Water Quality and Predation; Figures 4-9 to 4-13), with other potential threat categories generally assessed to be at low magnitude or by their nature not assessable at the present time and with available information. Details for individual HUC's are provided within the sub-regional chapters that follow.

Passage (*dams, culverts, water diversions, tide gates, other barriers****).—*** Obstruction of upstream passage by large dams has accounted for the extensive elimination of mid and upper elevation reaches where spawning and rearing were likely to have occurred in the past (Figure 4-9). Most major dams in California lack fish passage facilities. All impassable dams were constructed prior to 1985 and therefore represent a historical loss of habitat, rather than current threats. However, this extensive loss of crucial habitat may be a major element in the regional decline of many HUC populations, due to the metapopulation dynamics of Pacific Lamprey and apparently high levels of exchange between drainages.

Currently operating fish passage facilities, when present, were generally designed for salmonid passage and often prevent or limit the upstream migration of adult lampreys. In many cases, they may also impact downstream migration success of juveniles, either through diversion of flow or mortality passing the dam at fish screens or overflow structures.

Culverts with perched outlets block upstream passage. However, they are often located at smaller road-crossings in tributaries and therefore accounted for relatively low scope in most HUC's where they were considered a threat. Available culvert passage assessments for salmonids were limited use for assessing passage for lampreys due to differences in passage capabilities.

A special case for passage issues 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 Sacramento and San Joaquin drainages. 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.

Dewatering and StreamFlow Management (*reservoirs, water diversions, instream projects****).—*** Flow management and seasonal desiccation of lamprey habitat was frequently considered a substantial threat to local lamprey populations (Figure 4-10). Multi-year ammocoete populations, which reside in the stream substrate for up to seven years, were particularly susceptible to seasonal or occasional desiccation, as were over-summering adults. Dewatering of stream habitat due to diversion of flows or pumping (instream and groundwater) was ranked as a major threat (moderate to severe scope and severity) in roughly half of the HUC's, including all sub-regions, and the highest (or equivalent) threat in 25% of the HUCs.

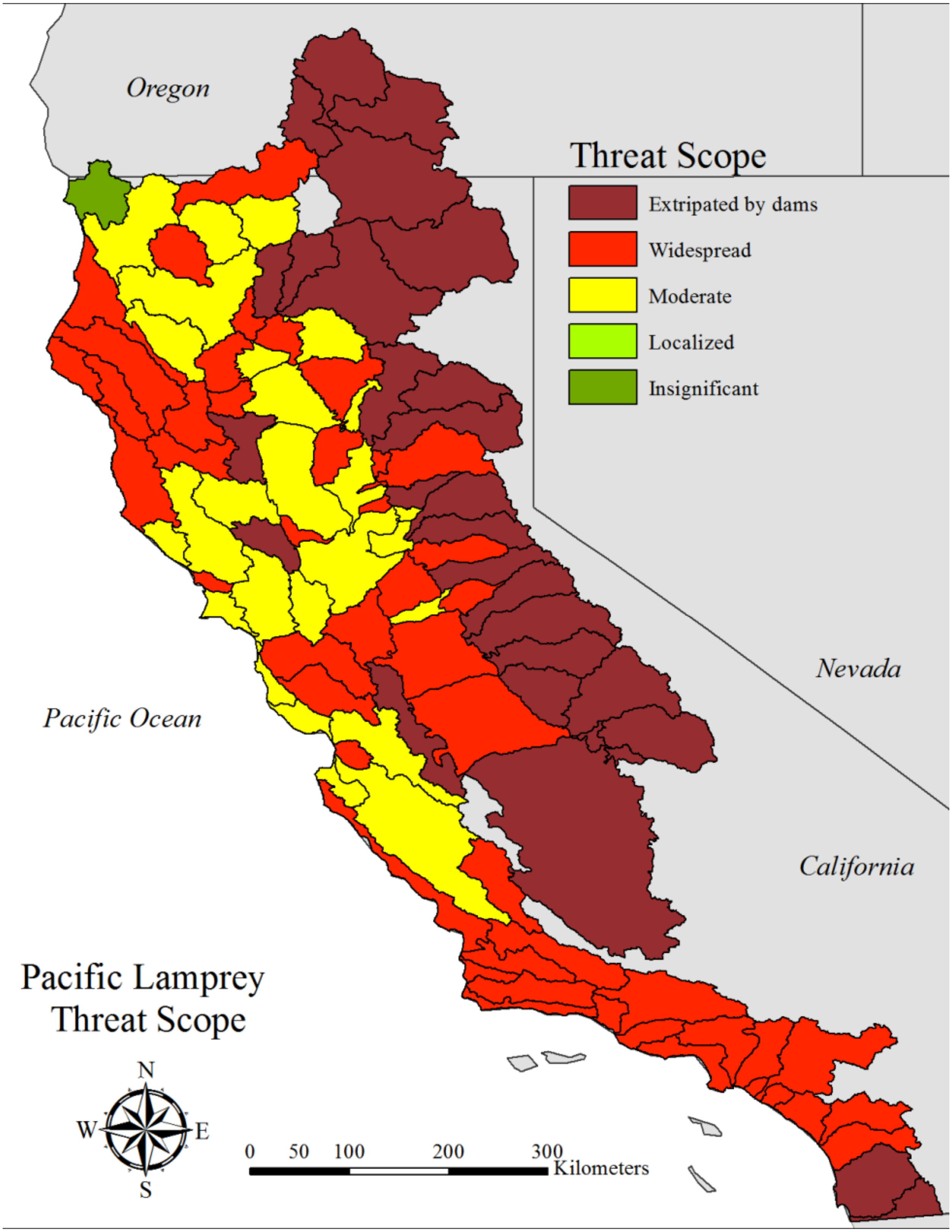


Figure 4-7. **Scope of threats to Pacific Lamprey in California** at level of 4th Field HUC's.

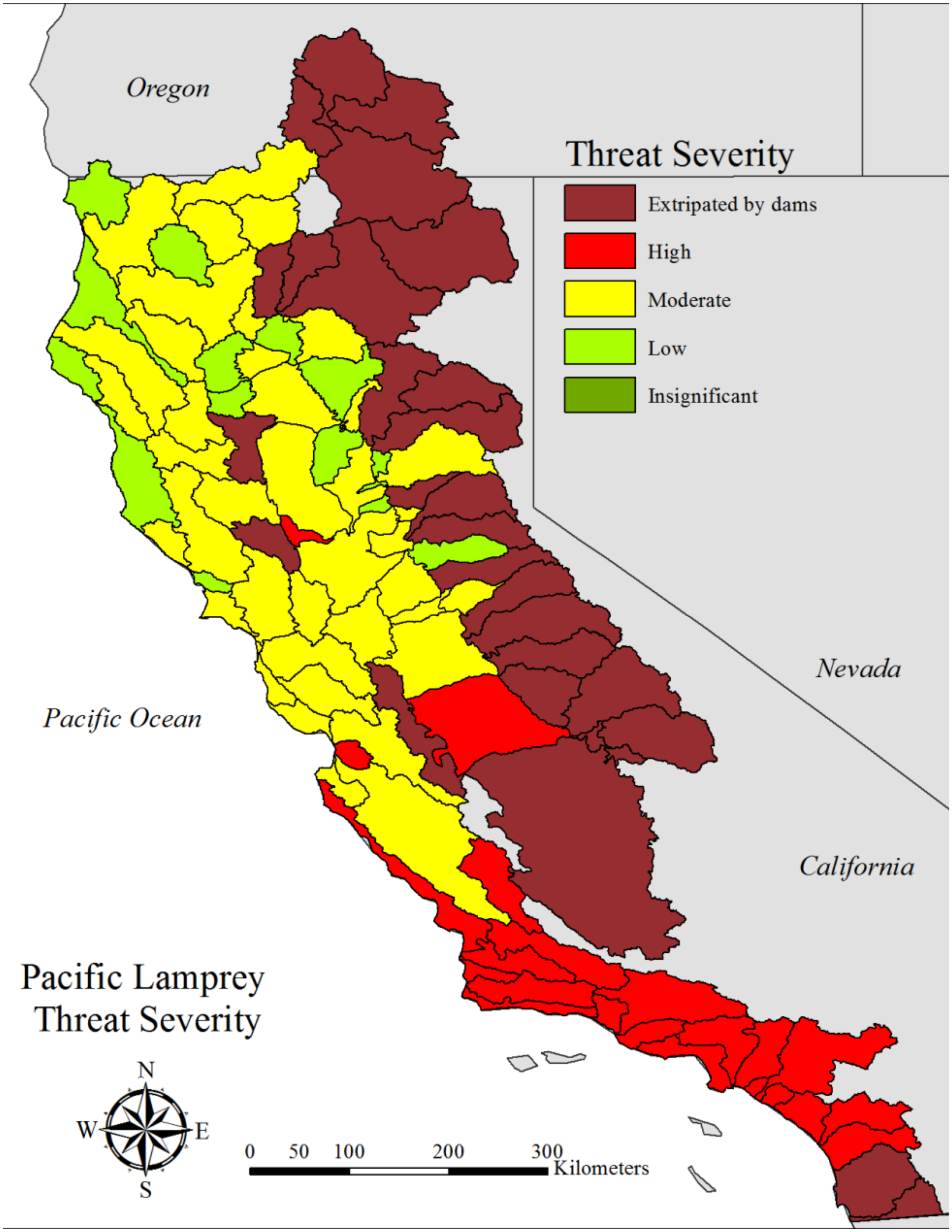


Figure 4-8. **Severity of threats to Pacific Lamprey in California** at level of 4th Field HUC's.

Dewatering due to reservoir management was also assessed as a substantial threat in nine HUC's, primarily in south coastal and southern sub-regions, where flow is cutoff and retained by reservoirs, as well as in the mainstem Klamath River where rapid flow ramping can result in high mortality of ammocoetes.

Arid climatic conditions resulting in low flow or naturally desiccated channels was a particular concern in southern mid-coastal and southern California HUCs, especially as drought conditions exacerbated other threats (e.g. water quality, flow diversions, and streambed alteration).

Stream and Floodplain Degradation (channelization, loss of side channel habitat, scouring).— Although there has been extensive alteration of stream bed and riparian habitat in California, degradation of stream channel habitat was generally considered a relatively low threat, with exceptions primarily due to extensive channelization, often associated with vegetation removal, in more urban HUCs or to dredging and gravel mining in some Sacramento and North Coast HUCs (Figure 4-11). In no HUC's did this category rise to a combined high scope and severity.

Water Quality (*Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source)*.— Water Quality was generally assessed as a moderate but non-imminent threat, except as it was associated with higher summer water temperatures (Figure 4-12). Water temperature, especially when combined with higher nutrient loadings and associated algal blooms or substrate-choking algal carpets were considered moderate to high threats in river reaches where they occurred (about 25% of HUC's). Affected HUC's were primarily in the North Coast and southern sub-regions, where summer air temperatures, low/shallow flows and high nutrients occurred together. Nevertheless, the actual impact to the lamprey population was difficult to quantify, and the dynamics of these threats, especially with regard to sediment conditions and in southern populations, has not been well investigated.

Water quality issues related to contamination were generally widespread, but unresolved and generally difficult to assess. Runoff of pesticides, organic compounds and heavy metals were particular concerns in urban and agricultural areas; however, their effects on the lamprey population is not known. Legacy metals from historical mining (e.g. mercury and arsenic) are also concerns, but again there is little information to aid in assessing the level of threat represented within a HUC. It is probable that contaminants are having adverse effects on lampreys, especially resident ammocoetes, in many HUCs, but at this time we have insufficient information to assess the magnitude of effects. We recommend evaluation of contaminant effects and survey of ammocoete presence/survival in areas subject to higher levels of industrial, urban or agricultural chemicals.

Predation.— The role of predation as a threat to current lamprey populations was generally ranked insignificant in severity, with scope being dependent on the distribution and relative abundance of native and non-native aquatic predators (Figure 4-13). Notable exceptions were: a) the lower Sacramento/ San Joaquin and S.F. Bay HUCs with relatively high populations of Striped Bass, a large non-native predator capable of consuming all life-stages of lampreys, including adults; b) the Eel River HUCs where introduction of Pikeminnow (a large predatory minnow native to the Sacramento and Russian drainages, but not the Eel) has introduced a new predator with relatively high abundance, and c) the lower Klamath River, and perhaps other rivers, where seals and sea lions feed on migrating runs of adult lampreys near the mouth. However, the character and severity of these threats could not be assessed, and they were ranked as Unknown for the time being.

Harvest/Overutilization.— Harvest was not considered a major threat in any of California's HUC's (ranked Insignificant in both scope and severity). We encountered no evidence for substantial harvest of lampreys, however there is some tribal harvest for consumption, primarily in the North Coast sub-region (i.e. Klamath and Eel drainages). There is no commercial fishery for lampreys in California, and commercially available bait lampreys (frozen) are imported from Alaska. In 2010 CDFG established a daily bag limit of five adult lamprey. Collection of Pacific Lampreys for bait (both adults and ammocoetes) probably still occurs, although we have not been able to assess at what levels. A concerted daily effort to catch lampreys on the spawning grounds where they are especially vulnerable could have a substantial effect on a local population.

Small Population Size.— Small effective population size was not seen as a threat in most of California's HUC's (ranked Insignificant in both scope and severity), except in southern populations (see below). This is primarily due to the generally widespread distribution of lampreys (as evidenced by ammocoete presence) in most HUC's (below impassable barriers) and the evidence for considerable genetic mixing between populations and regional metapopulation dynamics (see Chap. 2 - Biology). The exception is in the southern populations, below Big Sur, where all populations are ranked at risk (high scope and severity) for this threat due to the apparent absence, or extremely low numbers, of ammocoetes in all southern HUC's. Absence of ammocoete pheromones reduces or eliminates attraction of migrating adult Pacific Lampreys 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.

Disease.— The effects of disease on lampreys was not assessed. We know very little about disease in natural lamprey populations (summarized in Methods/Generalized Threats/Disease). While it was generally recognized that disease could have a substantial effect on the success of a local population, no instance of it playing a role in the mortality or decline of a natural population was reported in any of the stakeholder assessment discussions.

Lack of Awareness.— This is a difficult threat to assess or quantify and was not ranked. Nevertheless, there is certainly a general lack of awareness of lampreys throughout the public, conservation and fisheries management communities in California. Many times people are unaware of the role of lampreys in the ecosystem or even their presence within a particular drainage, and in some cases there is a general antipathy towards lampreys. Lamprey needs are frequently not considered in habitat management plans, instream flow management, salmocentric stream restoration or fish passage projects. This can lead to adverse effects, especially in the seasonal dewatering of ammocoete habitat or design of fish passage structures that effectively exclude lampreys due to design features such as jumps or angular edges. Increased education, outreach, coordination and inclusion in conservation planning will be essential for long-term conservation of lampreys in California and is a major component of the PLCI.

Ocean Conditions.— No information was assessed regarding the effects of oceanic conditions on outmigrating juvenile and adult lamprey, although it was generally recognized that this phase of their life-history may have a substantial effect on the success of not only local populations but also the entire regional metapopulation. Areas of concern were status of the lamprey's prey-base, predation on adult lampreys by marine mammals and oceanic fishes, influence of oceanographic conditions (e.g. temperature, currents and productivity), and accumulation of heavy metals (e.g. mercury) in the food chain.

Climate Change.— No information was assessed regarding the effects of climate on either marine or freshwater stages of lamprey, although it was generally recognized that climate change would affect populations, particularly in the southern portion of their range. Potential impacts that would exacerbate current threats included: a) continued desiccation of drainages, either directly through water usage (surface diversion or groundwater pumping), or due to rising temperatures, increased aridity, or reduced precipitation, b) shifts in seasonal precipitation patterns altering migration cues (up or downstream) or passage through sandbars, and c) changes in distribution or abundance of marine prey-base.

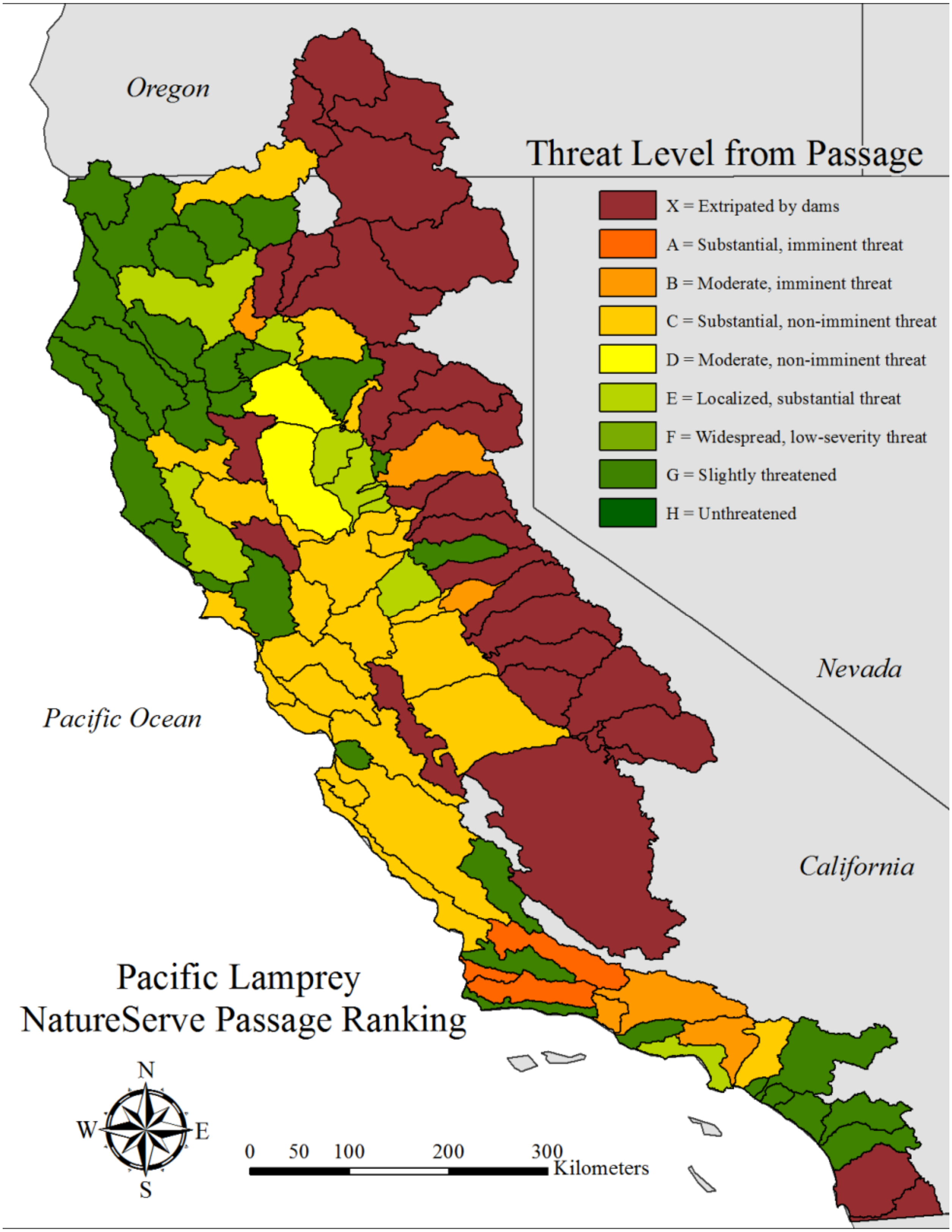


Figure 4-9. **Passage constraints as threats to Pacific Lamprey in California**. Ranked at level of 4th Field HUC's.

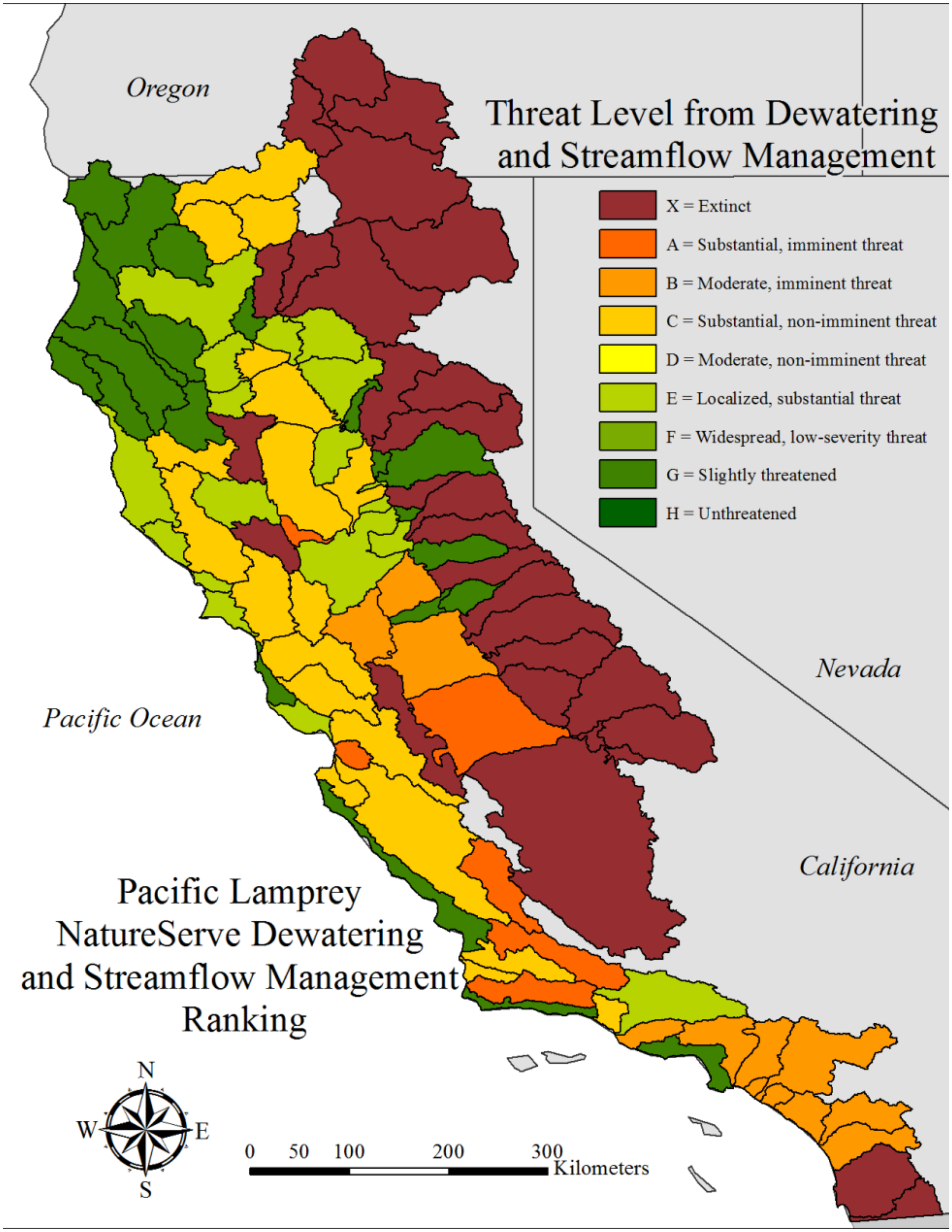


Figure 4-10. **Dewatering and flow management as threats to Pacific Lamprey in California**. Ranked at level of 4th Field HUC's.

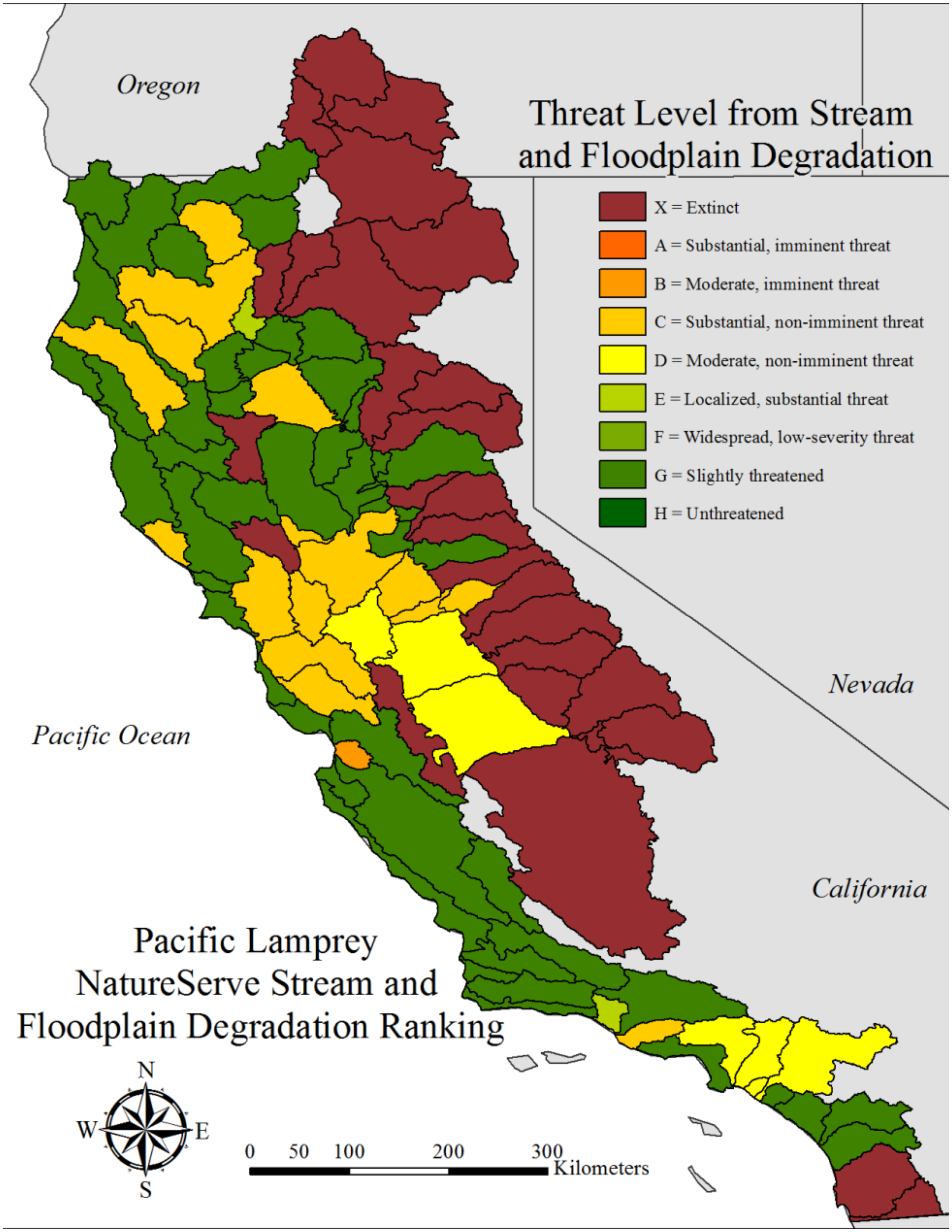


Figure 4-11. **Stream and Floodplain Degradation as threats to Pacific Lamprey in California**. Ranked at level of 4th Field HUC's.

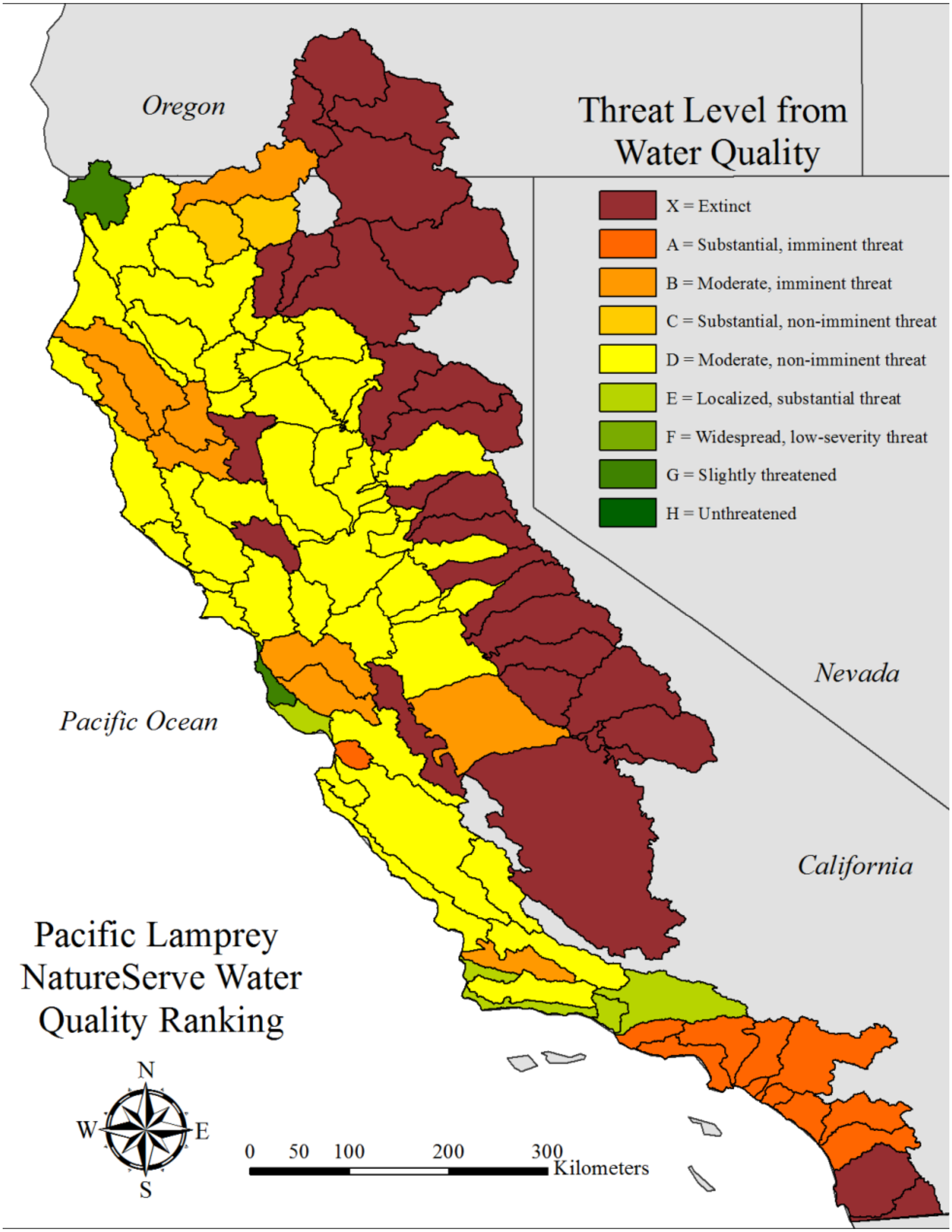


Figure 4-12. **Water Quality conditions as threats to Pacific Lamprey in California**. Ranked at level of 4th Field HUC's.

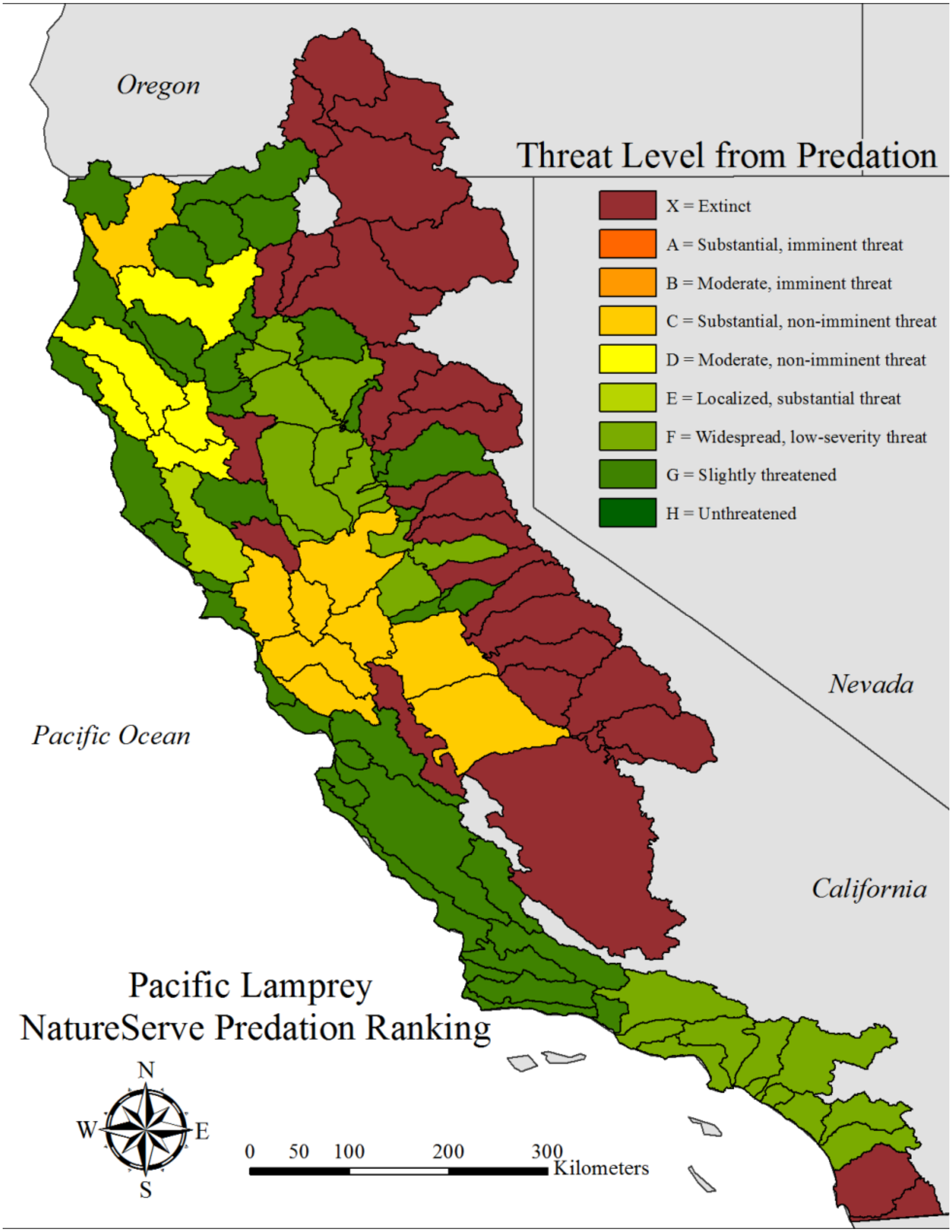


Figure 4-13. **Predation as a threat to Pacific Lamprey in California**. Ranked at level of 4th Field HUC's.

5. NORTH COAST SUB-REGION

The North Coast Sub-Region includes all coastal drainages from Punta Gorda (Mattole River) north to the Oregon border, including the northern half of the Northern California Coastal (01) and the entire Klamath (02) USGS accounting units (Figure 5-1. Map). It includes 19 watersheds (4th field HUCS), ranging from 1,292 - 7,759 km^2 (Table 5-1). The sub-region extends from the coast inland, cutting through the Klamath and Cascade mountain ranges into the interior and occupies the Coast Range, Klamath Mountains, Cascade, and Eastern Cascade, slopes and foothills ecoregions. Due to sub-regional differences in hydrology, habitat and threats, we have grouped the HUC's into three sub-groupings: Klamath River, Eel River and Coastal.

Population Status of Pacific Lamprey in the North Coast Sub-Region

***Historical Range Extent*.—** Pacific Lamprey are assumed to have been widely distributed and abundant historically in the North Coast Sub-region, based on current distribution, available habitat and tribal knowledge of fisheries. The principal uncertainty is how far they extended into the upper Klamath Lake Basin (east of the Cascades), for which there are no records. However, for the purpose of this assessment we assume that they were able to utilize all habitat with anadromous access. This is based on the evidence for anadromous salmonids in the past (Hamilton et al. 2005), the widespread presence of other species of lamprey throughout the Klamath Basin, and the absence of natural barriers.

***Current Occupancy*.—** Pacific Lamprey currently occupy most historical anadromous habitat in the North Coast Sub-region downstream of impassable dams, except perhaps in the higher gradient reaches or smaller tributaries. The principal dams in the sub-region are the Klamath River dams, with the lowest being Iron Gate (constructed 1962, but preceded by Copco #1 constructed a short distance upstream in 1912), the Lewiston and Trinity dams on the Trinity River (constructed 1962), and the Van Arsdale (constructed 1907; fish ladder 1922) and Scott (constructed 1922) dams on the upper Eel River.

***Ratio of Current Occupancy to Historical Range Extent*.—** With the exception of the entire upper Klamath Basin, which was blocked in 1917 by the construction of Copco #1 Dam, the North Coast sub-region has seen relatively little loss of historical distribution by obstruction of passage, generally < 10%. The Lewiston/Trinity dams blocked about 1,860 km^2 of the upper Trinity River (ca. 35% of the HUC). Scott Dam blocks about 750 km^2 of the Upper Eel HUC (ca. 40%), and the Van Arsdale Dam, with a difficult fish ladder constructed in 1922, restricts access to another 140 km^2. Obstruction of smaller tributaries by culverts is currently being assessed in the Eel Drainage.

***Population Size*.—** Population size (adults) in the sub-region, similarly to all other areas, is poorly understood and not formally monitored. However, unlike other areas, there is a long tribal history of subsistence fishing in the North Coast drainages, especially in the Eel and Klamath rivers. Tribal participants estimated 1,000-10,000 adult lampreys migrating into their drainages in recent years (distributed among HUCs). The Hoopa Valley Tribe caught an estimated 2,755 adults in the lower Trinity River in 2012 providing a very conservative estimate of adult population for the HUC (Hoopa preliminary tribal creel estimate; Billy Matilton pers. com), and at least 700 adults were collected at and passed over Van Arsdale Dam in Spring 2012 by CDFG. Nevertheless, there is no formal counting of lampreys in the sub-region, and these estimates represent a rough minimum count. Downstream migrant monitoring at screw-traps is generally focused on salmonids and hampered, especially in the Klamath, by the presence of additional lamprey species in the catch, inability to sample during high flows utilized by outmigrating juveniles, and seasonal monitoring that may miss the principal lamprey migration times.

***Short Term Trend*.—** While in most areas, the lack of formal monitoring of adult migrations makes any quantification of population trends impossible, the presence of a long tribal fishery in the North Coast with living recollections of past lamprey runs allows us to get some sense of declining numbers. Tribal fishermen who fished in the 1970-80's recollect much larger runs and suggest declines of at least 90% from those days and consistently low runs since the mid 1980's with continued decline. Such declines are in agreement with records from the Oregon Coast at Winchester Dam on the North Fork Umpqua River (see Figure 1-1).

***NatureServe Risk Ranks*.—** NatureServe risk ranks generally varied from imperiled to vulnerable (S2-S3), except for the extinct upper Klamath Basin HUCs and the Smith River, which was the only HUC with a ranking of Apparently Secure (S4). The Smith River was also the only HUC in any of the West Coast Regions to be ranked as secure. See discussion of threats below.

Figure 5-1. **Map of the** North Coast **Sub-Region** and its watersheds (4th field HUCs).

Table 5-1. Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the North Coast Sub-Region. Unoccupied HUCs are included for reference - historically non-anadromous HUCs are indicated by "N/A", and populations extirpated by impassable dams prior to 1985 are indicated as "Extinct". NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure.

NORTH COAST		Distribution				Max. Threats		
Watershed	**HUC**	**Maximum Historical (km^2)**	**Ratio Current/ Historical**	**Population Size (#)**	**Short-Term % Decline**	**Scope**	**Severity**	**Risk Rank**
Klamath River:								
Williamson	18010201	3,761	0.00	Extinct	-	-	-	SX
Sprague	18010202	4,152	0.00	Extinct	-	-	-	SX
Upper Klamath Lake	18010203	1,883	0.00	Extinct	-	-	-	SX
Lost	18010204	7,759	0.00	Extinct	-	-	-	SX
Butte	18010205	NA	-	-	-	-	-	-
Upper Klamath	18010206	3,680	0.75	250-1000	50 - 70%	High	Mod.	S2
Shasta	18010207	2,041	0.90	250-1000	50 - 70%	Mod	Mod	S2
Scott	18010208	2,106	0.90	250-1000	50 - 70%	Mod	Mod	S2
Salmon	18010210	1,946	1.00	1000-2500	50 - 70%	High	Low	S3
Trinity	18010211	5,329	0.75	1000-2500	50 - 70%	Mod.	Mod.	S2
South Fork Trinity	18010212	2,360	1.00	1000-2500	50 - 70%	Mod.	Mod.	S2
Lower Klamath	18010209	3,964	1.00	1000-2500	50 - 70%	Mod.	Mod.	S3
Eel River:								
Lower Eel	18010105	3,982	1.00	1000-2500	50 - 70%	High	Mod.	S2
Middle Fork Eel	18010104	1,942	1.00	1000-2500	50 - 70%	High	Mod.	S2
South Fork Eel	18010106	1,779	1.00	1000-2500	50 - 70%	High	Mod.	S2
Upper Eel	18010103	1,823	0.75	1000-2500	50 - 70%	High	Mod.	S2
Coastal:								
Smith	18010101	2,075	1.00	Unknown	Unknown	Insignif.	Low	S4
Mad-Redwood	18010102	2,989	1.00	Unknown	50 - 70%	High	Low	S3
Mattole	18010107	1,292	1.00	Unknown	Unknown	High	Low	S3

Threats and Limiting Factors to Pacific Lamprey in the North Coast Sub-Region

Threats and limiting factors to Pacific Lamprey in the North Coast Sub-Region are provided in Table 5-2 for the principal five threats, also discussed below. The remaining threat categories were either of low risk throughout the sub-region or were not considered in this assessment as a whole due to lack of information (see discussion under Chap. 4 - California Regional Summary: Small Population Size, Disease, Lack of Awareness, Ocean Conditions, and Climate Change). While Harvest was not a major threat in most of California, the north coastal region is the only area where there is tribal harvest; however, it is carried out at a subsistence level and ranked as low to insignificant in scope and severity.

***Summary*.—** The primary threats in the North Coast sub-region vary between areas. The mainstem Klamath River is primarily affected by the presence of multiple hydropower dams, demands for agricultural water and flow management. The Scott River is affected by water withdrawals and the legacy effects of streambed alteration. The Trinity is affected by the Trinity/Lewiston dams, water withdrawals, water management and the legacy effects of streambed alteration, as well as instream dredging. In the Eel River watershed the primary threats were associated with water quality issues associated with high water temperatures and nutrient loading, as well as watershed management effects on channel morphology and bedload dynamics in the Lower Eel, and two large dams and diversions in the Upper Eel. Predator threats were not resolved, but included marine mammals at the mouth of the Klamath, Brown Trout in the Trinity, and introduced Pikeminnow in the Eel. The three smaller coastal HUCs (Smith, Mad-Redwood and Mattole) and the Salmon (tributary to the Klamath) were all ranked relatively low for threats.

Passage (*dams, culverts, water diversions, tide gates, other barriers****)*.—** Major impassable dams caused the extirpation of all the upper Klamath Basin HUCs, as well as isolation of the upper Trinity. The upper Eel River also lost about a quarter of its watershed to the Scott Dam, and the Van Arsdale Dam downstream restricts upstream passage by lampreys, although some do pass the dam. Otherwise, passage concerns in the remaining watersheds are generally limited to culverts and smaller diversions on tributaries and were generally ranked low (scope and severity).

Dewatering and StreamFlow Management (*reservoirs, water diversions, instream projects****)*.—** Flows in the Klamath River itself are heavily managed. Flow-ramping to meet hydroelectric demands can produce rapid drops in water-level and mortality of ammocoetes in shoreline sediments, and agricultural demands can reduce flows, which when combined with high summer temperatures and eutrophic conditions has resulted in major fish kills. Dewatering for agricultural uses, including groundwater pumping, also ranked as high in the Scott River. Outside the Klamath Basin dewatering and flow management were generally ranked as low (scope and severity) in the Eel and other coastal drainages, except in the Upper Eel where the Potter Valley Project diverts a large proportion of summer flow into the Russian River Basin, reducing instream flow for a considerable reach below Van Arsdale Dam.

***Stream and Floodplain Degradation (channelization, loss of side channel habitat, scouring)*.—** Stream degradation was generally ranked as low as a threat, except in four HUCs, all ranked moderate in scope and severity. The Scott River was ranked for degradation due to gravel operations, channelization, rip-rapping, and historical logging operations. The two Trinity HUCs were ranked due to instream gravel operations, loss of complexity due to historical mining and water management, and dredge mining. While in the Lower Eel, historical watershed management has shifted the system to one dominated by coarse bedload, changed the timing and intensity of runoff, and shifted the riparian corridor from narrow and tree-lined with deeper pools to wide, shallow and denuded.

Water Quality (*Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source)***.**—** Water quality issues were generally ranked as widespread, but low in severity throughout the sub-region, except in the Klamath River itself (Upper Klamath HUC) where significant eutrophication affects water quality in the Summer and Fall, and in the Eel River where high summer water temperatures, low flows promote the growth of algae and associated dissolved oxygen effects.

Predation.**—** Predation was not generally considered a threat in the north coastal streams, except in the Eel River where introduced Pikeminnow (native to the Russian River and Central Valley drainages) are now common in the mainstem, and in the Trinity River which supports a large Brown Trout population. Large Pikeminnow are piscivorous and are known to consume juvenile lampreys. Brown Trout are also known predators of juvenile lamprey and feed nocturnally, so they may encounter lamprey more often than other predatory fishes do. The impact of either predator on local populations is not known and may be ameliorated by the generally nocturnal activity patterns of lampreys and downstream migration during periods of high flow and turbidity. In the lower Klamath River, and perhaps other rivers, seals and sea lions feed on migrating runs of adult lampreys near the mouth, and this pressure has increased as pinniped populations increase. Nevertheless, the character and severity of threats due to predators could not be assessed, and they were ranked as Unknown for the time being.

Table 5-2. Principal threat rankings, maximum threat level and NatureServe ranks for Pacific Lamprey within the North Coast Sub-Region. See maps in Chapter 4. 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: 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.

NORTH COAST			Individual Threats (Scope - Severity)				
Watershed	Risk Rank	Maximum Threat	Passage	Dewatering /Flow	Stream Degradation	Water Quality	Predation
Klamath River:							
Williamson	SX	X	X	-	-	-	-
Sprague	SX	X	X	-	-	-	-
Upper Klamath Lake	SX	X	X	-	-	-	-
Lost	SX	X	X	-	-	-	-
Butte	NA	-	-	-	-	-	-
Upper Klamath	S2	B	3 - 3	3 - 3	1 - 1	4 - 3	2 - 1
Shasta	S2	C	2 - 2	3 - 3	1 - 1	3 - 3	1 - 1
Scott	S2	C	2 - 2	3 - 3	3 - 3	3 - 3	2 - 1
Salmon	S3	D	2 - 2	1 - 1	1 - 1	4 - 2	1 - 1
Trinity	S2	C	2 - 3	3 - 2	3 - 3	4 - 2	3 - U
South Fork Trinity	S2	C	2 - 2	1 - 1	3 - 3	4 - 2	2 - 1
Lower Klamath	S3	C	2 - 2	2 - 2	2 - 2	4 - 2	4 - U
Eel River:							
Lower Eel	S2	B	2 - 2	2 - 2	3 - 3	4 - 3	3 - U
Middle Fork Eel	S2	B	2 - 2	2 - 2	1 - 1	4 - 3	3 - U
South Fork Eel	S2	B	2 - 2	2 - 2	1 - 1	4 - 3	3 - U
Upper Eel	S2	B	3 - 3	3 - 3	1 - 1	4 - 3	3 - U
Coastal:							
Smith	S4	G	1 - 2	1 - 1	1 - 1	1 - 1	1 - 1
Mad-Redwood	S3	D	2 - 2	2 - 2	1 - 1	4 - 2	2 - 1
Mattole	S3	D	2 - 2	2 - 2	1 - 1	4 - 2	2 - 1

6. NORTH CENTRAL COAST SUB-REGION

The North Central Coast Sub-Region includes all coastal drainages from Punta Gorda in the north to the Golden Gate in the south, including the southern half of the Northern California Coast and the outer coast portion of the San Francisco Bay USGS accounting units (Figure 6-1. Map). It includes five watersheds (4th field HUCS), ranging from 402 - 3,849 km^2 (Table 6-1). The sub-region occupies the Coast Range and Southern and Central Californian Chaparral / Oak Woodlands ecoregions.

Table 6-1. **Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the North Central Coast Sub-Region**. Unoccupied HUCs are included for reference - historically non-anadromous HUCs are indicated by "N/A", and populations extirpated by impassable dams prior to 1985 are indicated as "Extinct". NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure.

N. CENTRAL COAST		Distribution				Max. Threats		
Watershed	HUC	Maximum Historical (km^2)	Ratio Current/ Historical	Population Size (#)	Short-Term % Decline	Scope	Severity	Risk Rank
Big-Navarro-Garcia	18010108	3,241	1.00	Unknown	Unknown	High	Low	S3
Gualala-Salmon	18010109	898	1.00	Unknown	Unknown	Mod.	Mod.	S2
Russian	18010110	3,849	0.90	250-1000	Unknown	Mod.	Mod.	S3
Bodega Bay	18010111	402	0.90	Unknown	Unknown	High	Low	S2
Tomales-Drake Bays	18050005	897	0.75	Unknown	Unknown	Mod.	Mod.	S2

Population Status of Pacific Lamprey in the North Central Coast Sub-Region

***Historical Range Extent*.—** Pacific Lamprey are assumed to have been historically widely distributed and abundant in the North Central Coast drainages, based on current distribution, available habitat and lack of natural barriers.

***Current Occupancy*.—** Lamprey currently occupy most anadromous habitat in the sub-region, except perhaps the higher gradient reaches of tributaries. The principal impassable dams in the sub-region are Coyote Valley Dam (constructed 1958, 270 km^2) and Warm Springs Dam (1982, 340 km^2) in upper tributaries of the Russian River; and the Nicasio (1961) and Peters (1954) dams in the Lagunitas drainage (Tomales-Drake Bay).

***Ratio of Current Occupancy to Historical Range Extent*.—** On the whole, the North Central Coast has seen relatively little loss of historical distribution by obstruction of passage, generally < 10%.

***Population Size*.—** Population size (adults) in the sub-region, similarly to all other areas, is poorly understood and not formally monitored. Video monitoring of adults at Wohler Dam (a seasonal inflatable diversion dam) has been initiated on the Russian River (2000-2012); however timing of observations, incomplete coverage of potential passage routes, changes in protocol and seasonality result in highly variable effectiveness - the maximum count was 580 adults in 2007. Aside from these counts, there is no formal monitoring of lampreys in the sub-region, and these estimates represent a very rough minimum count.

***Short Term Trend*.—** The lack of formal monitoring of adult migrations makes any quantification of population trends impossible. However, there is nothing to suggest that declines have not been similar to the North Coast sub-region (see Chapter 5) and Oregon Coast at Winchester Dam on the North Fork Umpqua River (see Figure 1-1).

***NatureServe Risk Ranks*.—** NatureServe risk ranks varied from imperiled to vulnerable (S2-S3). See discussion of threats below.

Figure 6-1. **Map of the North Central Coast Sub-Region** and its watersheds (4th field HUCs).

Threats and Limiting Factors to Pacific Lamprey in the North Central Coast Sub-Region

Threats and limiting factors to Pacific Lamprey in the North Central Coast Sub-Region are provided in Table 6-2 for the principal five threats, also discussed below. The remaining threat categories were either of low risk throughout the sub-region or were not considered in this assessment as a whole due to lack of information (see discussion under Chap. 4 - California Regional Summary: Harvest, Small Population Size, Disease, Lack of Awareness, Ocean Conditions, and Climate Change).

Table 6-2. Principal threat rankings, maximum threat level and NatureServe ranks for Pacific Lamprey within the North Central Coast Sub-Region. See maps in Chapter 4.
Individual threat rankings for Scope and Severity: 1 to 4, Insignificant to High; U = Unknown.
NatureServe ranks: 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.

			Individual Threats (Scope - Severity)				
Watershed	**Risk Rank**	**Maximum Threat**	**Passage**	**Dewatering /Flow**	**Stream Degradation**	**Water Quality**	**Predation**
Big-Navarro-Garcia	S3	D	2 - 2	2 - 3	1 - 1	4 - 2	2 - 1
Gualala-Salmon	S2	C	2 - 2	2 - 3	3 - 3	4 - 2	2 - 1
Russian	S3	C	2 - 3	3 - 3	2 - 2	4 - 2	3 - 2
Bodega Bay	S2	D	2 - 2	2 - 3	2 - 2	4 - 2	2 - 1
Tomales-Drake Bays	S2	C	3 - 3	2 - 3	1 - 1	4 - 2	2 - 1

***Summary*.—** The primary threats in the North Central Coast sub-region were dewatering and to a limited extent passage in two HUCs. Most threats were ranked at low to moderate, with no severe threats in any HUCs.

Passage (*dams, culverts, water diversions, tide gates, other barriers****)*.—** Major barriers to passage were found in only two HUCs and did not affect large portions of the watersheds, except for the relatively small Lagunitas drainage within the Tomales-Drake Bay HUC.

Dewatering and StreamFlow Management (*reservoirs, water diversions, instream projects****)*.—** Dewatering of streams, resulting in reduced summer flows, was ranked as low in scope (often small-scale unregistered diversions) and moderate in severity in all but the Russian River, where the scope was broader due to more extensive agriculture (viticulture). Impacts were typically in smaller streams and exacerbated naturally arid summer conditions.

Stream and Floodplain Degradation (channelization, loss of side channel habitat, scouring).**—** Stream degradation was generally ranked as low, except in the Gualala-Salmon HUC, where instream gravel mining impacted the mainstem rivers.

Water Quality (*Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source)*.**—** Water quality issues were generally ranked as widespread, but low in severity throughout the sub-region.

Predation.**—** Predation was not considered a threat in the coastal streams, except in the Russian River where Smallmouth Bass are common in the mainstem. Bass are primarily diurnal predators on smaller fish and may feed on both ammocoetes and juveniles if they are encountered, but are unlikely to affect adult populations. Their impact on local populations is not known and may be ameliorated by the generally nocturnal activity patterns of lampreys and downstream migration during periods of high flow and turbidity.

7. SOUTH CENTRAL COAST SUB-REGION

The South Central Coast Sub-Region includes all coastal drainages from the Golden Gate to Point Conception, including the coastal portion of the San Francisco Bay and most of the Central California Coastal USGS accounting units (Figure 7-1. Map). It includes 13 watersheds (4th field HUCS), ranging from 574 - 8,519 km^2 (Table 7-1). The sub-region occupies the Coast Range and Southern and Central Californian Chaparral / Oak Woodlands ecoregions.

Table 7-1. **Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the South Central Coast Sub-Region**. Historically non-anadromous HUCs are indicated by "N/A". NatureServe ranks: SX, Extinct; SH, Possibly extinct; and S1 to S4, critical to secure.

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

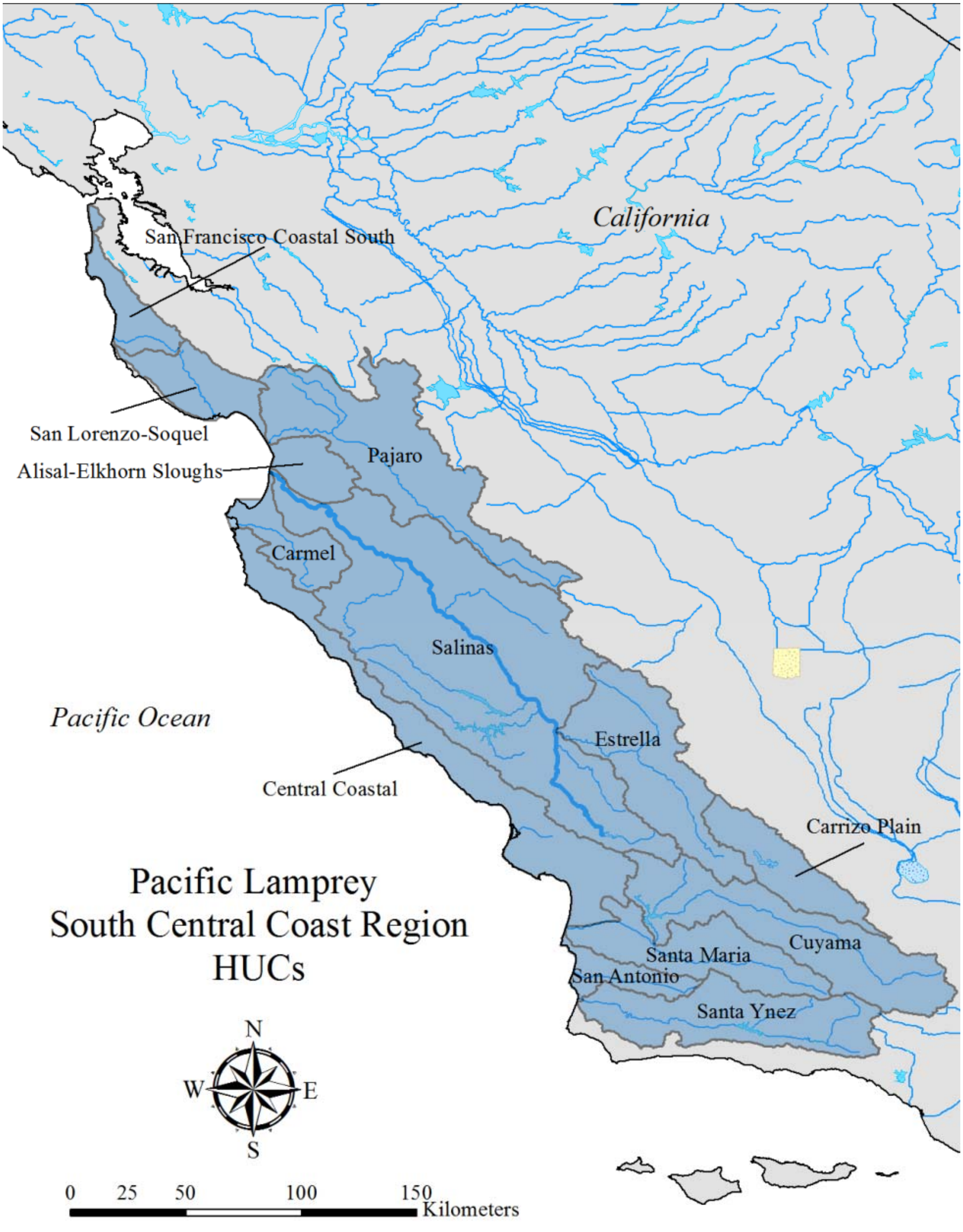


Figure 7-1. **Map of the South Central Coast Sub-Region** and its watersheds (4th field HUCs).

Population Status of Pacific Lamprey in the South Central Coast Sub-Region

***Historical Range Extent*.—** Pacific Lamprey are assumed to have been widely distributed historically and abundant in the South Central Coast drainages, based on 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 sub-region north of Big Sur, except perhaps the higher gradient reaches of tributaries. However, recent surveys indicate that lampreys have disappeared from all coastal streams south of the Big Sur River. Furthermore, even occupied drainages have had major habitat loss by impassable dams and desiccation of habitat by reservoir management and pumping (see Threats below).

***Ratio of Current Occupancy to Historical Range Extent*.—** As a result, the ratio of current to historical habitat has been substantially reduced by 25-90% in all occupied HUCs and five of twelve HUCs are probably extinct or do not contain viable populations.

***Population Size*.—** Population size (adults) in the sub-region, 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 1970's and, more recently, the loss of the San Luis Obispo population at some time between 2005-2011 (Goodman and Reid unpub. data). Declines in occupied HUCs north of Big Sur may be similar to the North Coast sub-region (see Chapter 5) and Oregon Coast at Winchester Dam on the North Fork Umpqua River (see Figure 1-1). 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. See discussion of threats below.

Threats and Limiting Factors to Pacific Lamprey in the South Central Coast Sub-Region

Threats and limiting factors to Pacific Lamprey in the South Central Coast Sub-Region are provided in Table 7-2 for the principal five threats, also discussed below. While small population size was not a major threat in most of the California, it was a concern in this sub-region, especially south of Big Sur, and is also discussed below. The remaining threat categories were either of low risk throughout the sub-region or were not considered in this assessment as a whole due to lack of information (see discussion under Chap. 4 - California Regional Summary: Harvest, Disease, Lack of Awareness, Ocean Conditions, and Climate Change).

***Summary*.—** Pacific Lampreys have apparently disappeared from all South Central Coast drainages south of Big Sur at this time. Therefore, those HUC's 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 and dewatering of streams due to the extensive use of water for agricultural, as well as natural aridity. 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 was also a concern in two HUCs. The absence of resident lamprey populations in the southern streams also presented a barrier to future recolonization due to the absence of ammocoete pheromones to attract migrating adults into the drainage and low adult numbers that 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 high 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). In only three HUCs was passage not considered a major threat.

Dewatering and StreamFlow 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 purposes in most HUCs further exacerbates the adverse conditions in local streams. In the Salinas River, by far the largest drainage basin in this sub-region (includes the Estrella HUC, a tributary) high permeability of the sandy lower river combined with heavy agricultural groundwater pumping results in periods where the river channel has dry reaches, limiting access by adults to upstream spawning habitat and periodically causing mass mortalities of outmigrating juveniles when flows, even during periodic storm events, do not reach the sea. Reservoir management and agricultural use of water in the Pajaro, Carmel, Cuyama (Santa Maria tributary) and Santa Ynez also severly reduce the available perrenial 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 sub-region.

Water Quality (*Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source)***.**—** South Central Coast includes major agricultural and minor urban areas, and as such has water quality issues with contaminants; however, 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 to be a major threat to lamprey populations.

Small 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 HUC's. Absence of ammocoete pheromones reduces or eliminates attraction of migrating adult Pacific Lampreys into the drainage (see Chap. 2 Biology), hindering reestablishment of the population. Extremely low adult numbers reduce the probability of encounter with potential mates if an adult does enter the drainage.

Table 7-2. Principal threat rankings, maximum threat level and NatureServe ranks for Pacific Lamprey within the South Central Coast Sub-Region. See maps in Chapter 4. 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: 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.

			Individual Threats (Scope - Severity)				
Watershed	**Risk Rank**	**Maximum Threat**	**Passage**	**Dewatering /Flow**	**Stream Degradation**	**Water Quality**	**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 - 2	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

8. SOUTH COAST SUB-REGION

The South Coast Sub-Region includes all drainages that from Point Conception south to the Mexican border, including the Ventura-San Gabriel, Santa Ana and Laguna-San Diego coastal USGS accounting units (Figure 8-1. Map). It includes 18 watersheds (4th field HUCS), ranging from 233 - 4,403 km^2 (Table 8-1). The sub-region occupies the Southern California Mountain and Southern and Central Californian Chaparral / Oak Woodlands ecoregions.

Table 8-1. **Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the South Coast Sub-Region**. Unoccupied HUCs are included for reference - historically non-anadromous HUCs are indicated by "N/A", and populations extirpated by impassable dams prior to 1985 are indicated as "Extinct". NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure.

SOUTH COAST		**Distribution**				**Max. Threats**		
Watershed	**HUC**	**Maximum Historical (km^2)**	**Ratio Current/ Historical**	**Population Size (#)**	**Short-Term % Decline**	**Scope**	**Severity**	**Risk Rank**
Santa Barbara Coastal	18060013	964	0.001	Extinct?	70 - 99%	High	High	SH
Santa Barbara Channel Islands	18060014	NA	-	-	-	-	-	-
Ventura	18070101	708	0.001	Extinct?	70 - 99%	High	High	SH
Santa Clara	18070102	4,170	0.001	Extinct?	70 - 99%	High	High	SH
Calleguas	18070103	989	0.001	Extinct?	-	High	High	SH
Santa Monica Bay	18070104	1,504	0.001	Extinct?	70 - 99%	High	High	SH
Los Angeles	18070105	2,171	0.001	Extinct?	-	High	High	SH
San Gabriel	18070106	1,861	0.001	Extinct?	-	High	High	SH
San Pedro Channel Islands	18070107	NA	-	-	-	-	-	-
Seal Beach	18070201	233	0.001	Extinct?	-	High	High	SH
San Jacinto	18070202	NA	-	-	-	-	-	-
Santa Ana	18070203	4,403	0.001	Extinct?	70 - 99%	High	High	SH
Newport Bay	18070204	414	0.001	Extinct?	-	High	High	SH
Aliso-San Onofre	18070301	1,287	0.001	Extinct?	-	High	High	SH
Santa Margarita	18070302	1,920	0.001	Extinct?	-	High	High	SH
San Luis Rey-Escondido	18070303	2,021	0.001	Extinct?	70 - 99%	High	High	SH
San Diego	18070304	3,658	0.00	Extinct	-	-	-	SX
Cottonwood-Tijuana	18070305	1,216	0.00	Extinct	-	-	-	SX

Figure 8-1. **Map of the South Coast Sub-Region** and its watersheds (4th field HUCs).

Population Status of Pacific Lamprey in the South Coast Sub-Region

***Historical Range Extent*.—** Pacific Lamprey are assumed to have been distributed historically in most, if not all, the South Coast drainages, based on available habitat and lack of natural barriers. However, it is not known how abundant specific populations were, or if there was cyclical variability in populations due to climatic conditions. Southern California approaches the southern natural distribution of Pacific Lamprey (Rio Santo Domingo, Baja California), and abundances may have been naturally lower in the arid southern HUCs, but except in the Santa Clara for the 1990's (see below), we have no records of population abundance before recent declines and loss of these populations.

***Current Occupancy*.—** Pacific Lampreys have apparently disappeared from all South Coast HUCs at this time. The only substantial population in this region in the last 27 years was present in the Santa Clara drainage; however, adult lampreys have not been encountered in the Santa Clara since 2001, and the last lamprey seen was a single juvenile in 2006, in spite of relatively extensive surveying/monitoring in the region (Swift and Howard 2009, Reid and Goodman unpub. data). Scattered individuals have been encountered in the Ventura (2005), Malibu (1993), Santa Ana (1991) and San Luis Rey (1997) HUCs over the last 27 years, but none more recently than 2005 (Swift and Howard 2009). This represents a general range contraction of Pacific Lamprey northward from historically occupied drainages. Although some extirpations can be attributed to specific factors such as water quality, passage or dewatering, the threats affecting other extirpated drainages are less clear. This suggests the potential for, either a lack of understanding of specific threats leading to local extirpations, or factors affecting multiple streams such as ocean conditions or regional metapopulation dynamics.

***Ratio of Current Occupancy to Historical Range Extent*.—** As a result, the ratio of current to historical habitat is zero in all South Coast HUCs.

***Population Size*.—** Population size (adults) in the sub-region, similarly to all other areas, is poorly understood and has generally not been monitored. The Santa Clara, an exception, was monitored from 1991-2006 at the Freeman Diversion, with the highest count of 908 adults at the fish ladder in 1994 (Chase 2001, Swift and Howard 2009). However, these counts were highly variable in period and protocol of monitoring, so counts were conservative. Active monitoring of the Santa Clara drainage is continuing, in order to determine whether lampreys return to reestablish the population. However, barring recolonization, we consider all South Coast HUCs to be functionally extinct at this time.

***Short Term Trend*.—** Although the limited historical monitoring of adult migrations makes any quantification of population trends impossible. Even the Santa Clara, apparently the strongest historical population, has declined from a viable population in the 1990's to apparent loss in the last decade.

***NatureServe Risk Ranks*.—** All South Coast HUCs have NatureServe risk ranks of Extinct (SX) or Possibly Extinct (SH). See discussion of threats below.

Threats and Limiting Factors to Pacific Lamprey in the South Coast Sub-Region

Threats and limiting factors to Pacific Lamprey in the South Coast Sub-Region are provided in Table 8-2 for the principal five threats, also discussed below. While small population size was not a major threat in most of the California, it was a concern in all South Coast HUCs and is also discussed below. The remaining threat categories were either of low risk throughout the sub-region or were not considered in this assessment as a whole due to lack of information (see discussion under Chap. 4 - California Regional Summary: Harvest, Disease, Lack of Awareness, Ocean Conditions, and Climate Change).

***Summary*.—** Pacific Lampreys have apparently disappeared from all South Coast HUCs at this time. Therefore, this sub-region was assessed for threats that would prevent lampreys from recolonizing or affect populations were they to become reestablished. The principal threats to lampreys in southern California were dewatering of streams due to the extensive use of water for agricultural and urban purposes, as well as natural aridity, and poor water/habitat quality, primarily associated with higher temperatures and low or seasonal flows. Passage was a moderate threat in only four HUCs, except where it completely blocked suitable habitat and no recolonization would be possible; however, these were the two southernmost HUCs and unlikely to be recolonized in the near future. The absence of resident lamprey populations in all southern California streams also presented a barrier to future recolonization due to the absence of ammocoete pheromones to attract migrating adults into the drainage and low adult numbers that 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 not ranked as a major threat (low in scope and severity) in most of the sub-region and was generally represented by minor obstructions such as culverts, road crossings and channelized reaches. Notable exceptions were the Ventura, Santa Clara, Santa Monica Bay (Malibu Creek), and San Gabriel River, all of which contained large impassable dams in some portion of the HUC. The Santa Clara also has a large diversion dam with substantial passage (upsteam and downstream) issues that are currently under review as part of a habitat conservation plan (United Water). However, lampreys have historically passed the diversion in some numbers and it does not represent a complete barrier. The two southernmost HUCs (San Diego and Cottonwood-Tijuana) have large impassable dams blocking all suitable habitat were lampreys to attempt to recolonize.

Dewatering and StreamFlow Management (*reservoirs, water diversions, instream projects****)*.—** Southern California is naturally arid and the extensive use of water for agricultural and urban purposes further exacerbates the adverse conditions in local streams. Low flows in lower reaches except during periodic storm events limit access to migrating adults and can prevent outmigrating juveniles from reaching the sea. At times, flows are insufficient to open sand bars at the mouths of some rivers, completely blocking passage.

***Stream and Floodplain Degradation (channelization, loss of side channel habitat, scouring)*.—** Many Southern California streams are highly modified and often denuded or channelized in urban areas. Nevertheless, there remains considerable habitat in most HUCs that would be relatively suitable for lampreys.

Water Quality (*Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source)***.— Southern California, 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. 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 major threats to potential habitat for lampreys and resulted in high threat ranks for most HUCs.

Predation.**—** Non-native predatory fishes are present in most southern California HUCs. Nevertheless, while there is certainly predation on larval and juvenile lampreys by introduced centrarchids (bass and sunfish) and catfishes, they have generally occupied the system since the late 1800's and were generally not considered to be a major threat to lamprey populations.

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

Table 8-2. **Principal threat rankings, maximum threat level and NatureServe ranks for Pacific Lamprey within the South Coast Sub-Region**. See maps in Chapter 4. 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: 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.

SOUTH COAST			Individual Threats (Scope - Severity)				
Watershed	Risk Rank	Maximum Threat	Passage	Dewatering /Flow	Stream Degradation	Water Quality	Predation
Santa Barbara Coastal	SH	A	2 - 2	2 - 2	1 - 1	3 - 2	2 - 1
Santa Barbara Channel Islands	NA	-	-	-	-	-	-
Ventura	SH	A	4 - 3	3 - 3	3 - 2	3 - 2	2 - 1
Santa Clara	SH	A	4 - 3	2 - 3	1 - 1	3 - 2	3 - 1
Calleguas	SH	A	1 - 2	3 - 4	3 - 3	4 - 4	3 - 1
Santa Monica Bay	SH	A	3 - 2	2 - 2	1 - 1	4 - 4	3 - 1
Los Angeles	SH	A	4 - 3	4 - 3	4 - 2	4 - 4	3 - 1
San Gabriel	SH	A	3 - 3	4 - 3	4 - 2	4 - 4	3 - 1
San Pedro Channel Islands	NA	-	-	-	-	-	-
Seal Beach	SH	A	2 - 2	4 - 3	4 - 2	4 - 4	3 - 1
San Jacinto	NA	-	-	-	-	-	-
Santa Ana	SH	A	2 - 2	4 - 3	4 - 2	4 - 4	3 - 1
Newport Bay	SH	A	2 - 2	4 - 3	2 - 2	4 - 4	3 - 1
Aliso-San Onofre	SH	A	2 - 2	4 - 3	2 - 2	4 - 4	3 - 1
Santa Margarita	SH	A	2 - 2	4 - 3	2 - 2	4 - 4	3 - 1
San Luis Rey-Escondido	SH	A	2 - 2	4 - 3	2 - 2	4 - 4	3 - 1
San Diego	SX	X	X	-	-	-	-
Cottonwood-Tijuana	SX	X	X	-	-	-	-

9. SACRAMENTO SUB-REGION

The Sacramento Sub-Region 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 9-1. Map). It includes 34 watersheds (4th field HUCS), ranging from 96−7,041 km^2 (Table 9-1). The sub-region 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 Californian Chaparral / Oak Woodlands, Central California Valley, Sierra Nevada, Klamath Mountains, Cascade, and Eastern Cascade, slopes and foothills ecoregions. Due to sub-regional differences in hydrology, habitat and threats, we have grouped the HUC's into three sub-groupings: Upper Sacramento, East Foothills and Sierras, West Valley and Coast Range.

Population Status of Pacific Lamprey in the Sacramento Sub-Region

***Historical Range Extent*.—** Pacific Lamprey are assumed to have been widely distributed and abundant historically in the Sacramento Sub-region, based on current and historical records, available habitat and the absence of natural barriers. The principal uncertainty is how far they extended into the upper Pit River (above Fall River), for which there are no records. However, for the purpose of this assessment we assume that they were able to utilize all habitat with anadromous access. This is based on the evidence that anadromous salmonids made it at least as far as Fall River in the past, the widespread presence of a closely related 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 (Figure 4-3). 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 Sierra.

***Current Occupancy*.—** Pacific Lamprey currently only occupy habitat in the Sacramento Sub-region 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 flow 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.

***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% of total historical habitat), 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 Sierran drainages have been fully or essentially blocked (60% of historical habitat), and two HUCs in higher reaches of the Coast Ranges have been lost to dams (15% of historical habitat).

***Population Size*.—** Population size (adults) in the sub-region, 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 maximum counts of about 300 adults. 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.

***Short Term Trend*.—** The lack of long-term monitoring of adult migrations makes any quantification of population trends impossible.

***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.

Figure 9-1. **Map of the Sacramento Sub-Region** and its watersheds (4th field HUCs).

Table 9-1. Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the Sacramento Sub-Region. Historically non-anadromous HUCs are indicated by "N/A", and populations extirpated by impassable dams prior to 1985 are indicated as "Extinct". NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure.

SACRAMENTO		**Distribution**				**Max. Threats**		
Watershed	**HUC**	**Maximum Historical (km^2)**	**Ratio Current/ Historical**	**Population Size (#)**	**Short-Term % Decline**	**Scope**	**Severity**	**Risk Rank**
Upper Sacramento:								
Upper Pit	18020002	6,752	0.00	Extinct	-	-	-	SX
Lower Pit	18020003	7,041	0.00	Extinct	-	-	-	SX
McCloud	18020004	1,774	0.00	Extinct	-	-	-	SX
Sacramento headwaters	18020005	1,561	0.00	Extinct	-	-	-	SX
Sacramento - Upper Clear	18020112	703	0.10	Unknown	Unknown	High	Mod.	S1
East Foothills and Sierras:								
Upper Cow - Battle	18020118	2,169	0.90	250-1000	Unknown	Mod.	Mod.	S2
Lower Cow - Lower Clear	18020101	1,098	1.00	Unknown	Unknown	High	Low	S3
Mill - Big Chico	18020119	2,343	0.90	Unknown	Unknown	High	Low	S3
Butte - Upper	18020120	522	0.37	Unknown	Unknown	Mod.	Mod.	S2
Butte - Lower	18020105	1,552	1.00	Unknown	Unknown	High	Low	S3
Feather - North Fork	18020121	3,129	0.00	Extinct	-	-	-	SX
Feather - N.F. East Branch	18020122	2,658	0.00	Extinct	-	-	-	SX
Feather - Middle Fork	18020123	3,519	0.00	Extinct	-	-	-	SX
Feather - Lower	18020106	1,792	0.90	Unknown	Unknown	Mod.	Mod.	S3
Honcut headwaters	18020124	287	1.00	Unknown	Unknown	High	Low	S2
Yuba - Upper	18020125	3,395	0.10	Unknown	Unknown	High	Mod.	S1
Yuba - Lower	18020107	96	1.00	Unknown	Unknown	High	Low	S2
Bear - Upper	18020126	940	0.00	Extinct	-	-	-	SX
Bear - Lower	18020108	271	1.00	Unknown	Unknown	High	Low	S2
Upper Coon - Upper Auburn	18020127	223	0.75	Unknown	Unknown	Mod.	Mod.	S2
American - North Fork	18020128	2,616	0.00	Extinct	-	-	-	SX
American - South Fork	18020129	2,213	0.00	Extinct	-	-	-	SX
American - Lower	18020111	776	0.90	Unknown	Unknown	Mod.	Mod.	S2
West Valley and Coast Range:								
Cottonwood headwaters	18020113	1,571	0.90	Unknown	Unknown	High	Low	S3
Cottonwood - Lower	18020102	861	0.90	Unknown	Unknown	Mod.	Mod.	S2
Upper Elder - Upper Thomes	18020114	856	1.00	Unknown	Unknown	High	Low	S3
Sacramento - Lower Thomes	18020103	2,982	0.50	Unknown	Unknown	Mod.	Mod.	S2
Stony - Upper	18020115	1,929	0.00	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	0.00	Extinct	-	-	-	SX
Sacramento - Lower	18020109	4,565	0.90	Unknown	Unknown	Mod.	Mod.	S3

Threats and Limiting Factors to Pacific Lamprey in the Sacramento Sub-Region

Threats and limiting factors to Pacific Lamprey in the Sacramento Sub-Region are provided in Table 9-2 for the principal five threats, also discussed below. The remaining threat categories were either of low risk throughout the sub-region or were not considered in this assessment as a whole due to lack of information (see discussion under Chap. 4 - California Regional Summary: Harvest, Small Population Size, Disease, Lack of Awareness, Ocean Conditions, and Climate Change).

***Summary*.—** 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 Forebay Diversion Facility (CDFG) in the lower San Joaquin delta, which potentially impact passage for large numbers of downstream migrating juveniles from the Sacramento drainages. 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 represented by Striped Bass in the lower river reaches that serve as major migratory corridors for both adults and outmigrating juveniles.

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% of 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% of historical habitat), and two HUCs in higher reaches of the Coast Ranges have been completely lost to dams (15% of 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.

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 San Joaquin delta, which potentially impacts passage for large numbers of downstream migrating juveniles from the Sacramento drainage when flows are diverted south into the delta. Assessment of entrainment and passage effects at these facilities is currently underway (Bridges, Reyes, Reid and Goodman, unpub. data) 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 StreamFlow Management (**reservoirs, water diversions, instream projects)*.—** Stream flow 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. 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. Higher water temperatures under 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, Striped Bass are 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. Mitigating conditions may include generally nocturnal activity patterns of lampreys and downstream migration during periods of high flow and turbidity.

Table 9-2. Principal threat rankings, maximum threat level and NatureServe ranks for Pacific Lamprey within the Sacramento Sub-Region. See maps in Chapter 4.
Individual threat rankings for Scope and Severity: 1 to 4, Insignificant to High; U = Unknown.
NatureServe ranks: 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.

			Individual Threats (Scope - Severity)				
Watershed	**Risk Rank**	**Maximum Threat**	**Passage**	**Dewatering /Flow**	**Stream Degradation**	**Water Quality**	**Predation**
Upper Sacramento:							
Upper Pit	SX	X	X	-	-	-	-
Lower Pit	SX	X	X	-	-	-	-
McCloud	SX	X	X	-	-	-	-
Sacramento headwaters	SX	X	X	-	-	-	-
Sacramento - Upper Clear	S1	B	4 - 3	1 - 1	2 - 3	4 - 2	2 - 1
East Foothills and Sierras:							
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 - Upper 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
West Valley and Coast Range:							
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

10. SAN JOAQUIN SUB-REGION

The San Joaquin Sub-Region includes all drainages in the southern Central California Valley, including the San Joaquin and Tulare sub-basins, downstream (north) to the delta and confluence with the Sacramento, including the San Joaquin and Tulare USGS sub-regions and accounting units (Figure 10-1. Map). It includes 14 watersheds (4th field HUCS) in the San Joaquin sub-basin, ranging from 629 - 6,921 km^2, and four watersheds in the Tulare sub-basin that are considered to have had anadromous access prior to the diversion of inflows to Lake Tulare in the late 1800's, ranging from 328 - 4,018 km^2 (Table 10-1). The San Joaquin Sub-Region occupies the Central Californian Chaparral / Oak Woodlands, Central California Valley, and Sierra Nevada ecoregions.

Due to sub-regional differences in hydrology and historical use we have separated the San Joaquin and Tulare sub-basins in the tables. Although there was mention of lampreys in Lake Tulare, the southernmost historical documentation for anadromous salmonids along the Sierran foothills is for the Kings drainage (Yoshiyama et al. 1996). Therefore, only Lake Tulare and the three northernmost Sierran HUCs (Dry, Kings and Mill, a tributary of the Kings) were treated as historical habitat, absent further information. However, all anadromous access to the Tulare sub-basin was lost by the 1870's due to diversion of its inflows and drainage of the lakebed for agricultural purposes, and the Tulare Basin was not analyzed further in the Assessment.

Population Status of Pacific Lamprey in the San Joaquin Sub-Region

***Historical Range Extent*.—** Pacific Lamprey are assumed to have been widely distributed and abundant historically in the San Joaquin Sub-region (north of the Tulare Basin), based on current and historical records, available habitat and the absence of natural barriers. The principal uncertainty is how extensive they were on the west side of the valley, for which there are no historical records of lamprey or salmonids (Panoche-San Luis Reservoir). This HUC is in the rain shadow of the coast ranges and quite arid; most of its streams are frequently seasonal, and even under natural conditions there may have been little permanent habitat available for resident larval lampreys.

A second uncertainty is the extent to which Pacific Lamprey extended into the upstream reaches of the Sierra Nevada. We were unable to find vouchered historical specimens from higher elevations in the San Joaquin (now above impassable dams). However, in 2011 we did confirm the presence of Pacific Lamprey above a barrier falls representing the upper limit for anadromous salmonids in the Cosumnes River (elev. 340'; Goodman and Reid, unpub. data), and we were able to 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 (Figure 4-3) in similar habitat and elevations. 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 Sierra.

***Current Occupancy*.—** Pacific Lamprey currently only occupy habitat in the San Joaquin Sub-region downstream of impassable dams, primarily on the valley floor and foothills. The west-side streams are typically dry except in the rainy season and are further constrained by small-scale passage barriers; we are not aware of any anadromous salmonid populations in these drainages. The principal higher elevation drainage available to lampreys is the undammed Cosumnes, which flows out of lower elevations in the central Sierras and does not have the benefit of large snowpack to maintain high flows later in the summer. Nevertheless, it does maintain a population of Pacific Lamprey, which are able to reach further upstream of natural barriers that block salmonids.

***Ratio of Current Occupancy to Historical Range Extent*.—** The presence of large impassable dams along the sierran foothills of the San Joaquin has severely limited the current range of anadromous lamprey, and much of the area lost is from the higher gradient foothill and mountain reaches that provide good water quality, spawning and rearing habitat. Under current conditions lampreys can only utilize about 65% of the sub-regional area. However, if one excludes the three San Joaquin River and Delta HUCs (San Joaquin: Middle Upper, Middle Lower and Delta) that are primarily composed of valley floor habitat highly modified by agricultural or urban uses and provide little spawning or rearing habitat, habitat loss just due to dams reaches 84%.

***Population Size*.—** Population size (adults) in the sub-region, similarly to all other areas, is poorly understood and not monitored.

***Short Term Trend*.—** The lack of long-term monitoring of adult migrations makes any quantification of population trends impossible.

***NatureServe Risk Ranks*.—** NatureServe risk ranks varied from critically imperiled (1 HUC) to vulnerable (S1-S3), or completely extirpated by dams (7 HUCs). See discussion of threats below.

Figure 10-1. **Map of the San Joaquin Sub-Region** and its watersheds (4th field HUCs).

Table 10-1. Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the San Joaquin Sub-Region. Unoccupied HUCs are included for reference - historically non-anadromous HUCs are indicated by "N/A", and populations extirpated by impassable dams prior to 1985 are indicated as "Extinct". NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure.

SAN JOAQUIN		**Distribution**				**Max. Threats**		
Watershed	**HUC**	**Maximum Historical (km^2)**	**Ratio Current/ Historical**	**Population Size (#)**	**Short-Term % Decline**	**Scope**	**Severity**	**Risk Rank**
<u>**San Joaquin**</u>:								
Panoche-San Luis Reservoir	18040014	2,948	-	-	-	-	-	-
San Joaquin - Upper	18040006	4,415	0.00	Extinct	-	-	-	SX
Upper Chowchilla-Upper Fresno	18040007	2,482	0.001	Extinct?	-	High	High	SH
Merced - Upper	18040008	2,838	0.00	Extinct	-	-	-	SX
Tuolumne - Upper	18040009	4,184	0.00	Extinct	-	-	-	SX
Stanislaus - Upper	18040010	2,587	0.00	Extinct	-	-	-	SX
Calaveras - Upper	18040011	971	0.10	Unknown	Unknown	High	Mod.	S1
Calaveras / Mormon Slough	18040004	629	1.00	Unknown	Unknown	Mod.	Mod.	S2
Mokelumne - Upper	18040012	2,038	0.00	Extinct	-	-	-	SX
Cosumnes - Upper	18040013	1,654	1.00	Unknown	Unknown	High	Low	S3
Cosumnes / Lower Mokelumne	18040005	1,963	1.00	Unknown	Unknown	High	Mod.	S2
San Joaquin - Middle-Upper	18040001	6,921	0.37	Unknown	Unknown	High	High	S2
San Joaquin - Middle-Lower	18040002	4,758	1.00	Unknown	Unknown	High	Mod.	S3
San Joaquin Delta	18040003	2,477	1.00	Unknown	Unknown	High	Mod.	S2
<u>**Tulare**</u>:								
Tulare-Buena Vista Lakes	18030012	22,324	0.00	Extinct	-	-	-	SX
Dry - Upper	18030009	328	0.00	Extinct	-	-	-	SX
King - Upper	18030010	4,018	0.00	Extinct	-	-	-	SX
Mill	18030008	363	0.00	Extinct	-	-	-	SX
Kaweah - Upper	18030007	NA	-	-	-	-	-	-
Tule - Upper	18030006	NA	-	-	-	-	-	-
Upper Deer-Upper White	18030005	NA	-	-	-	-	-	-
Upper Poso	18030004	NA	-	-	-	-	-	-
Kern -Upper	18030001	NA	-	-	-	-	-	-
Kern -South Fork	18030002	NA	-	-	-	-	-	-
Kern - Middle/Upper Tehachapi	18030003	NA	-	-	-	-	-	-
Upper Los Gatos-Avenal	18030011	NA	-	-	-	-	-	-

Threats and Limiting Factors to Pacific Lamprey in the San Joaquin Sub-Region

Threats and limiting factors to Pacific Lamprey in the San Joaquin Sub-Region are provided in Table 10-2 for the principal five threats, also discussed below. The remaining threat categories were either of low risk throughout the sub-region or were not considered in this assessment as a whole due to lack of information (see discussion under Chap. 4 - California Regional Summary: Harvest, Small Population Size, Disease, Lack of Awareness, Ocean Conditions, and Climate Change).

***Summary*.—** Beyond the historical elimination of much of the lamprey habitat in the San Joaquin by impassable dams, the primary threats to currently occupied HUCs were passage constraints and stream channel degradation in the Calaveras and lower Cosumnes-Mokelumne HUCs, and flow management and water quality in the San Joaquin HUCs. A major uncertainty is the effects of the large water diversions at the Tracy Pumping Facility (USBR) and Clifton Forebay Diversion Facility (CDFG) in the lower San Joaquin, which potentially impact 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 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 represented by Striped Bass in the lower river reaches that serve as major migratory corridors for both adults and outmigrating juveniles.

Passage (*dams, culverts, water diversions, tide gates, other barriers****)*.—** The presence of large impassable dams along the Sierran foothills of the San Joaquin has severely limited the current range of anadromous lamprey, and much of the area lost is from the higher gradient foothill and mountain reaches that provide good water quality, spawning and rearing habitat. Under current conditions lampreys can only utilize about 65% of the sub-regional area, mostly on the valley floor. Most mainstem rivers remain accessible up to the large foothill dams. The Cosumnes River is the only river with access to its upper reaches with no major barriers, although there is a weir in the lower river (elev. ca. 150 ft), it has a fish ladder and apparent natural passage around it. There is also a natural barrier falls that apparently blocks salmonids near the Sacramento County line (elev. ca. 200 ft), but lampreys pass it and are present in the upper Cosumnes. On the Calaveras River the New Hogan Dam blocks passage to all but 12.2 km of the upper river, while migration in the lower river and tributaries is hindered by numerous weirs and culverts.

A special case for passage issues (ranked as 4-U for the three mainstem San Joaquin 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, Reid, Bridges and Reyes unpub. data) 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 StreamFlow Management (*reservoirs, water diversions, instream projects****)*.—** Stream flow is highly manipulated in the San Joaquin system, resulting in channel drying in the middle reaches of the San Joaquin and lower reaches of the Mokelumne rivers, extensive diversion into agricultural ditches, and loss of flow to state water projects. Manipulation of flow in the delta by the major pumping projects 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 San Joaquin system is highly modified, the actual threat of stream and floodplain degradation to lampreys was rated as low to moderate in the lower reaches of occupied HUCs.

Water Quality (*Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source)***.— The San Joaquin 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. The San Joaquin River itself also has considerable issues with high water temperatures and low dissolved oxygen, although again the direct impacts to the lamprey population are not known.

Predation.— Non-native predatory fishes are common in the San Joaquin 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 San Joaquin River itself, Striped Bass are 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. Mitigating conditions may include generally nocturnal activity patterns of lampreys and downstream migration during periods of high flow and turbidity.

Table 10-2. Principal threat rankings, maximum threat level and NatureServe ranks for Pacific Lamprey within the San Joaquin Sub-Region. See maps in Chapter 4. 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: 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.

			Individual Threats (Scope - Severity)				
Watershed	**Risk Rank**	**Maximum Threat**	**Passage**	**Dewatering /Flow**	**Stream Degradation**	**Water Quality**	**Predation**
San Joaquin:							
Panoche-San Luis Reservoir	SH	A	4 - 4	-	-	-	-
San Joaquin - Upper	SX	X	X	-	-	-	-
Upper Chowchilla-Upper Fresno	SX	X	X	-	-	-	-
Merced - Upper	SX	X	X	-	-	-	-
Tuolumne - Upper	SX	X	X	-	-	-	-
Stanislaus - Upper	SX	X	X	-	-	-	-
Calaveras - Upper	S1	B	4 - 3	2 - 2	3 - 3	4 - 2	2 - 1
Calaveras / Mormon Slough	S2	C	3 - 3	2 - 2	3 - 3	4 - 2	2 - 1
Mokelumne - Upper	SX	X	X	-	-	-	-
Cosumnes - Upper	S3	D	2 - 2	2 - 2	1 - 1	4 - 2	3 - 1
Cosumnes / Lower Mokelumne	S2	B	3 - 2	4 - 3	3 - 3	4 - 2	3 - 1
San Joaquin - Middle-Upper	S2	A	4 - U	4 - 4	4 - 2	4 - 3	4 - U
San Joaquin - Middle-Lower	S3	B	4 - U	4 - 3	4 - 2	4 - 2	4 - U
San Joaquin Delta	S2	B	4 - U	4 - 3	4 - 2	4 - 2	4 - U
Tulare:							
Tulare-Buena Vista Lakes	SX	X	X	-	-	-	-
Dry - Upper	SX	X	X	-	-	-	-
King - Upper	SX	X	X	-	-	-	-
Mill	SX	X	X	-	-	-	-
Kaweah - Upper	N/A	-	-	-	-	-	-
Tule - Upper	N/A	-	-	-	-	-	-
Upper Deer-Upper White	N/A	-	-	-	-	-	-
Upper Poso	N/A	-	-	-	-	-	-
Kern -Upper	N/A	-	-	-	-	-	-
Kern -South Fork	N/A	-	-	-	-	-	-
Kern - Middle/Upper Tehachapi	N/A	-	-	-	-	-	-
Upper Los Gatos-Avenal	N/A	-	-	-	-	-	-

11. SAN FRANCISCO BAY SUB-REGION

The San Francisco Bay Sub-Region includes all drainages that enter San Francisco and its component bays from the confluence of the Sacramento and San Joaquin rivers to the Golden Gate, including the San Francisco Bay USGS accounting unit, without the outer coastal HUCs that are included in our coastal sub-regions (Figure 11-1. Map). It includes four watersheds (4th field HUCS), ranging from 1,695−3,171 km^2 (Table 11-1). The sub-region occupies the Central Californian Chaparral / Oak Woodlands ecoregion.

Table 11-1. Population status, maximum threat level and NatureServe ranks for Pacific Lamprey in the San Francisco Bay Sub-Region. NatureServe ranks: SX, Extinct; SH, Believed extinct; and S1 to S4, critical to secure.

SAN FRANCISCO BAY		**Distribution**				**Max. Threats**		
Watershed	**HUC**	**Maximum Historical (km^2)**	**Ratio Current/ Historical**	**Population Size (#)**	**Short-Term % Decline**	**Scope**	**Severity**	**Risk Rank**
Suisun Bay	18050001	1,695	0.37	Unknown	Unknown	Mod.	Mod.	S2
San Pablo Bay	18050002	3,171	0.75	Unknown	Unknown	Mod.	Mod.	S3
San Francisco Bay	18050004	3,135	0.37	Unknown	Unknown	High	Mod.	S2
Coyote	18050003	2,208	0.25	Unknown	Unknown	High	Mod.	S2

Population Status of Pacific Lamprey in the San Francisco Bay Sub-Region

***Historical Range Extent*.—** Pacific Lamprey are assumed to have been widely distributed and abundant historically in the San Francisco Bay Sub-region, except perhaps the higher gradient reaches of small or seasonal tributaries, based on current distribution, available historical habitat and lack of natural barriers.

***Current Occupancy*.—** Currently, Pacific Lamprey have been excluded from much of their historical habitat due to passage barriers and urbanization of stream channels.

***Ratio of Current Occupancy to Historical Range Extent*.—** Three of the HUCs surrounding San Francisco have lost over 66-75% of their historical range, while the San Pablo HUC still retains access to much of its available habitat.

***Population Size*.—** Population size (adults) in the sub-region, similarly to all other areas, is poorly understood and not formally monitored.

***Short Term Trend*.—** Recent declines in San Francisco Bay HUCs may be similar to the North Coast sub-region (see Chapter 5) and Oregon Coast at Winchester Dam on the North Fork

Umpqua River (see Figure 1-1). 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). See discussion of threats below.

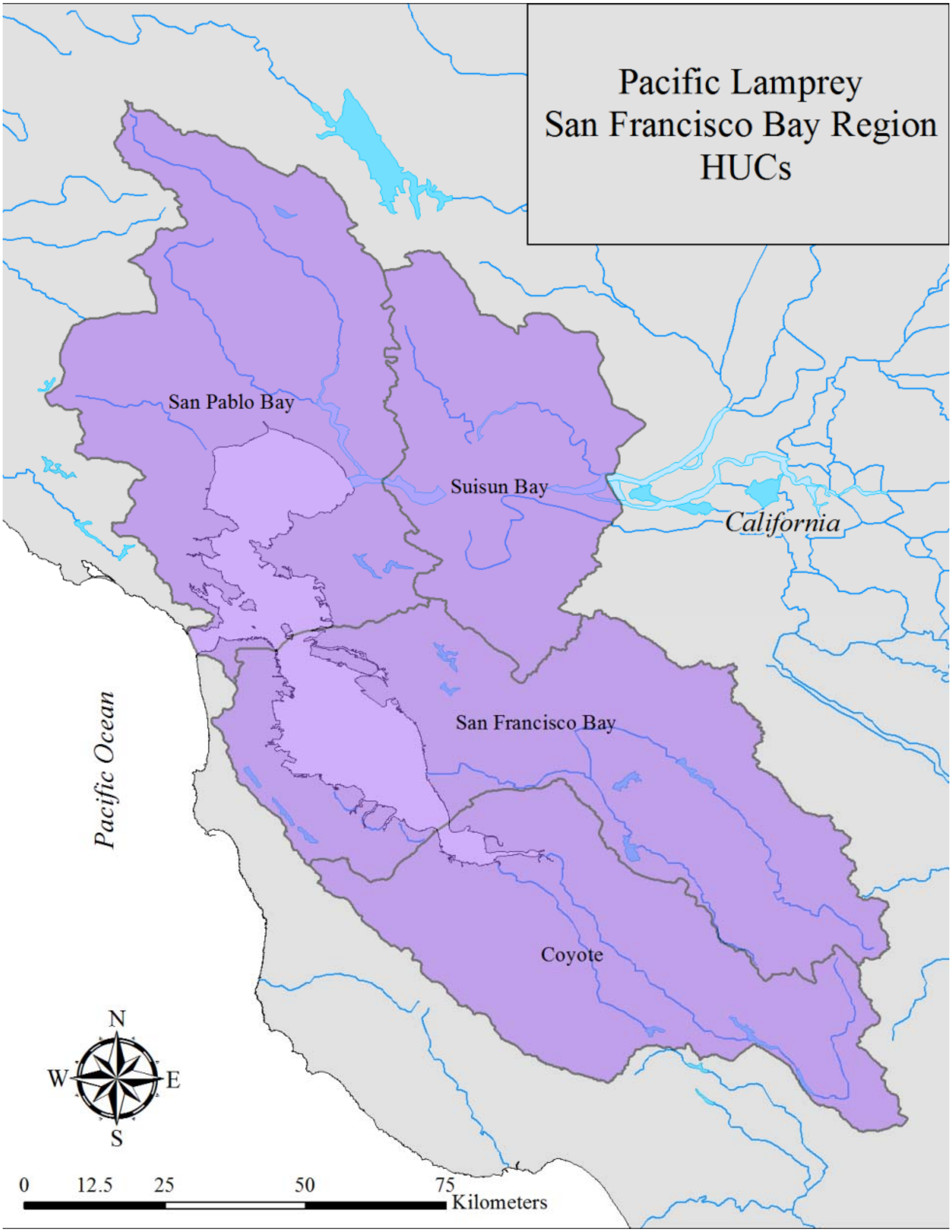


Figure 11-1. **Map of the San Francisco Bay Sub-Region** and its watersheds (4th field HUCs).

Threats and Limiting Factors to Pacific Lamprey in the San Francisco Bay Sub-Region

Threats and limiting factors to Pacific Lamprey in the San Francisco Bay Sub-Region are provided in Table 11-2 for the principal five threats, also discussed below. The remaining threat categories were either of low risk throughout the sub-region or were not considered in this assessment as a whole due to lack of information (see discussion under Chap. 4 - California Regional Summary: Harvest, Small Population Size, Disease, Lack of Awareness, Ocean Conditions, and Climate Change).

Table 11-2. Principal threat rankings, maximum threat level and NatureServe ranks for Pacific Lamprey within the San Francisco Bay Sub-Region. See maps in Chapter 4.
Individual threat rankings for Scope and Severity: 1 to 4, Insignificant to High; U = Unknown.
NatureServe ranks: 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.

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

***Summary*.—** The urban nature of much of the San Francisco Bay area influenced many of the threats to lampreys. Passage barriers, flow management and stream channel degradation were all generally ranked as moderate (scope and severity) in the San Francisco Bay region. Water quality was considered less of a threat in the less developed northern HUCs and moderate overall in the two heavily urbanized southern HUCs, both of which contain rural habitat as well. The predation threat represented by Striped Bass in the bay and estuaries that serve as major migratory corridors for both adults and outmigrating juveniles is unresolved.

***Passage (**dams, culverts, water diversions, tide gates, other barriers**)*.—** Passage barriers were generally ranked as moderate (scope and severity) in the San Francisco Bay region due to reservoir and diversion dams on the Peninsula and in the south and eastern drainages, as well as many smaller passage barriers associated with urbanization (e.g. culverts, concrete drop structures, buried stream channels). In the north, San Pablo Bay drainages had fewer major barriers to passage and none that obstructed the mainstem reaches of the principal streams (ranked 2-2).

***Dewatering and StreamFlow Management (**reservoirs, water diversions, instream projects**)*.—** Urbanization, diversion, reservoir retention, channelization and agricultural diversions all combined with general arid summer conditions in much of the Bay Area to rank moderate (scope and severity) in all four HUCs.

***Stream and Floodplain Degradation (channelization, loss of side channel habitat, scouring)*.—** Urban water mangement, channelization, and loss of riparian habitat in much of the Bay Area ranked moderate (scope and severity) in all four HUCs.

Water Quality (*Water temperature, chemical poisoning and toxins, accidental spills, chemical treatment, sedimentation, non-point source)***.—** Widespread water quality issues were noted with contaminants, urban runoff and agricultural uses (in the north); however, the effects on local lamprey populations has not been evaluated. Threats due to water quality were generally ranked as widespread but low in the north and moderate in the more urbanized south.

***Predation*.—** Non-native predatory fishes are common in the Bay Area. 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. Striped Bass are abundant in the bay and estuaries 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. Mitigating conditions may include generally nocturnal activity patterns of lampreys and downstream migration during periods of high flow and turbidity. For this reason predation severity was ranked as Unknown.

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13. APPENDICES

Appendix A. Calculating Overall Status Scores in NatureServe (from NatureServe 2009)

The progression of tasks automatically performed by the rank calculator to generate a calculated rank score is:

1. Rules for the use of factors (e.g., range extent, short term trend) are applied to status factors that have assigned ratings.
2. Rules for minimum required factors are applied (either two rarity factors or 1 rarity and 1 trend or threat).
3. Conditions for automatic status rank assignment are applied to the assigned ratings. If a rarity factor has a U, the conservation status rank is SU; if a rarity factor has an X, the conservation status is SX; if a rarity factor has a Z, the conservation status is SH.
4. A specific point value is assigned by the calculator for each factor rating value.
5. A prescribed weight is applied by the calculator to each individual factor.
6. Three sub-scores are calculated based on the points and weightings assigned to the factors contained within each category.
7. A specific weight is assigned to each factor category and, with the category sub-scores, used to compute an overall calculated status score.

The rank calculator automatically translates calculated scores to the appropriate conservation status ranks according to the value ranges and rank equivalencies shown in Table 9 (from NatureServe 2009).

Table A-1. Score Value Ranges for NatureServe Conservation Status Ranks.

Value Range for Calculated Score	Calculated Status Rank	Status Description
score containing U (unknown)	SU	Status rank is unknown
score containing X (extirpated)	SX	Presumed extirpated
score containing Z (zero)	SH	Possibly extirpated
score ≤ 1.5	S1	Critically imperiled
1.5 < score ≤ 2.5	S2	Imperiled
2.5 < score ≤ 3.5	S3	Vulnerable
3.5 < score ≤ 4.5	S4	Apparently secure
score > 4.5	S5	Secure

Appendix B. Descriptions of the Level III EcoRegions occupied by Pacific Lamprey in the California Region.

Additional information can be found at the EPA website (http://www.epa.gov/wed/pages/ecoregions/level_iii.htm).

Coast Range **(01)**
The Coast Range consists of Coastal Lowlands, Coastal Uplands, and Volcanics sub-ecoregions. Elevation of this ecoregion ranges from sea level to 1,737 m (5,700 ft). Mean precipitation ranges from 127 to over 500 cm (50−200 in) per year. In the western portion of this region, the Coast Range low mountains are covered by highly productive, rain-drenched coniferous forests. Sitka spruce and coastal redwood forests originally dominated the fog-shrouded coast, while a mosaic of western red cedar, western hemlock, and seral Douglas-fir blanketed inland areas. Today Douglas-fir plantations are prevalent on the intensively logged and managed landscape, with western hemlock, Sitka spruce, western red cedar forests, red alder, Pacific silver fir, big leaf maple, and wetlands also found. Land use is a mosaic of forestry, rural/urban residential development, pastureland, and recreation. The Coastal Lowlands encompass estuarine marshes, freshwater lakes, black-water streams, marine terraces, and sand dune areas. Elevations range from sea level to 91 m (300 ft). Many of its wetlands have been converted into dairy pastures. The Coastal Uplands extend to an elevation of about 150 m (500 ft). The climate of the Uplands is marine-influenced with an extended winter rainy season, enough fog during the summer dry season to reduce vegetal moisture stress, and a lack of seasonal temperature extremes. The uplands roughly correspond with the historic distribution of Sitka spruce, of which the distribution has been greatly reduced by logging. The Volcanics portion of the Coastal Ecoregion varies in elevation from 300−1200 m (1000−4000 ft) and is disjunct. Columnar and pillow basalt outcrops occur. Its mountains may have been offshore seamounts engulfed by continental sediments about 200 million years ago. The basaltic substrate preserves relatively stable summer stream flows that still support spring Chinook Salmon and summer Steelhead. Its forests are intensively managed. The Mid-Coastal Sedimentary portion is commonly underlain by massive beds of siltstone and sandstone. Its dissected, forested mountains are more rugged than the rest of the ecoregion and are prone to mass movement when the vegetal cover is removed. Stream gradients and fluvial erosion rates can be high.

***Cascades* (04)**

This mountainous ecoregion is underlain by Cenozoic volcanics and has been affected by alpine glaciations. It is characterized by steep ridges and river valleys in the west, a high plateau in the east, and both active and dormant volcanoes. Elevations range from 244 m upwards to 4,392 m at Mount Rainier. Its moist, temperate climate supports an extensive and highly productive coniferous forest. At the lower elevations the forests consist of western hemlock, western red cedar, Douglas-fir, grand fir, white fir, Pacific silver fir, some Shasta red fir, and mountain hemlock. Herbaceous and shrubby subalpine meadow vegetation; mountain hemlock, ponderosa pine, and subalpine fir stands occur at high elevations. Land use is mainly forestry and recreation, followed by pastureland and grazing. Mean annual precipitation varies by elevation, ranging between 114 and 356 cm (45−140 in) over the ecoregion.

***Sierra Nevada* (05)**
The Sierra Nevada is a deeply dissected fault-block mountain range that rises sharply from the arid basin and range ecoregions on the east and slopes gently toward the Central California Valley to the west. The eastern portion has been strongly glaciated and generally contains higher mountains than are found in the Klamath Mountains (78) to the northwest. Much of the central and southern parts of the region is underlain by granite as compared to the mostly sedimentary and metamorphic formations of the Klamath Mountains and the volcanic rocks of the Cascades (4). The higher elevations of this region are largely federally owned and include several national parks. The vegetation grades from mostly ponderosa pine and Douglas-fir at the lower elevations on the west side, pines and Sierra juniper on the east side, to fir and other conifers at the higher elevations. Alpine conditions exist at the highest elevations.

***Southern and Central California Chaparral and Oak Woodlands* (06)**
The primary distinguishing characteristic of this ecoregion is its Mediterranean climate of hot dry summers and cool moist winters, and associated vegetative cover comprising mainly chaparral and oak woodlands; grasslands occur in some lower elevations and patches of pine are found at higher elevations. Most of the region consists of open low mountains or foothills, but there are areas of irregular plains in the south and near the border of the adjacent Central California Valley ecoregion. Large parts of the region are grazed by domestic livestock; relatively little land has been cultivated, although some valleys are or were important agricultural centers.

***Central California Valley* (07)**
Flat, intensively farmed plains having long, hot dry summers and mild winters distinguish the Central California Valley from its neighboring ecoregions that are either hilly or mountainous, forest or shrub covered, and generally nonagricultural. Nearly half of the region is in cropland, about three fourths of which is irrigated. Environmental concerns in the region include salinity due to evaporation of irrigation water, groundwater contamination from heavy use of agricultural chemicals, wildlife habitat loss, and urban sprawl.

***Southern California Mountains* (08)**
Like the other ecoregions in central and southern California, the Southern California Mountains has a Mediterranean climate of hot dry summers and moist cool winters. Although

Mediterranean types of vegetation such as chaparral and oak woodlands predominate in this region, the elevations are considerably higher, the summers are slightly cooler, and precipitation amounts are greater than in adjacent ecoregions, resulting in denser vegetation and some large areas of coniferous woodlands. Severe erosion problems are common where the vegetation cover has been destroyed by fire or overgrazing.

Eastern Cascade Slopes and Foothills **(09)**
The East Cascades Ecoregion varies dramatically from its cool, moist border with the West Cascades Ecoregion to its dry eastern border where it meets sagebrush country. The Eastern Cascade Slopes and Foothills Ecoregion is in the rainshadow of the Cascade Mountains. Its climate exhibits greater temperature extremes and less precipitation than ecoregions to the west. Terrain ranges from forested uplands to marshes and agricultural fields at lower elevations. Open forests of ponderosa pine and some lodgepole pine distinguish this region from the higher ecoregions to the west where fir and hemlock forests are common, and the lower dryer ecoregions to the east where shrubs and grasslands are predominant. The vegetation is adapted to the prevailing dry continental climate and is highly susceptible to wildfire. Historically, creeping ground fires consumed accumulated fuel and devastating crown fires were less common in dry forests. Volcanic cones and buttes are common in much of the region. Elevation ranges from 183− 2,530 m (600−8,300 ft). Mean annual precipitation ranges between 250 and 140 cm (10−55 in). Tourism, recreation, forestry, and agriculture support a diverse economy.

Klamath Mountains **(78)**
The Klamath Mountains Ecoregion contains wide ranges in elevation, topography and climate -- from the lush, rainy west to the dry, warmer interior valleys to cold, snowy mountains. The Klamath-Siskiyou region of southwest Oregon and northwest California is recognized internationally for its global biological significance and is considered a world “Centre of Plant Diversity” by the World Conservation Union. The Klamath Mountains Ecoregion has the second fastest-growing human population in Oregon behind the Willamette Valley. Much of the population growth is concentrated in valleys along the Interstate 5 corridor. Demands for choice building sites often coincide with good quality habitat.

This physically and biologically diverse ecoregion covers the highly dissected ridges, foothills, and valleys of the Klamath and Siskiyou mountains. It also extends south in California to include the mixed conifer and montane hardwood forests that occur in the North Coast Range mountains. The region’s mix of granitic, sedimentary, metamorphic, and extrusive rocks contrasts with the predominantly volcanic rocks of the Cascades (4) to the east. It was unglaciated during the Pleistocene epoch, when it served as a refuge for northern plant species. The regions diverse flora, a mosaic of both northern Californian and Pacific Northwestern conifers and hardwoods, is rich in endemic and relic species. The mild, subhumid climate of the Klamath Mountains is characterized by a lengthy summer drought.

Appendix C. Ichthyological museum collections reviewed and examined for historical voucher specimens of Pacific Lamprey in California (2009-2012).

Code	Institution
ANSP	Academy of Natural Sciences at Philadelphia
CMN	Canadian Heritage Information Network - Canadian Museum of Nature Fish Collection
CU	Cornell University Museum of Vertebrates (CUMV) - Fish Collection
FMNH	Field Museum - FMNH Fish Collection
KU	University of Kansas Biodiversity Institute - Fish Tissue Collection
LACM	Los Angeles County Museum of Natural History (LACM) - Vertebrate specimens
MCZ	MCZ-Harvard University - MCZ Fish Collection
ROM	Royal Ontario Museum - Fish specimens
SBMNH	Santa Barbara Museum of Natural History
TCWC	Texas Cooperative Wildlife Collection (TCWC) - Ichthyology Specimens
TNHC	Texas Natural History Science Center - Texas Natural History Collections (TNHC)
TU	Tulane University Museum of Natural History - Royal D. Suttkus Fish Collection
UMMZ	University of Michigan Museum of Zoology
USNM	National Mus. of Natural History, Smithsonian Inst. - NMNH Vertebrate Zoology Fishes Collections
UWFC	University of Washington Fish Collection - Fish specimens
CAS	Calif. Academy of Sciences
OSU	Oregon State University
HSU	Humboldt State University
FMNH	Field Museum Natural History, Chicago
UCD	University California, Davis; Dept. Fish and Wildlife
CSUS	California State University, Sacramento; Dept. Biological Sciences
UCZM	University Museum of Zoology Cambridge (UMZC) - Zoological specimens
YPM	Yale University Peabody Museum - Peabody Ichthyology