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Pacific Lamprey in Humboldt Bay Tributaries: A Summary of Information and Identification of Research Needs

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Cover photo: Satellite imagery of the Humboldt Bay area.

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ACKNOWLEDGMENTS

This review relies heavily on lamprey data and observations contributed by numerous biologists and other natural resource professionals who have worked extensively in Humboldt Bay tributaries over the years. These individuals are listed in Table 2. Without their hard work and willingness to provide data and observations, this review would not be possible. We are also grateful to staff from the Wiyot Tribe Natural Resources Department (WNRD) for providing an in-depth review of this document and for their continued support for lamprey research, monitoring, and conservation in northern California. This work was funded through a FY 2013 U.S. Fish and Wildlife Service (USFWS) Tribal Wildlife Grant.

1 INTRODUCTION

1.1 Background and Need

Relatively little data or other information on Pacific lamprey (*Entosphenus tridentatus*) are available for California, particularly for Humboldt Bay and its tributaries (Luzier et al. 2011, Goodman and Reid 2012). In contrast, an extensive amount of research and monitoring has focused on salmon and steelhead in the region, and much of the data collected on lamprey are incidental to the salmonid monitoring. Other than this incidental data, the primary source of information on Pacific lamprey in Humboldt Bay tributaries comes from anecdotal observations made by local biologists, tribal members, and other residents of the area. However, these data and information have not been synthesized or reported and thus are not available to inform local fisheries managers or groups working towards lamprey conservation (e.g., the USFWS Pacific Lamprey Conservation Initiative). Accordingly, the goal of this report is to review and synthesize available information on Pacific lamprey in Humboldt Bay and its tributaries in order to provide the Wiyot Tribe and other regional stakeholders with an enhanced understanding of the biology, key information gaps, and research and monitoring needs for this important species.

1.2 Review Methods

Available information on Pacific lamprey in the Humboldt Bay watershed was synthesized from the following sources:

- peer-reviewed literature and technical reports;
- results from written questionnaires, phone interviews, and email correspondence with fisheries biologists and other basin stakeholders; and
- museum records and online databases.

This review focuses on Pacific lamprey, but records of western brook lamprey and unidentified lamprey species were also compiled and summarized herein.

1.3 Study Area

The study area for this review includes Humboldt Bay and all watersheds draining into it. This area is within the Ancestral Territory of the Wiyot Tribe (Figure 1). Significant Humboldt Bay drainages, from south to north, include: Salmon Creek, Elk River, Freshwater Creek (including Ryan Creek for this review), Jacoby Creek, and numerous smaller tributaries flowing into the northern half of Humboldt Bay (including Rocky Gulch, North Jacoby, Beith, Grotzman, and

Campbell creeks, Janes Creek, Jolly Giant Creek, and Mad River Slough) (Figure 1). Of these watersheds, Elk River and Freshwater Creek are by far the largest, followed by Salmon and Jacoby creeks (Table 1). The tributaries flowing into northern Humboldt Bay have relatively small watersheds, with Janes Creek being the largest.

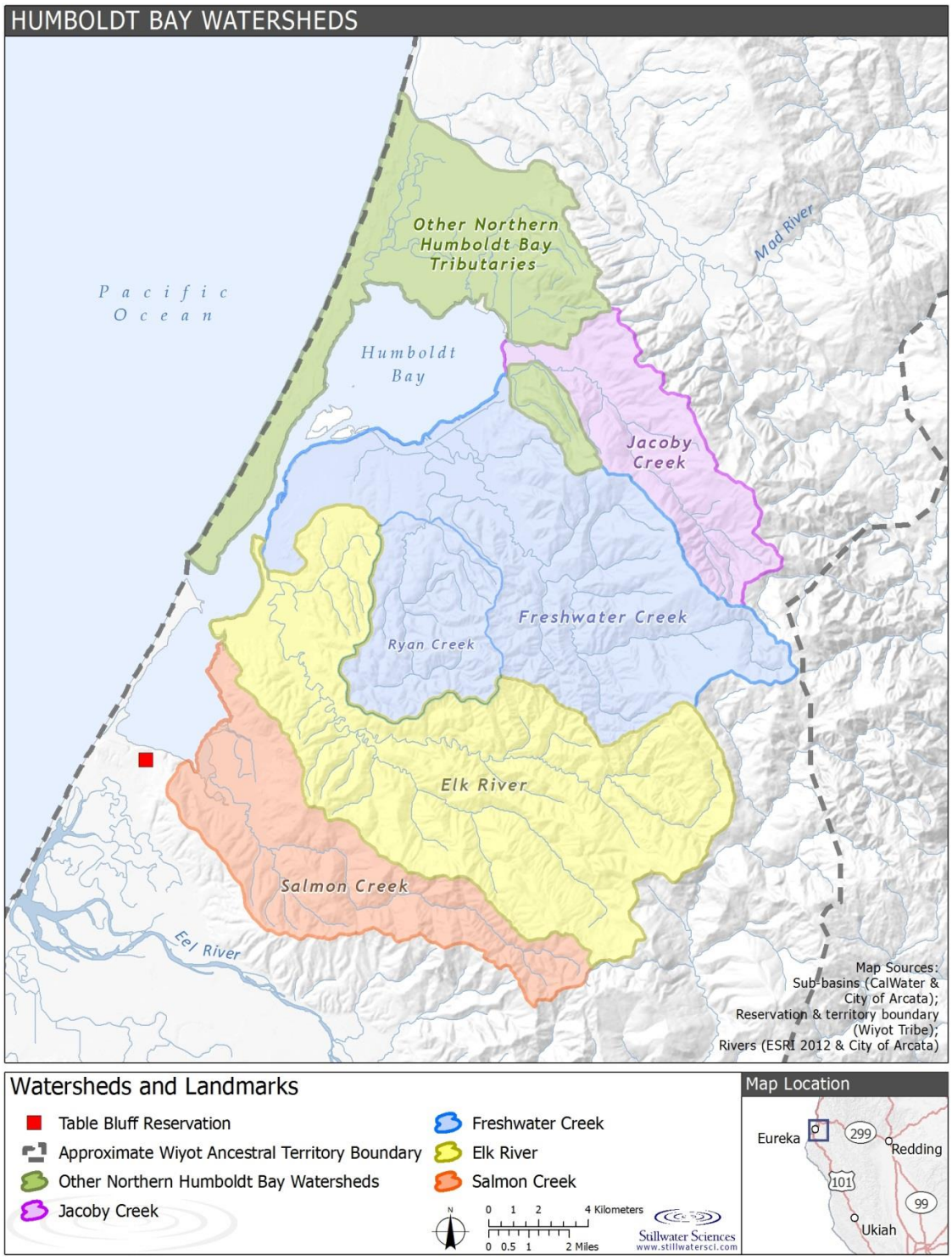

Figure 1. Overview map showing Humboldt Bay watersheds.

Table 1. Contributing drainage areas of watersheds draining into Humboldt Bay, listed from south to north. Refer to detailed watershed maps in Section 2 for locations of each stream.

Watershed	Contributing drainage area		
	Acres	km^2	mi^2
Salmon Creek	16,769	67.9	26.2
Elk River	37,270	150.8	58.2
Freshwater Creek watershed	39,536	160.0	61.8
Freshwater Creek[1]	30,099	121.8	47.0
Ryan Creek[2]	9,437	38.2	14.7
Jacoby Creek	10,843	43.9	16.9
Other Northern Humboldt Bay watersheds	18,211	73.7	28.5
Rocky Gulch[3]	770	3.1	1.2
Washington Gulch[3]	851	3.4	1.3
Gannon Slough	2,557	10.3	4.0
North Jacoby Creek	558	2.3	0.9
Beith Creek	753	3.0	1.2
Grotzman Creek	479	1.9	0.7
Fickle Hill Creek	206	0.8	0.3
Campbell Creek	561	2.3	0.9
Janes Creek[4]	2,864	11.6	4.5
Jolly Giant Creek[5]	1,029	4.2	1.6
Mad River Slough[6]	10,991	44.5	17.2
Humboldt Bay watershed total	**123,480**	**499.7**	**192.9**

[1] Includes Fay Slough and small streams draining the northern side of Eureka.
[2] Listed here separately from Freshwater Creek since it is often treated as a separate watershed.
[3] Often treated as part of Jacoby Creek, but shown separately here as it drains directly into Humboldt Bay.
[4] Includes entire McDaniel Slough watershed.
[5] Includes Butcher Slough watershed.
[6] Includes Samoa Peninsula.

1.4 Humboldt Bay Watershed Overview

An overview of the geographical, climatic, forest, and land-use characteristics of the Humboldt Bay watershed is provided below. Refer to Barnhart et al. (1992) and (HBWAC and RCAA 2005) for a more detailed account of the key features of the Bay and its contributing watersheds.

Humboldt Bay is the largest estuary in California north of San Francisco (HBWAC and RCAA 2005), draining an area of approximately 500 km^2. Elevations of the ridges forming much of the eastern watershed boundary average approximately 1,500 ft, but maximum elevation reaches 2,700 ft at the headwaters of Freshwater Creek near Kneeland. Approximately two–thirds of the watershed area is relatively steep and predominately managed for timber production (HBWAC and RCAA 2005). The lower elevation portions of the watershed generally consist of relatively flat lands that are associated with floodplains in lower reaches of streams and wetlands, tidal marshes, and sloughs surrounding the Bay. Forests in the Humboldt Bay watershed are comprised primarily of mixed conifers, dominated by redwood (*Sequoia sempervirens*) and Douglas fir

(*Pseudotsuga menziesii*) trees. Other common forest species include tan oak (*Lithocarpus densiflorus*), grand fir (*Abies grandis*), Sitka spruce (*Picea sitchensis*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*). Red alder (*Alnus rubra*), willow (*Salix sp.*), and big leaf maple (*Acer macrophyllum*) are the most common riparian tree species (Barnhart et al. 1992, HBWAC and RCAA 2005).

The climate of the Humboldt Bay region is characterized by distinct wet and dry periods. The vast majority of the rainfall occurs in late-fall through early spring, with little rain occurring otherwise. Mean annual precipitation data from 1981 to 2010 ranged from approximately 40 in at Eureka to over 70 in at Kneeland (PRISM Climate Group, Oregon State University, http://prismmap.nacse.org/nn/), with significant annual variability. Air temperatures generally remain moderate year round due to the marine influence on the region, which results in relatively cool summer water temperatures compared with more inland watersheds. The mean monthly air temperature at Eureka varies by only 10 degrees Fahrenheit throughout the year, with the lowest mean in January (47°F) and the highest mean in August (57°F) (Barnhart et al. 1992).

Land use in the upland reaches of the Humboldt Bay watershed is dominated by intensive timber production. Lower elevation portions drain through vast agricultural lands and more populated areas including the cities of Arcata and Eureka. A large percentage of historically tidally influenced land and wetlands surrounding the bay have been converted to agricultural, residential, commercial, or industrial uses (HBWAC and RCAA 2005).

2 RESULTS

Twenty-three natural resource professionals (primarily fisheries biologists) who currently work or previously worked within the Humboldt Bay watershed responded to a request for information on Pacific lamprey (Table 2). The respondents provided varying amounts of data and other information on the species and also provided contact information for other potentially knowledgeable individuals. Several likely knowledgeable contacts did not respond to the information request. Eight online fish collection databases were also searched for records of Pacific lamprey presence in Humboldt Bay tributaries, but no records were located (Table 3).

Table 2. Natural resource professionals who provided information on lamprey in Humboldt Bay tributaries.

Contact/s	Organization	Information provided
Allan Renger	California Department of Fish and Wildlife (CDFW)	Observations from Elk R and various CDFW Stream Inventory Reports; contact info
Colin Anderson	CDFW	Data and observations from Freshwater Cr outmigrant trapping and spawning surveys; contact info
Michelle Gilroy Justin Garwood	CDFW	CDFW library and NCCCSI database query; contact info
Mike Wallace	CDFW	Data from seining in Salmon Cr, Elk R, and Freshwater Cr estuaries; contact info
Nick Simpson	CDFW	Observations and data from Elk River
Mike McDowall Julie Neander	City of Arcata	Outmigrant trapping data and field notes from Jolly Giant Cr
Ryan Bourque Pat Righter	Green Diamond Resource Company	Outmigrant trap data and observations from Ryan Cr

Contact/s	Organization	Information provided
Eric Nelson	Humboldt Bay National Wildlife Refuge	Observations from Salmon Cr estuary; contact info
Julie Donell	Humboldt Redwood Company	Contact info
Terry Roelofs	Institute For River Ecosystems	Various observations from Freshwater Cr and other Humboldt Bay tributaries; contact info
Tim Salamunovich	Normandeau Associates	Observations, reports, and data from various streams crossed by Mad River Pipeline Project; contact info
Mitch Farro	Pacific Coast Fish, Wildlife and Wetlands Restoration Association	Salmon Cr spawning survey information
Trevor Lucas	Pacific States Marine Fisheries Commission	Observations from Elk R
Ross Taylor	Ross Taylor and Associates	Observations from Morrison Gulch and associated report
Dennis Halligan	Stillwater Sciences	Observations from Janes Cr
Josh Strange	Stillwater Sciences	Observations from Jolly Giant Cr
Bret Harvey Rodney Nakamoto	USDA Forest Service Pacific Southwest Research Station	Data from numerous years of sampling upper Jacoby Cr; contact info
Damon Goodman	USFWS	Lamprey collection records from various streams
Tim Nelson	Wiyot Tribe	Observations from Janes Cr

Table 3. Online fish collection databases searched for Pacific lamprey records in Humboldt Bay tributaries.

Museum or database	Website	Date searched	Number of Pacific lamprey records[1]
California Academy of Sciences	http://collections.calacademy.org/ich/	5/2/2014	0
Smithsonian Museum of Natural History	http://collections.mnh.si.edu/search/fishes/	5/2/2014	0
Humboldt State University Fish Collection	http://www.humboldt.edu/fish/	5/1/2014	0
FishNet	http://www.fishnet2.net/	5/2/2014	0
UC Davis Museum of Wildlife and Fish Biology	http://museums.ucdavis.edu/	5/2/2014	0
The Museum of Vertebrate Zoology at Berkeley	http://mvz.berkeley.edu/Collections.html	5/2/2014	0
The University of Washington Fish Collection	http://biology.burkemuseum.org/ichthyology/database/search.php	5/2/2014	0

[1] Includes searches for records of *Entosphenus tridentatus* and *Lampetra tridentata*, the currently and previously recognized scientific names for Pacific lamprey, respectively.

The sub-sections below summarize available information on lamprey distribution for each watershed draining into Humboldt Bay, emphasizing definitive records of Pacific lamprey, but also including records of western brook lamprey (*Lampetra richardsonii*) and unidentified lamprey species. Exact geographical coordinates were not available for many observations and therefore we do not provide conventional distribution maps. Rather, for each watershed we include a tabular list of records of streams where lampreys have been documented and discuss approximate known upper and lower distributions or other notable records. Locations of the streams where lampreys have been documented can be referenced in the detailed maps provided for each watershed below.

2.1 Humboldt Bay

This review did not identify any information on Pacific lamprey in open-water portions of Humboldt Bay, and the use of the bay by each life stage remains a large data gap. However, as described below, ammocoetes of unknown species have been captured in tidally influenced reaches in the lower reaches of Elk River and Salmon, Freshwater, and Jacoby creeks. Following metamorphosis into the adult form, Pacific lampreys must pass through Humboldt Bay during their outmigration to the ocean, but it is unknown how long they remain in the bay or whether they begin feeding parasitically prior to entering the ocean. After growing to full size in the ocean, adult Pacific lampreys pass through the bay on the way to spawn. The amount of time migrating adults spend in the bay prior to entering spawning streams is unknown.

2.2 Salmon Creek

Very few data or observations of Pacific lamprey from the Salmon Creek watershed were found during this review (Table 4, Figure 2), which is not surprising given the lack of targeted surveys. A single Pacific lamprey redd was documented on 18 March 2013 during California Department of Fish and Wildlife (CDFW) salmonid spawning surveys, approximately 1,000 m upstream from Little Salmon Creek (C. Anderson, CDFW, unpubl. data). Since salmonid spawning surveys typically end in the early spring, prior to the onset of most lamprey spawning, the lack of lamprey redd observations is expected.

Ammocoetes of unknown species were recently found in freshwater portions of lower Salmon Creek and its delta in the Humboldt Bay National Wildlife Refuge (Figure 2). In 2010, numerous ammocoetes were observed in fine sediments excavated from the channel during a large restoration project on the refuge (E. Nelson, USFWS, pers. comm., 5 May 2014) (http://www.fws.gov/refuge/Humboldt_Bay/wildlife_and_habitat/SalmonCreekRestoration.html). This location is tidally influenced; although muted (E. Nelson, USFWS, pers. comm., 6 May 2014). Small numbers of unidentified ammocoetes were also collected periodically during seining at two sites adjacent to the Salmon Creek restoration project (in the pre-restoration channel) during monthly surveys conducted from 2005–2009 (M. Wallace, CDFW, unpub. data). These sites were also tidally influenced, but freshwater. Ammocoetes were not detected at a site located further downstream (near the tidegate) during 2005–2009 sampling. Limited salinity data from 2005 and 2006 indicates that salinity was generally relatively high (~30 ppt) at the downstream site, but low (~0.2 ppt) at the two upstream sites where ammocoetes were detected (M. Wallace, CDFW, unpub. data). Ammocoetes were not captured during 2012 and 2013 sampling of the newly restored channel and off-channel ponds, which now have higher salinities than the old channel due to recent tide-gate modifications (M. Wallace, CDFW, unpub. data).

Very few ammocoetes have been recorded upstream of the Salmon Creek estuary. An unknown number of unidentified ammocoetes were located during 2002 coho electrofishing surveys conducted by CDFW in a reach approximately 1,500 m upstream of the Little Salmon Creek confluence. However, no lampreys were detected during electrofishing surveys targeting salmonids at 20 sites throughout Salmon Creek (CDFG 1997). The upper distribution of Pacific lamprey in Salmon Creek and use of Little Salmon Creek and other tributaries for holding, spawning, and rearing remain a data gap.

No records of western brook lampreys in Salmon Creek were found in this review, but based on their generally wide distribution in other Humboldt Bay tributaries (see below), they are presumably present throughout much of the watershed.

Table 4. Known records of lamprey detection in the Salmon Creek watershed by species and life stage.

Stream	Tributary to	Year/s detected	Life stage[1]	Method	Source
Pacific lamprey					
Salmon Cr	Humboldt Bay	2013	R	Spawning survey	C. Anderson, CDFW, unpubl. data
Unknown lamprey species					
Salmon Cr (estuary)	Humboldt Bay	2006–2009	A	Seining	M. Wallace, CDFW, unpub. data
		2010	A	Substrate excavation	E. Nelson, USFWS, pers. comm. 5 May 2014
Salmon Cr	Humboldt Bay	1992	UK	Outmigrant trap	CDFW, NCCCSI database query, Aug 2014[2]
		2002	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[2]

[1] A = ammocoete, R = redd, UK = unknown

[2] North Coast California Coho Salmon Investigation (NCCCSI) Project database query. Some records include multiple sources from various locations and years. Original sources are available from CDFW libraries in Eureka and Arcata, CA.

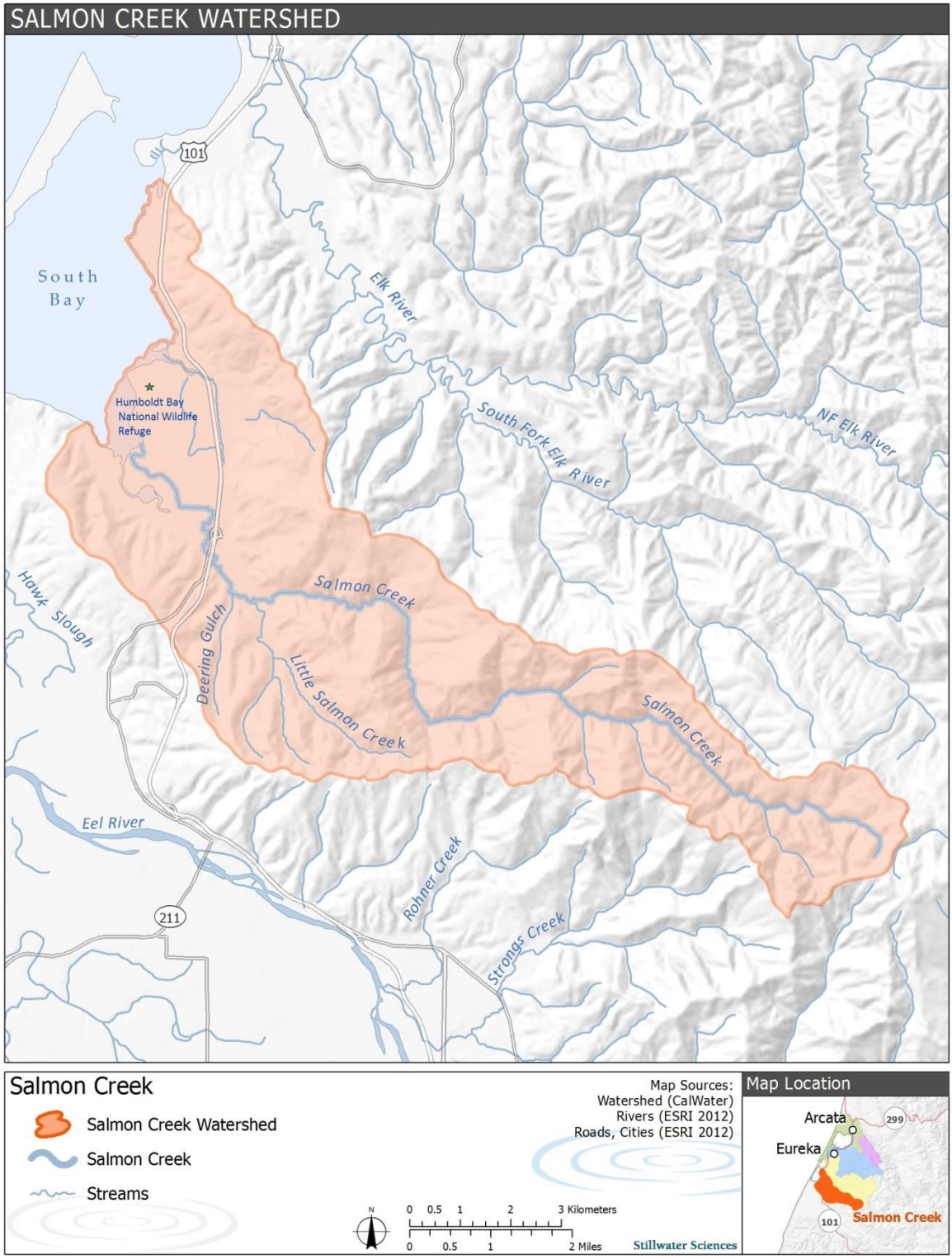

Figure 2. Salmon Creek watershed map indicating names and locations of significant tributaries.

2.3 Elk River

Only four Pacific lamprey observations were found for the Elk River watershed. Three of these observations (two redds and one ammocoete) were in the lower South Fork Elk River approximately 300 m upstream of Tom Gulch, and one was in the North Fork Elk River near the confluence with the North Branch (Table 5, Figure 3). As observed in Freshwater Creek (Section 2.4), Pacific lampreys are expected to be widespread in the mainstem and low gradient tributaries of Elk River, but focused surveys are needed to better document their distribution and relative abundance.

Ammocoetes of unknown species have been documented throughout the mainstem Elk River and numerous tributaries, including the upper reaches of the North and South forks and several relatively small tributaries (Table 5). Small numbers of unidentified ammocoetes were also periodically collected at sites throughout tidally influenced reaches of the lower Elk River during monthly seining surveys conducted from 2005–2009 (Table 5). Notably, in 2008 a single ammocoete was collected in the estuary as far downstream as the old railroad bridge, approximately 2,200 m from the mouth of the Elk River (M. Wallace, CDFW, unpub. data). Lampreys were not detected in seining of Swain Slough (M. Wallace, CDFW, unpub. data), but unidentified ammocoetes have been captured in Martin Slough at two sites near Fairway Drive (Normandeau and Associates 2011; T. Salamunovich, Normandeau and Associates, pers. comm. 16 June 2014) and in several small tributaries to Martin Slough (Table 5, Figure 3).

A single definitive record of western brook lamprey in Elk River comes from the South Fork Elk River (D. Goodman, USFWS, unpubl. data), approximately 300 m upstream of Tom Gulch. Western brook lampreys are expected to be widespread in the watershed as documented in Freshwater Creek.

Table 5. Known records of lamprey detection in the Elk River watershed by species and life stage. Streams are ordered from downstream to upstream within species.

Stream	Tributary to	Year/s detected	Life stage[1]	Method	Source
Pacific lamprey					
South Fork Elk River	Elk River	2013	R	Spawning survey	C. Anderson, CDFW, unpubl. data
		2013	A	UK	D. Goodman, USFWS, unpubl. data
		2014	R	Visual	T. Lucas, PSMFC, pers. comm., 9 June 2014
North Fork Elk River		early 2000s	R, S	Visual	A. Renger, CDFW, pers. comm., 6 June 2014
Western brook lamprey					
South Fork Elk River	Elk River	2013	A	UK	D. Goodman, USFWS, unpubl. data
Unknown lamprey species					
Elk River (estuary)	Humboldt Bay	2005–2009	A	Seining	M. Wallace, CDFW, unpub. data

Stream	Tributary to	Year/s detected	Life stage[1]	Method	Source
Martin Slough	Swain Slough	2004	A	E-fishing	TRPA (2004)
		2006	A	E-fishing	CDFG (2006)
		2006	A	E-fishing	T. Salamunovich, Normandeau and Associates, pers. comm. 16 June 2014
		2011	A	E-fishing	Normandeau and Associates (2011)
Unnamed Tributary ("Barnum Cr")	Martin Slough	2011	A	E-fishing	Normandeau and Associates (2011)
"Wetland Tributary"[2]		2011	A	E-fishing	Normandeau and Associates (2011)
"K St. Tributary"		2011	A	E-fishing	Normandeau and Associates (2011)
Elk River	Humboldt Bay	2011	A	Substrate excavation	N. Simpson, CDFW, pers. comm. 20 June 2014
Clapp Gulch	Elk River	2011	A	Substrate excavation	N. Simpson, CDFW, pers. comm. 20 June 2014
Railroad Gulch		2011	A	Substrate excavation	N. Simpson, CDFW, pers. comm. 20 June 2014
South Fork Elk River		1994	A	E-fishing	CDFG (1994a)
		1994, 2001, 2002	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
		2011	A	Substrate excavation	N. Simpson, CDFW, pers. comm. 20 June 2014
Tom Gulch	South Fork Elk River	1994	A	E-fishing	CDFG (1994b)
North Fork Elk River	Elk River	1994–2003	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
		2011	A	Substrate excavation	N. Simpson, CDFW, pers. comm. 20 June 2014
		2005	UK	Visual	CDFG (2005)
Lake Cr	North Fork Elk River	1990	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
North Branch North Fork Elk River		1999, 2001, 2002	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]

[1] A = ammocoete, R = redd, S = spawning stage adult, UK = unknown

[2] Tributary not show on watershed map (Figure 3). It enters Martin Slough from northwest just downstream of the "K-St. Tributary".

[3] NCCCSI Project database query. Some records include multiple sources from various locations and years. Original sources are available from CDFW libraries in Eureka and Arcata, CA.

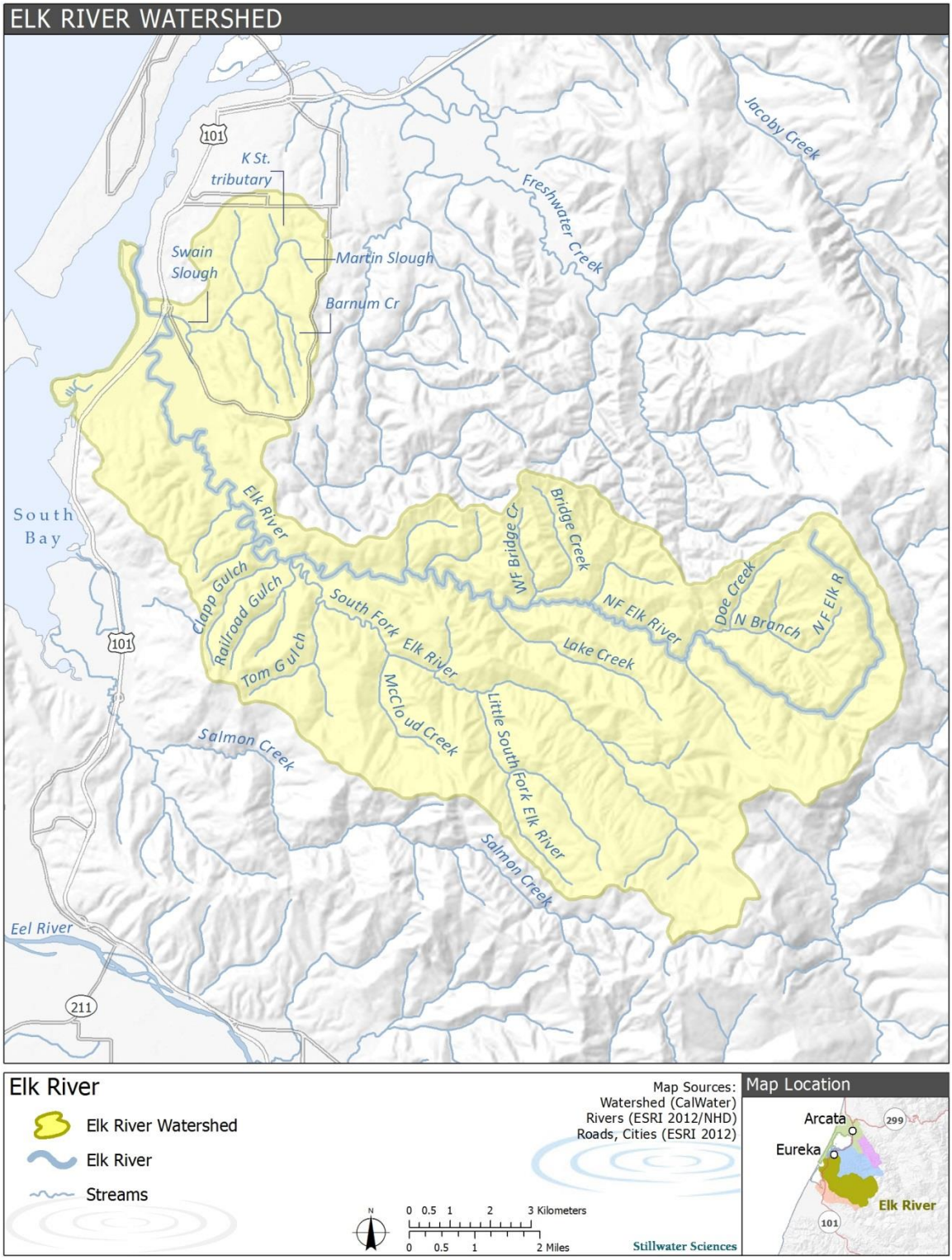

Figure 3. Elk Creek watershed map indicating names and locations of significant tributaries.

2.4 Freshwater Creek

A substantial amount of information on lamprey distribution and life history was available for the Freshwater Creek watershed due to past and current intensive research and monitoring of salmon and steelhead by CDFW and other groups, as well as a more recent emphasis on collecting and recording lamprey data by CDFW, Green Diamond Resource Company, and the Wiyot Tribe (Table 6, Stillwater Sciences et al. 2016).

This review indicated that Pacific lampreys are widely distributed within the Freshwater Creek watershed. In recent years, migrating, holding, or spawning adults and/or redds have been detected in the mainstem from the Humboldt Fish Action Council (HFAC) weir upstream to approximately 3,000 m upstream of South Fork Freshwater Creek (C. Anderson, CDFW, unpubl. data; Figure 4). Significant numbers of adults, presumably mostly spawning stage or post-spawn individuals, have also been captured incidentally during spring outmigrant trapping for salmonids—in Ryan Creek (Green Diamond Resource Company, unpub. data; 11 years of trapping; Appendix A), mainstem Freshwater Creek, Cloney Gulch, Graham Gulch, Little Freshwater Creek, and South Fork Freshwater Creek (C. Anderson, CDFW, unpubl. data; 7 years of trapping; Appendix B). These data indicate that at least some Pacific lamprey likely spawn in these streams in some years. Tellingly, Pacific lampreys were not detected in Cloney Gulch until after a barrier culvert at the mouth was modified in 2002, or in Graham Gulch until after a perched culvert at the mouth was replaced in 2005 (Appendix B). Adult Pacific lampreys were not captured during 7 years of outmigrant trapping in lower McCready Gulch, but adult western brook lamprey and unknown ammocoetes were captured there in most years (Table 6). Additional data on Freshwater Creek Pacific lamprey adult life history, from initial migration from the ocean through spawning, are synthesized in Stillwater Sciences et al. (2016).

Ammocoetes of unknown species have been documented in Freshwater Creek and several tributaries during various fish sampling activities (Table 6). Notably, ammocoetes were detected in several very small tributaries, including an unnamed tributary to Ryan Creek and Cochran Creek, a tributary to Fay Slough (Figure 4). Small numbers of ammocoetes were also periodically captured during 2003–2009 seining surveys in tidally influenced reaches of lower Freshwater Creek. Ammocoetes were captured as far downstream as the HFAC weir, but not at several sites sampled further downstream, which likely have higher salinities (M. Wallace, CDFW, unpub. data). No lampreys were captured during seining sampling of Wood Creek, Fay Slough, or Park Street Marsh (M. Wallace, CDFW, unpub. data); though less sampling effort was devoted to these sites and capture efficiency of lampreys is very low for the seine nets used. Significant numbers of ammocoetes of unknown species have also been incidentally captured during outmigrant trapping in Freshwater Creek, McCready Gulch, Cloney Gulch, Little Freshwater Creek, and South Fork Freshwater Creek (Table 6, Appendix B).

Adult western brook lamprey have been documented during spawning surveys and outmigrant trapping in mainstem Freshwater Creek and various tributaries, and they likely spawn and rear throughout much of the watershed. Additionally, western brook lamprey adults and ammocoetes identified to genus (*Lampetra*) have been recently captured in lower Ryan Creek (Table 6, Appendix A).

Table 6. Known records of lamprey detection in the Freshwater Creek watershed by species and life stage. Streams are ordered from downstream to upstream within species.

Stream	Tributary to	Year/s detected	Life stage[1]	Method	Source
Pacific lamprey					
Freshwater Cr	Humboldt Bay	2009	A	UK	D. Goodman, USFWS, unpubl. data
		2001–2007	S[2]	Outmigrant traps	CDFW, unpubl. data
		2007–2014	S, I	Outmigrant trap	CDFW, unpubl. data
		2011–2014	R, S, C	Spawning survey	C. Anderson, CDFW, unpubl. data
Ryan Creek	Freshwater Slough	2004–2014	S[2]	Outmigrant Trap	Green Diamond Resource Company, unpub. data
		2014	A	Outmigrant Trap	Green Diamond Resource Company, unpub. data
Cloney Gulch	Freshwater Cr	2003–2007	S[2]	Outmigrant traps	CDFW, unpubl. data
Graham Gulch		2007	S[2]	Outmigrant trap	CDFW, unpubl. data
Little Freshwater Cr		2001–2007	S[2]	Outmigrant trap	CDFW, unpubl. data
South Fork Freshwater Cr		2001–2007	S[2]	Outmigrant trap	CDFW, unpubl. data
Western brook lamprey					
Freshwater Cr	Humboldt Bay	2009	A	UK	D. Goodman, USFWS, unpubl. data
		2001–2007	S	Outmigrant traps	CDFW, unpubl. data
		2014	S, R	Spawning survey	C. Anderson, CDFW, pers. comm., 5 May 2014
Ryan Creek	Freshwater Slough	2004–2006, 2014	S	Outmigrant Trap	Green Diamond Resource Company, unpub. data
		2014	A[4]	Outmigrant Trap	Green Diamond Resource Company, unpub. data
		2014	A	UK	D. Goodman, USFWS, unpubl. data
McCready Gulch	Freshwater Cr	2001, 2003–2005	S	Outmigrant trap	CDFW, unpubl. data
Cloney Gulch		Recent years	S, R	Spawning survey	C. Anderson, CDFW, pers. comm., 5 May 2014
		2003–2007	S	Outmigrant trap	CDFW, unpubl. data
Graham Gulch		2007	S	Outmigrant trap	CDFW, unpubl. data
Little Freshwater Cr		2001–2007	S	Outmigrant trap	CDFW, unpubl. data
South Fork Freshwater Cr		2001–2007	S	Outmigrant trap	CDFW, unpubl. data

Stream	Tributary to	Year/s detected	Life stage[1]	Method	Source
Unknown lamprey species					
Freshwater Slough	Humboldt Bay	2003	I[5]	seining	M. Wallace, CDFW, unpub. data
Ryan Creek	Freshwater Slough	2004–2014	A	Outmigrant Trap	Green Diamond Resource Company, unpub. data
Unnamed "Tributary B"	Ryan Cr	2002	UK	Snorkel	CDFW, NCCCSI database query, Aug 2014[3]
Cochran Cr	Fay Slough	2001, 2003	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
Freshwater Cr	Humboldt Bay	1989–2003 various	UK	Various	CDFW, NCCCSI database query, Aug 2014[3]
		2001–2007, 2011	A	Outmigrant traps	CDFW, unpubl. data
		2003–2009	A	Seining	M. Wallace, CDFW, unpub. data
McCready Gulch	Freshwater Cr	1992	UK	Outmigrant trap	CDFW, NCCCSI database query, Aug 2014[3]
		2002	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
		2001–2007	A	Outmigrant trap	CDFW, unpubl. data
Cloney Gulch		1994	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
		2003–2007	A	Outmigrant trap	CDFW, unpubl. data
		2004	UK	Visual	CDFG (2004)
Little Freshwater Cr		1994, 2001	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
		2001–2007	A	Outmigrant trap	CDFW, unpubl. data
South Fork Freshwater Cr		2001–2007	A	Outmigrant trap	CDFW, unpubl. data

[1] A = ammocoete, R = redd, C = carcass, S = spawning stage adult, I = immature adult; UK = unknown

[2] These records were assumed to be spawning state adults based on timing and locations of traps, but may have included some immature adults.

[3] NCCCSI Project database query. Some records include multiple sources from various locations and years. Original sources are available from CDFW libraries in Eureka and Arcata, CA.

[4] This record includes ammocoetes identified as *Lampetra* species based on caudal pigmentation and could include river lampreys in addition to western brook lampreys.

[5] This individual, captured on 30 April 2003 was most likely an immature adult Pacific lamprey due to capture timing and location in Freshwater Slough, but data provided did not identify species.

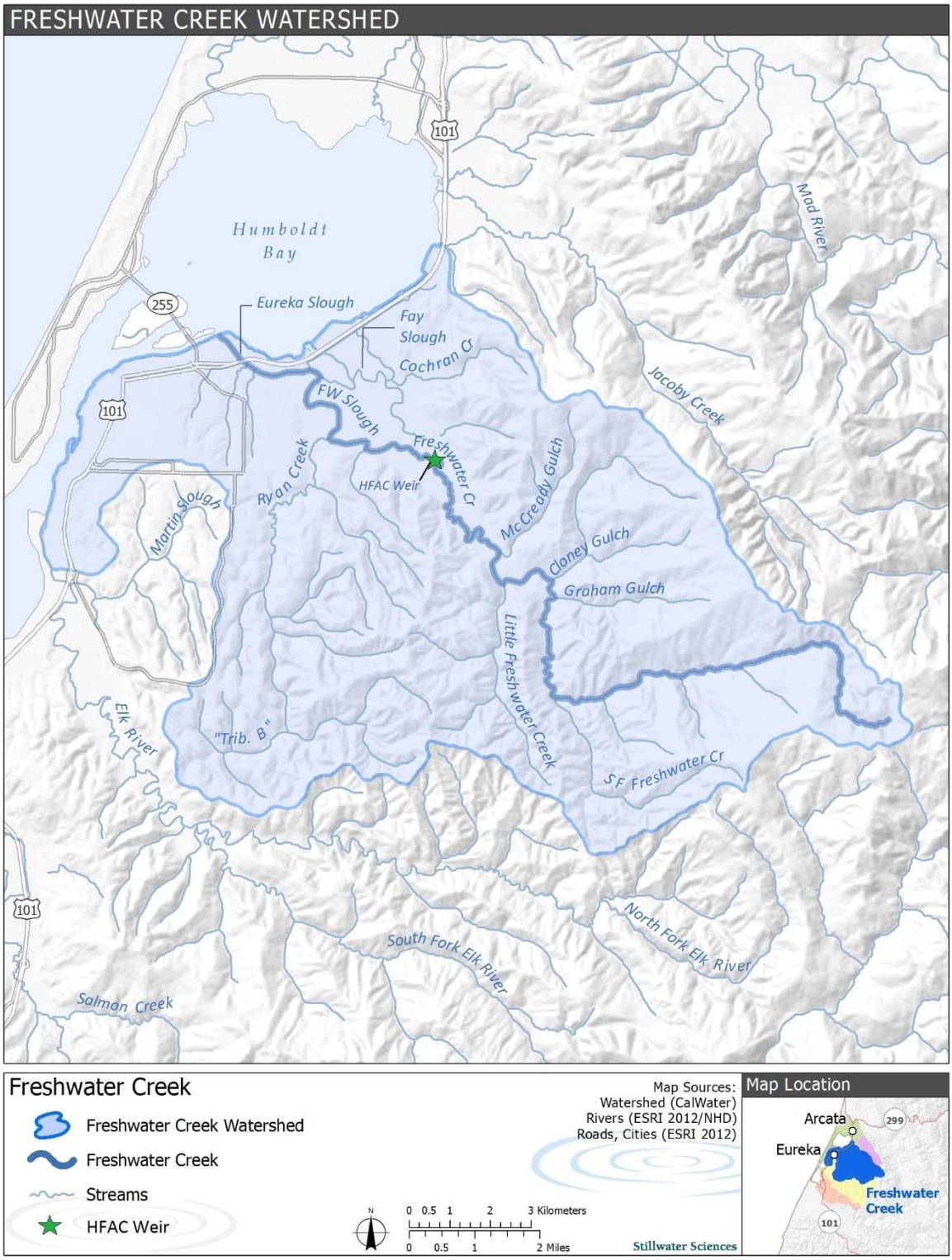

Figure 4. Freshwater Creek watershed map indicating names and locations of significant tributaries.

2.5 Jacoby Creek

Very few data or observations of Pacific lamprey in the Jacoby Creek watershed were discovered during this review (Table 7). Two Pacific lamprey redds were documented on 5 April 2011 during CDFW salmonid spawning surveys, in the vicinity of Brookwood Drive (C. Anderson, CDFW, unpubl. data).

Unidentified ammocoetes have been located during electrofishing surveys of mainstem Jacoby Creek, including over 100 individuals collected during construction of the Mad River Pipeline Project at a site approximately 400 m upstream of the confluence with Humboldt Bay (Table 7; TRPA 2003). Ammocoetes have also been documented in Golf Course Creek and Morrison Gulch (Table 7).

No lampreys were captured during 12 years of multiple-pass electrofishing surveys in a 2.8 km section of Jacoby Creek upstream of a waterfall recognized as barrier to anadromous salmonids (R. Nakamoto, USDA Forest Service, pers. comm., 7 July 2014). The waterfall is located approximately 6 river miles from Humboldt Bay (Figure 5). Although these surveys were conducted with traditional electrofisher settings aimed at capturing salmonids, recent research indicates that such multi-pass electrofishing surveys have a high likelihood of detecting ammocoetes if they are present (Dunham et al. 2013). Thus, these results strongly indicate the absence of lampreys in Jacoby Creek upstream of the waterfall.

Table 7. Known records of lamprey detection in the Jacoby Creek watershed by species and life stage. Streams are ordered from downstream to upstream within species.

Stream	Tributary to	Year/s detected	Life stage[1]	Method	Source
Pacific lamprey					
Jacoby Cr	Humboldt Bay	2011	R	Spawning survey	C. Anderson, CDFW, unpubl. data
Unknown lamprey species					
Jacoby Cr	Humboldt Bay	1998, 1993, 1996, 2002, 2003	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[2]
		2003	A	E-fishing	TRPA (2003)
Golf Course Cr	Jacoby Cr	1996	A	E-fishing	CDFG (1996)
Morrison Gulch		2001	A	E-fishing	RTA (2001)

[1] A = ammocoete, R = redd

[2] NCCCSI Project database query. Some records include multiple sources from various locations and years. Original sources are available from CDFW libraries in Eureka and Arcata, CA.

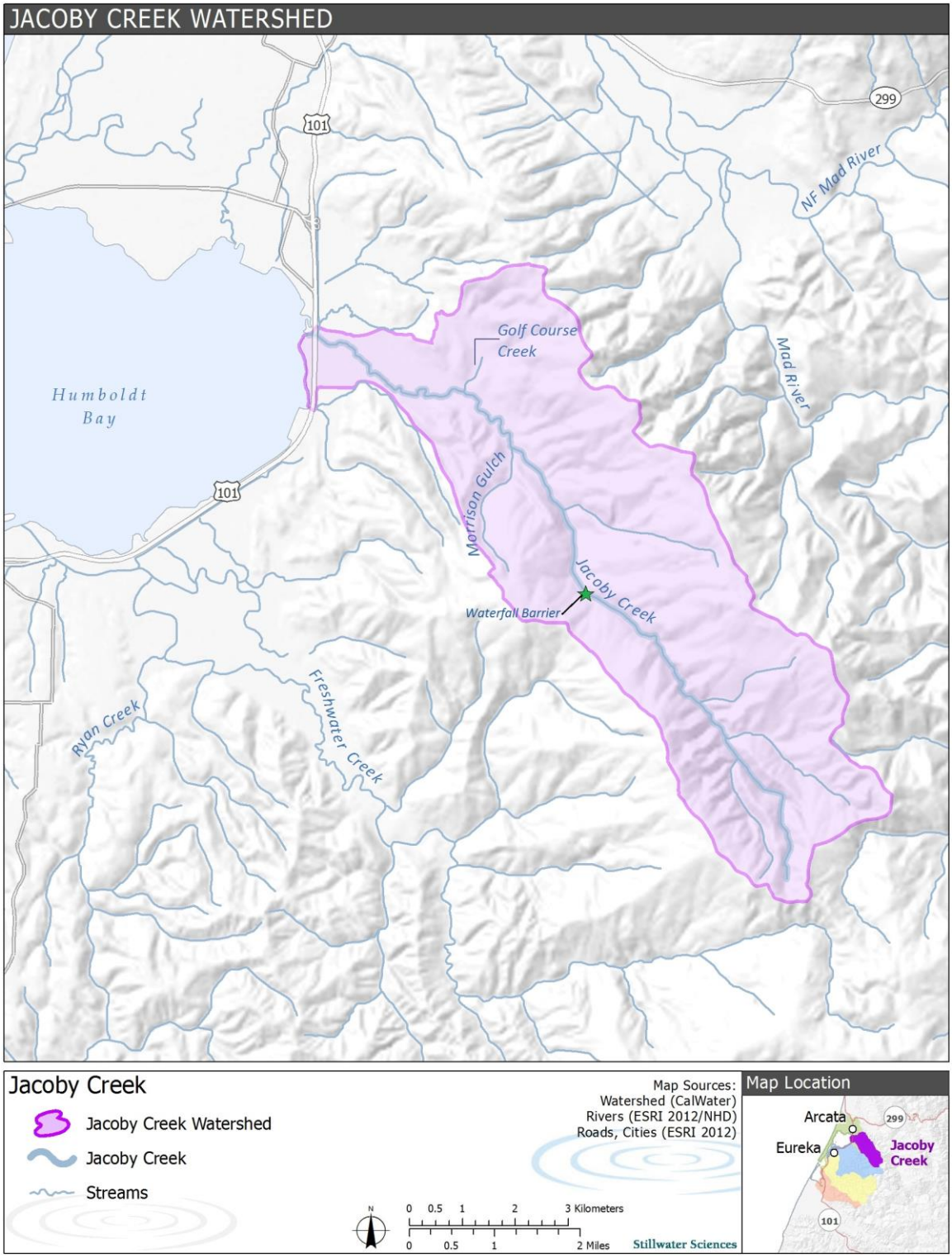

Figure 5. Jacoby Creek watershed map indicating names and locations of significant tributaries.

2.6 Other Northern Humboldt Bay Tributaries

Lampreys have been documented in several smaller streams that flow directly into the northern part of Humboldt Bay (Table 8, Figure 6). The only definitive observations of Pacific lamprey found during this review were from Jolly Giant Creek, a largely urban stream flowing through Arcata. Two separate observations of an adult Pacific lamprey were made near Shay Park in the 1990s (Table 8). One of the observations was of spawning stage adult building a redd and the other was presumably also a spawning stage adult. A Pacific lamprey carcass was also recorded in Jolly Giant Creek during outmigrant trapping conducted by the City of Arcata in 1986 (City of Arcata, unpub. data).

Ammocoetes of unknown species have also been recorded in Jolly Giant Creek, as well as Rocky Gulch, Beith, Janes Creek, and South Fork Janes Creek, during various fisheries surveys (Table 8). A spawning adult western brook lamprey was recently observed in Janes Creek (D. Halligan, Stillwater Sciences, pers. comm., 3 June 2014).

Table 8. Known records of lamprey detection in other Northern Humboldt Bay tributaries by species and life stage. Streams are ordered from south to north within species.

Stream	Tributary to	Year/s detected	Life stage[1]	Method	Source
Pacific lamprey					
Jolly Giant Cr	Humboldt Bay	1986	C	Outmigrant trap	City of Arcata, unpub. data
		1990s	S, R	Visual	J. Strange, Stillwater Sciences, pers. comm., 6 June 2014
		1994	S[2]	Visual	M. Wallace, CDFW, pers. comm., 5 June 2014
Western brook lamprey					
Janes Cr	McDaniel Slough	2000s	S, R	Visual	D. Halligan, Stillwater Sciences, pers. comm., 3 June 2014
Unknown lamprey species					
Rocky Gulch	Humboldt Bay	2001, 2003, 2005	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
		2003	A	E-fishing	TRPA 2003
Beith Cr	Gannon Slough	2003	A	Dip net	TRPA 2003
Jolly Giant Cr	Humboldt Bay	1986	UK	Outmigrant trap	City of Arcata, unpub. data
		UK	A	E-fishing	T. Roelofs, pers. comm., 17 June 2014
		1992-1995, 1997, 1998, 2002, 2003	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
Janes Cr	McDaniel Slough	1999, 2001–2003	A	E-fishing	CDFW, NCCCSI database query, Aug 2014[3]
		2013	A	Visual	T. Nelson, Wiyot Tribe, pers. comm., 3 June 2014
South Fork Janes Cr	Janes Cr	1980s	A	E-fishing	T. Roelofs, pers. comm., 17 June 2014

[1] A = ammocoete, R = redd, C= carcass, S = spawning stage adult, UK = unknown
[2] Sexual maturity of this individual is unknown, but it was presumably spawning stage since it was observed visually.
[3] NCCCSI Project database query. Some records include multiple sources from various locations and years. Original sources are available from CDFW libraries in Eureka and Arcata, CA.

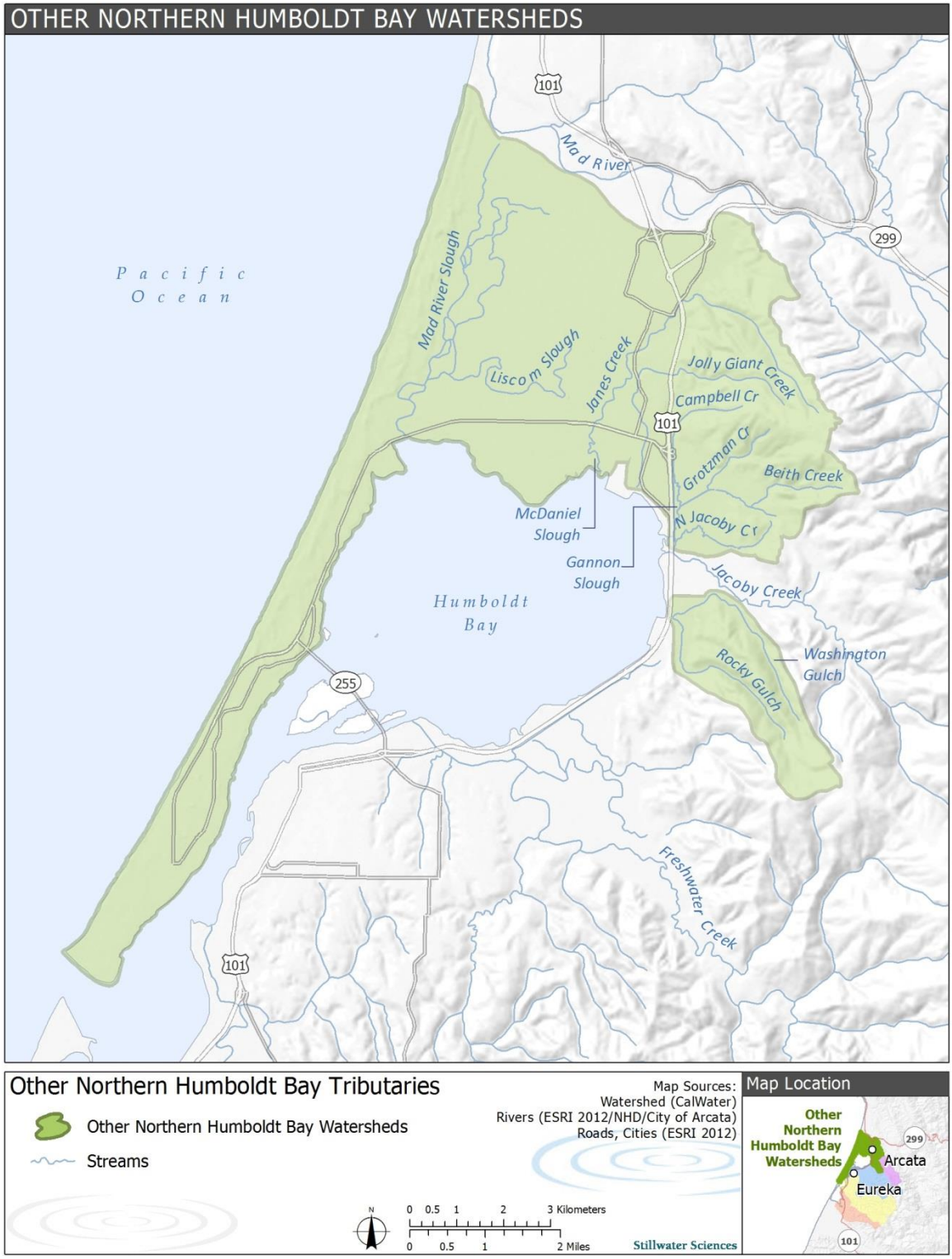

Figure 6. Map indicating names and locations of significant tributaries included in the "Other Northern Humboldt Bay Tributaries" study area.

3 DISCUSSION AND RECOMMENDATIONS

3.1 Summary of Findings and Implications

Presence of Pacific lamprey in each major Humboldt Bay watershed, widespread distribution within Freshwater Creek and in several of its tributaries, and evidence of spawning in relatively small streams such as Jolly Giant Creek and Graham Gulch (drainage areas of 4.2 km^2 and 6.5 km^2, respectively) suggest the species is widely distributed within the Humboldt Bay watershed. Notably, this review also indicated ammocoetes of unknown species were documented throughout the watershed—including both small headwater streams and tidally influenced reaches near Humboldt Bay. However, very little information was available to inform upper distribution or species presence within many stream reaches in the study area. Furthermore, with the exception of Freshwater Creek, where focused studies are being conducted and more extensive data are available, this review demonstrated that, overall, very little data are available to describe Pacific lamprey life history and assess population status in the Humboldt Bay watershed.

This review should be viewed as a starting point for understanding distribution, status, and life history, and data gaps for lampreys in the Humboldt Bay watershed. Many of the data sources had significant limitations and, while considerable effort was made to locate and summarize all available information here, additional lamprey data for the study area likely exist. The vast majority of the lamprey data located during this review came from research and monitoring surveys designed to sample anadromous salmonids, either through spawning surveys for redds and adults, electrofishing surveys for juveniles, or seining in lower stream reaches. With the exception of recent surveys in Freshwater Creek, most salmonid spawning surveys in Humboldt Bay tributaries are completed by the end of the coho salmon or steelhead spawning seasons (February or April, respectively) and therefore generally have no to little overlap with the lamprey spawning period. For this reason, these surveys are often not reliable indicators of presence or abundance of lamprey spawning in a given survey reach.

A noteworthy source of information on lamprey presence for numerous streams in the Humboldt Bay watershed was CDFW Stream Inventory Reports, provided by the Fortuna CDFW office. These reports, many of which documented lamprey presence, typically include results of standard habitat surveys, limited electrofishing surveys aimed at salmonids, and incidental fish observations. Since fish sampling for Stream Inventory surveys was limited in scale and not intended to target lampreys, lack of capture or observation cannot be interpreted as absence in the streams where an inventories were conducted. Traditional electrofishing surveys designed to capture juvenile salmonids have relatively low capture efficiency compared with using lamprey-specific electrofisher settings. Nonetheless, recent research indicates that regardless of settings used, probability of detection is relatively high when at least two passes of electrofishing are applied and at least 10 ammocoetes are present in a study reach (Dunham et al. 2013). Consequently, data from multi-pass electrofishing surveys for salmonids conducted over considerable distances generally provide a reliable indication as to presence or absence of significant lamprey populations in a sampled reach (Dunham et al. 2013). Seining, on the other hand is expected to have very low capture efficiency for ammocoetes, which generally avoid capture by being burrowed in the sediment and can pass through seine mesh (M. Wallace, CDFW, pers. comm., 6 May 2014). Nonetheless, seining detected ammocoetes at numerous sites in the study area.

Another notable source of information for this review was a query of an extensive database of fish presence from the North Coast California Coho Salmon Investigation (NCCCSI) project, provided by the Eureka and Arcata CDFW offices. This query turned up numerous records of

lamprey presence from a wide variety of sources. Many of the original sources in the NCCCSI database (including raw data and historical reports) are available at the Eureka and Arcata CDFW office libraries. Some of these reports may contain additional information on capture location, date, and species. Obtaining and reviewing all of these original reports was outside the scope of this review.

CDFW Stream Inventory Reports, the NCCCSI database, and various other sources rarely provided definitive documentation of lampreys by species, and therefore we reported the majority of these records as "unknown species". Thus, understanding of the distribution of Pacific lamprey compared with *Lamptera* species (western brook and river lampreys) is limited. Nevertheless, knowledge of locations where ammocoetes were detected provides a good starting point for planning future surveys to refine species-specific understanding of distribution.

3.2 Recommendations and Future Research

In addition to highlighting the relative lack of attention lampreys have received from natural resource managers in the Humboldt Bay watershed, this review revealed various data gaps that limit our understanding of Pacific lamprey basic biology and our ability to conserve and manage this species. These data gaps include lack of species-specific distribution data for many streams in the watershed, limited information on use of tidally influenced and brackish habitat by ammocoetes and migrating macrophthalmia and adults, minimal information on timing of adult migration and key holding areas, and little data on locations and prevalence of barriers to adult migration within the watershed.

To begin to address these and other data gaps and encourage lamprey conservation in the Humboldt Bay watershed, we recommend the following activities:

- Conduct species-specific distribution surveys throughout each tributary watershed, documenting both presence and upper distribution of Pacific lampreys and *Lampetra* species. These surveys should be done using lamprey-specific ammocoete electrofishing protocols (e.g., Reid and Goodman 2015, Stillwater Sciences and Wiyot Tribe Natural Resources Department 2016).
- Alternatively (or in tandem with electrofishing surveys), presence/absence of lamprey species could be rapidly assessed by testing for environmental DNA (eDNA) in water samples collected in streams of interest. The eDNA approach relies on collection and analysis of mitochondrial DNA that has detached from an organism and is loose in the aquatic environment. This technology shows promise for improving detection and abundance estimates of rare freshwater species (Thomsen et al. 2012, Taberlet et al. 2012, Rees et al. 2014) and has been used successfully to monitor various fishes (e.g., Jerde et al. 2011, Thomsen et al. 2012), including lampreys (Docker et al. 2014, Gustavson et al. 2015). Since this technique can detect even very small quantities of DNA, it has great potential for detecting lampreys in streams where abundance is low. Furthermore, eDNA has the potential to be a more cost-effective approach, since presence and distribution of a species can be determined simply by collecting water samples for subsequent laboratory analysis. A further merit of this approach is that it avoids much of the expense, time, training, permitting, and safety issues associated with traditional electrofishing surveys. Finally, streams with limited access could be sampled for lamprey presence by collecting water samples at more accessible point locations (e.g., bridges or confluences).
- Document the extent to which ammocoetes of each species and Pacific lamprey macrophthalmia use tidally influenced areas and sloughs in the estuaries of Humboldt Bay

tributaries, including describing the range of salinities tolerated. It would also be valuable to compare length-frequency and relative abundance of ammocoetes collected in tidally influenced areas with upstream reaches to improve understanding of the roles these areas play in population dynamics.

- Assess potential barriers to adult migration and remediate problem sites. The process developed to assess and prioritize barriers in the Eel River basin (Stillwater Sciences 2014) as well as information gained by other recent lamprey passage studies can be used to guide evaluation and remediation of passage barriers in Humboldt Bay tributaries.
- Continue to educate local biologists working in the watershed on lamprey identification and encourage them to include lamprey data and observations in published reports or share data with the Wiyot Tribe or the USFWS Pacific Lamprey Conservation Initiative.
- Continue coordinating with local CDFW staff in collecting and summarizing data and conducting focused studies in Freshwater Creek and other Humboldt Bay watersheds.
- Continue coordinating with biologists from local timber companies, such as Green Diamond Resource Company, to summarize lamprey data collected through their ongoing fish and habitat monitoring in the Humboldt Bay watershed.
- Encourage local biologists and restoration practitioners to consider lamprey-specific habitat requirements when designing and implementing restoration projects.
- Develop a lamprey species distribution database for the Humboldt Bay watershed that can be easily updated and shared with interested stakeholders.

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Appendices

Appendix A

Incidental Lamprey Data from 2004 to 2014 Salmonid Outmigrant Trapping Efforts in Ryan Creek, Provided by Green Diamond Resource Company

Table A-1. Incidental data on ammocoetes and adult lampreys captured from 2004–2014 during salmonid outmigrant trapping efforts in Ryan Creek. Unpublished data provided by Green Diamond Resource Company, 25 November 2014.[1]

Green Diamond Resouce Company - Lamprey Summary - Ryan Creek Screw Trap							
Year	ENTR A	ENTR AM	LAMP AM	LAMP U	LARI A	LASP AM	Total
2004	88	0	180	56	1	0	325
2005	51	0	809	129	11	0	1,000
2006	49	0	449	135	10	0	643
2007	86	0	459	361	0	0	906
2008	77	0	210	34	0	0	321
2009	16	0	425	66	0	0	507
2010	13	0	38	3	0	0	54
2011	26	0	50	1	0	0	77
2012	95	0	83	4	0	0	182
2013	58	0	45	15	0	0	118
2014	24	1	35	0	14	73	147
Grand Total	583	1	2,783	804	36	73	4,280

ENTR A = Pacific Lamprey Adult
ENTR AM = Pacific Lamprey Ammocoete
LAMP AM = Unidentified Lamprey Ammocoete
LAMP U = Unidentified Lamprey, Unknown Age Class
LARI A = Western Brook Lamprey Adult
LASP AM = Unidentified Lampetra Ammocoete

[1] The following is a summary of methods used to identify and record lamprey data at the Ryan Creek Screw Trap, provided by P. Righter, Green Diamond Resource Company: "The methods for speciation and determining age class for lamprey varied over time. Prior to the 2014 season, species identification was based on size and whether eyes were present. For example, western brook lamprey adults were approximately 100 mm with eyes and Pacific lamprey juveniles were approximately 100 mm without eyes. During the 2014 season we used the central California coast field ID key (Reid 2012). Data collected prior to using this key was post-processed to edit species and age class designations to be as accurate as possible. For example, western brook lamprey adults (LARI A) were changed to unknown lamprey of unknown age (LAMP U) unless noted as gravid and Pacific juveniles (LATR J) were changed to unknown lamprey ammocoetes (LAMP AM). Also, lampreys that were coded as LATR A were changed to ENTR A."

Appendix B

Summary of Lamprey Captures in Freshwater Creek Outmigrant Trapping from 2001 to 2014, Provided by CDFW

Table B-1. Adult Pacific lamprey captured in downstream migrant traps operated by CDFW in Freshwater Creek and tributaries. N/A = trap not operated. HFAC = Humboldt Fish Action Council weir; LMS = Lower mainstem; UMS = Upper mainstem; CLO = Cloney Gulch; SFO = South Fork Freshwater Creek; LFR = Little Freshwater Creek; MCR = McCready Gulch; GRA = Graham Gulch.

YEAR	HFAC	LMS	UMS	CLO	SFO	LFR	MCR	GRA
2001	N/A	87	46	0	19	13	0	0
2002	N/A	63	42	0	9	10	0	0
2003	N/A	62	47	4	7	7	0	0
2004	N/A	127	24	4	8	14	0	0
2005	N/A	65	83	1	25	2	0	0
2006	N/A	30	27	3	12	6	0	0
2007	29	56	8	5	3	7	0	2
2008	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2011	141[1,2]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2012	59[3]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2013	18[4]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2014	24[5]	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[1] Field staff were trained to sex adult lampreys halfway through the 2011 trapping season.
[2] 33 mature females, 50 mature males, and 70 unknown sex.
[3] 14 mature females, four mature males, and 41 sex unknown (sexually immature).
[4] Four mature females, five mature males, and nine sex unknown (sexually immature).
[5] Eight females, seven males, and nine sex unknown (sexually immature).

Table B-2. Lamprey ammocoetes of unknown species captured in downstream migrant traps operated by CDFW in Freshwater Creek and tributaries. N/A = trap not operated. HFAC = Humboldt Fish Action Council weir; LMS = Lower mainstem; UMS = Upper mainstem; CLO = Cloney Gulch; SFO = South Fork Freshwater Creek; LFR = Little Freshwater Creek; MCR = McCready Gulch; GRA = Graham Gulch.

YEAR	HFAC	LMS	UMS	CLO	SFO	LFR	MCR	GRA
2001	N/A	94	6	22	34	78	45	0
2002	N/A	131	83	21	76	18	5	0
2003	N/A	283	26	3	6	9	1	0
2004	N/A	410	20	2	15	2	8	0
2005	N/A	92	29	41	39	30	69	0
2006	N/A	349	46	15	1	1	29	0
2007	0	114	53	5	10	11	6	0
2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2011	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2012	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2013	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2014	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table B-3. Lampreys identified as adult western brook lamprey[1] captured in downstream migrant traps operated by CDFW in Freshwater Creek and tributaries. N/A = trap not operated. HFAC = Humboldt Fish Action Council weir; LMS = Lower mainstem; UMS = Upper mainstem; CLO = Cloney Gulch; SFO = South Fork Freshwater Creek; LFR = Little Freshwater Creek; MCR = McCready Gulch; GRA = Graham Gulch.

YEAR	HFAC	LMS	UMS	CLO	SFO	LFR	MCR	GRA
2001	N/A	102	11	4	42	12	3	0
2002	N/A	44	14	14	140	2	0	0
2003	N/A	678	11	4	2	21	6	0
2004	N/A	385	3	8	12	9	3	0
2005	N/A	218	4	1	2	50	13	0
2006	N/A	190	4	2	7	24	0	0
2007	0	291	3	1	6	18	0	5
2008	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2009	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2010	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2011	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2012	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2013	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2014	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[1] Numerous individuals were definitively identified as adult western brook lamprey by experienced field staff based on size, color, being clearly gravid, and/or having well-developed fins. However, since no formal training of field staff in lamprey identification was provided, it is possible that a small number of individuals included in these counts were actually Pacific lamprey macrophthalmia that were misidentified as adult western brook lamprey by less experienced field staff (C. Anderson, CDFW, pers. comm., 22 April 2015).