# Pacific Lamprey in the Eel River Basin: A Summary of Current Information and Identification of Research Needs


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# 1 INTRODUCTION

## 1.1 Background

The Eel River received its name due to the fact that it once contained vast numbers of Pacific lampreys (*Entosphenus tridentatus*, formerly *Lampetra tridentata*). Locally referred to as "eels," Pacific lamprey were once a key food resource for the Wiyot people and many other tribes throughout the Pacific Northwest and are still regarded as an important food source and indicator of ecosystem health by many tribal members and biologists (e.g., Close et al. 2002, Close et al. 2004, Petersen Lewis 2009). By most accounts, the population in the Eel River, as in most other California streams, appears to be have undergone a substantial decline; yet very little effort has been made to study or monitor it (Nawa 2003, Moyle et al. 2009). In addition to the near loss of this important food source, the decline of Pacific lampreys in the Eel River has likely disrupted natural food webs, predator-prey dynamics, nutrient cycles, and other ecosystem functions. This report summarizes available information on the species in the Eel River basin, including that from local biologists and tribal members, in order to provide the Wiyot Tribe and other stakeholders in the basin with an enhanced understanding of Pacific lamprey life history, distribution, changes in abundance, and causes of their decline. This is critical first step towards understanding factors limiting lamprey populations in the basin, identifying key information gaps, designing research and monitoring plans, and implementing actions to recover the species to their historical abundance, or, at a minimum, to a level allowing sustainable harvest and restoration of their ecological role in the watershed.

## 1.2 Methods

Information on Pacific lamprey in the Eel River basin was obtained from a variety of sources including:

- peer-reviewed literature and technical reports;
- correspondence with fisheries biologists and other stakeholders in the basin (Table 1);
- museums and online databases (Table 2);
- interviews with Wiyot Tribal members, especially eelers and their families (Appendices B and C); and
- responses to a questionnaire included in the monthly Wiyot newsletter (Appendix D).

Appendices B through D contain potentially sensitive tribal information and are thus not included in this report. They are contained in a stand-alone document available by request from the Wiyot Tribe.

## 1.3 Basin Overview

The Eel River is California's third largest watershed, with an area of 3,681 $mi^2$ (9,534 $km^2$). Precipitation in the basin averages 40 inches (102 cm) per year in the coastal lowlands, and 80–100 inches (203–254 cm) at higher elevations, accounting for 9% of California's annual run-off (but making up only 2% of the state's drainage area). The rainfall pattern in the basin is marked by wet winters and dry summers. During the period of record (1910–2009), discharge in the lower Eel River near Scotia (USGS gage 11477000) averaged 19,900 cfs for January and 138 cfs for September. The landscape varies from mountainous redwood and Douglas-fir forest near the coast to grassland and oak woodlands further inland. The geology of the watershed is naturally unstable and the Eel produces some of the highest sediment in the world (Brown and Ritter 1971). Land uses in the watershed include grazing, timber management, rural and residential development, recreation, gravel extraction, and specialty crop agriculture.

The Scott Dam was constructed in the upper Eel River in 1912 and forms Lake Pillsbury in northern Lake County. The river flows west approximately 10.5 miles (16.9 km) from Lake Pillsbury where it meets Van Arsdale Reservoir, created by Cape Horn Dam (constructed in 1907). An average of approximately 219 cfs is diverted from the Van Arsdale Reservoir and pumped south into the Russian River basin.

Figure 1 displays the Eel River watershed divided into the following subbasins: Lower Eel River and Estuary, Van Duzen River, Lower Mainstem Eel River, South Fork Eel River, Middle Main Eel River, North Fork Eel River, Middle Fork Eel River, and Upper Mainstem Eel River. These subbasins are addressed individually for describing Pacific lamprey life history and distribution in this report.

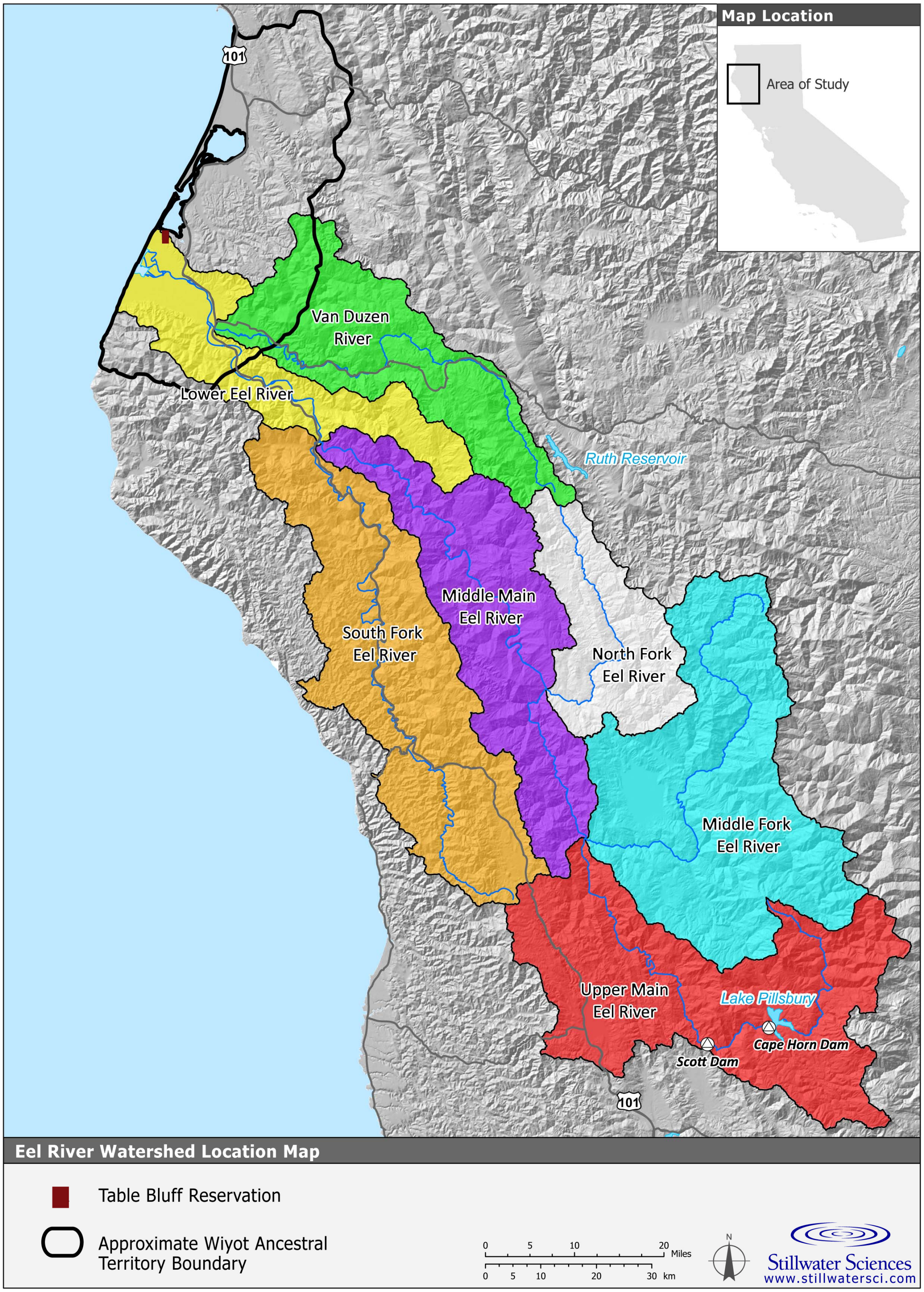


**Figure 1.** Locations of major sub-basins within the Eel River basin and approximate location of Wiyot Ancestral territory.

# 2 LIFE HISTORY

## 2.1 General Overview

Pacific lampreys are anadromous, rearing in freshwater before outmigrating to the ocean, where they grow to full size prior to returning to their natal streams to spawn (Figure 2). The species is distributed in streams along the northern margin of the Pacific Ocean, from central Baja California north along the west coast of North America to the Bering Sea in Alaska (Ruiz-Campos and Gonzales-Guzman 1996, Lin et al. 2008). It also found along the coast of Japan. Adults migrate into and spawn in a wide variety of river systems, from short coastal streams such as Freshwater Creek in Humboldt Bay, to tributaries of the Snake River in Idaho, where individuals migrate over 900 miles (1450 km) (Claire 2004).

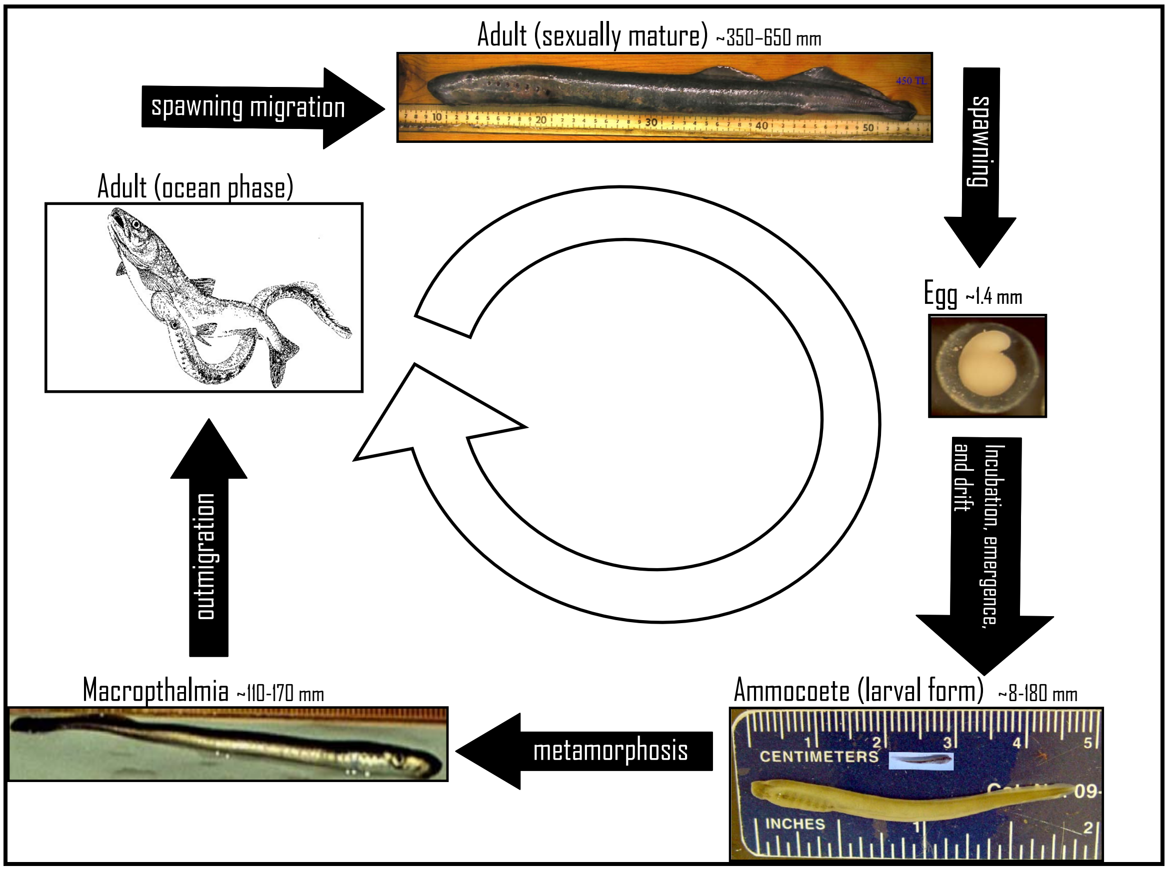


**Figure 2.** Pacific lamprey life cycle.

Spawning typically takes place from March through July depending on water temperature and local conditions such as seasonal flow regimes (Kan 1975, Brumo et al. 2009, Gunckel et al. 2009). Evidence from the Santa Clara River in southern California suggests that populations in the southern portion of their range can spawn as early as January, with peak spawning from February to April (Chase 2001); whereas inland and northern populations initiate spawning considerably later in the spring (Kan 1975, Beamish 1980, Brumo et al. 2009). Spawning occurs both in the mainstem of medium-sized rivers and smaller tributaries (Luzier et al. 2006, Brumo et al. 2009, Gunckel et al. 2009) and generally takes place in pool and run tailouts and low gradient riffles. Both males and females build nests (redds), which are approximately 40 x 40 cm in area and constructed in gravel and cobble substrate (Brumo 2006, Gunckel et al. 2009). Spawning substrate size typically ranges from approximately 25–90 mm (1.–3.5 in), with a median of 48 mm (1.9 in) (Gunckel et al. 2009). Water velocity above redds ranges from 0.2–1.0 m/s (median 0.6 m/s) and depth varies from approximately 0.2–1.2 m (0.7–4.0 ft) (Gunckel et al. 2009, A. Brumo, pers. obs.). Depending on their size, females lay between 30,000 and 240,000 eggs (Kan 1975) approximately 1.4 mm (0.06 in) in diameter (Meeuwig et al. 2004). In comparison, Chinook salmon generally lay approximately 4,000 to 12,000 eggs (e.g., Jasper and Evensen 2006). During spawning, eggs are deposited into the redd, where depending on water temperature, they Eggs hatch after approximately 15 days, depending on water temperatures (Meeuwig et al. 2004, Brumo 2006). The egg sac larval stage, known as prolarvae, spend another 15 days in the redd gravels until they emerge at night and drift downstream (Brumo 2006). Adult Pacific lampreys typically die within a few weeks after spawning (Kan 1975, Brumo 2006).

After drifting downstream, the eyeless larvae, known as ammocoetes, settle out of the water column and burrow into fine silt and sand substrate in low-velocity, depositional areas such as pools, alcoves, and side channels (Torgensen and Close 2004). Ammocoete presence has also been shown to be associated with presence of woody debris (Roni 2003, Graham and Brun 2006), and they appear to be more common in substrates containing organic matter such as leaves (A. Brumo, pers. obs.). Depending on factors influencing their growth rates, they remain in this habitat from 4 to 10 years, filter-feeding on algae and detrital matter prior to metamorphizing into an adult form (Pletcher 1963, Moore and Mallatt 1980, Beamish and Levings 1991, van de Wetering 1998). During metamorphisis individuals develop eyes, a suctoral disc, sharp teeth, and more-defined fins (McGree et al. 2008). After metamorphosis, smolt-like individuals known as macropthalmia migrate to the ocean—typically in conjunction with high-flow events between fall and spring—where they feed parasitically on a variety of marine fishes (Richards and Beamish 1981, Beamish and Levings 1991, van de Wetering 1998, Close et al. 2002).

Pacific lampreys are thought to remain in the ocean for approximately 18–40 months before returning to freshwater as sexually immature adults, typically from late winter until early summer (Kan 1975, Beamish 1980). Moyle et al. (2009) suggests the existence of separate runs in some river systems, one that migrates upstream in the spring and one that migrates in the fall and early winter. In the Klamath and Columbia rivers, Pacific lampreys have been reported to enter freshwater year round (Kan 1975, Larson and Belchik 1998, Petersen Lewis 2009). After an initial upstream migration, individuals remain inactive under boulders or similar substrate throughout the fall and winter months prior to emerging as sexually mature adults the following spring and undergoing a secondary migration into spawning areas (Bayer et al. 2001, Fox and Graham 2008). Unlike Pacific salmon and steelhead (and like the Great Lakes sea lamprey; Bergstedt and Seelye 1995), Pacific lampreys do not necessarily home to natal spawning streams (Moyle et al. 2009). Instead, migratory lampreys may select spawning locations based on the presence of a pheromone-like substance secreted by ammocoetes (Bjerselius et al. 2000, Vrieze and Sorensen 2001). Results of recent genetics research supports lack of homing by the Pacific lamprey. In a study of Pacific lamprey population structure, Goodman (2006) found little genetic differences among individuals sampled at widely dispersed sites across their range, indicating substantial genetic exchange among populations from different streams.

## 2.2 Eel River Life History Information

The following sections describe what is known about Pacific lamprey life history in the Eel River basin. Sources of information include published literature and reports, as well as interviews with Wiyot Tribal members and biologists working in the Eel River Basin. Table 1 and Appendix B list the individuals who were interviewed or otherwise contacted.

### 2.2.1 Spawning

Available information suggests that Pacific lampreys spawn throughout the Eel River basin and that spawning time in the basin is comparable to that documented in other river systems (e.g., Brumo et al. 2009, Gunckel et al. 2009). Perhaps the most systematic, large-scale assessment of lamprey spawning in the basin comes, not from spawning or redd surveys, but from studies using drift nets designed to capture newly hatched larval fishes. White and Harvey (2003) sampled drift of larval fishes and lampreys biweekly or monthly in the Van Duzen River basin from February through October 1997 at seven sites, five in the mainstem and two in Yager and Grizzly creeks, major tributaries to the Van Duzen. Harvey et al. (2002) sampled drifting larval fish at the mouths of 15 tributaries to the lower Eel, Van Duzen, and South Fork Eel rivers in late spring and summer of 1996 and 1997. They also sampled at mainstem sites, just upstream of each sampled tributary's confluence. Both of these studies documented the presence of small (<15 mm), newly-hatched ammocoetes at nearly every site sampled (B. Harvey, U.S. Forest Service, pers. comm.), indicating that spawning occurred upstream and was widespread in the South Fork Eel and Van Duzen rivers. Based on when newly-hatched ammocoetes were captured, most lamprey spawning occurred in the spring. Importantly, in these studies—and most studies and that document the ammocoete life stage of lampreys—ammocoetes were not identified to species and therefore do not definitively indicate the presence of Pacific lamprey spawning. Some of the ammocoetes captured could have been western brook lampreys (*Lampetra richardsoni*) or river lampreys (*Lampetra ayresi*), which are also present in the Eel River Basin.

Nearly all other information obtained on Pacific lamprey spawning in the Eel River basin was obtained from interviews with biologists who have spent a significant amount of time working in the basin and have observed spawning adults or their redds. Most this information is anecdotal or incidental to surveys designed to target other fish species such as steelhead.

In the mid-1980s, Bill Trush took detailed notes while observing spawning Pacific lampreys in an approximately 1,000-m reach of the upper South Fork Eel River near the Elder Creek confluence. He observed several hundred lamprey redds in that reach, characterized primarily as run, or flatwater habitat. He also observed numerous Pacific lampreys spawning in Elder Creek, a sizeable tributary. He noted that spawning generally commenced near the end of the steelhead spawning season, beginning in March, and that lamprey were still spawning in April (B. Trush, McBain & Trush, pers. comm.). Scott Harris (California Department of Fish and Game [CDFG], pers. comm.) has observed Pacific lamprey spawning from April through mid-July in the South Fork Eel River basin, and noted that spawning typically peaked slightly later in the mainstem (May or June) than in the tributaries (April or May). This timing is consistent with other observations of Pacific lamprey spawning (primarily in April and May) in Redwood, Salmon, and Bull creeks, all of which are tributaries to the South Fork Eel (S. Downie, CDFG, pers. comm.).

Spawning Pacific lampreys have been commonly observed in May and June in the upper mainstem Eel, between the Tomki Creek confluence and Cape Horn Dam (P. Steiner, Steiner Environmental Consulting, pers. comm.). Adult lampreys have also been captured moving upstream between mid-March and early June upstream of Outlet Creek and in Tomki Creek

(Ebert 2008). A pulse of lampreys moving upstream, presumably spawners, is typically observed at the Van Arsdale Fish ladder at Cape Horn Dam in early May, but no systematic records of abundance or timing have been kept (A. Grass, CDFG, pers. comm.). During more extensive monitoring from 1992 to 1995, low numbers of adult lampreys were captured in mid-March through April at Cape Horn Dam, with higher numbers arriving in late May through early July (Ebert 2008). The presence of numerous dying lampreys and carcasses below Cape Horn Dam in the summer of some years also suggests spring and early summer spawning (A. Grass, CDFG, pers. comm.). Snorkel surveys for summer steelhead in the North Fork Eel River documented lamprey carcasses and redds on May 8, 2002, indicating that spawning likely occurred in late April or early May (Scriven 2002).

There has been no effort to measure Pacific lamprey spawning habitat availability or quality in the basin. Preliminary observations indicate that suitable spawning substrate is abundant in much of the South Fork Eel and Van Duzen rivers (A. Brumo, pers. obs.). For this reason and due to their high fecundity, we hypothesize that spawning habitat does not typically limit Pacific lamprey populations in these areas; however, systematic surveys of spawning habitat availability and lamprey use would allow for better quantitative analysis of potential limiting factors in the basin to test this hypothesis.

### 2.2.2 Ammocoetes

Aside from numerous and widespread records of ammocoetes being captured during electrofishing surveys (see Section 3), little information is available regarding the ammocoete phase in the Eel River basin. Drift net samples indicate that both newly-hatched and older ammocoetes move downstream at night, with the former drifting primarily during the summer, and the latter moving almost exclusively during high winter and spring flows (Harvey et al. 2002, White and Harvey 2003). This finding is largely consistent with findings from the Coquille River in southwest Oregon (Brumo 2006).

No data is available regarding the length of time ammocoetes spend rearing in fresh water in the Eel River basin prior to metamorphosis and outmigration to the ocean. Time spent in fresh water likely varies among tributaries and is probably influenced by conditions that affect the growth rates of each cohort (Moore and Mallatt 1980, Morket et al. 1998). Understanding patterns in ammocoete growth and age at metamorphosis and outmigration are critical for understanding the ecology and population dynamics of the species, and ultimately, determining the factors limiting lamprey production throughout the basin. Aging of ammocoetes by identifying breaks in length frequency is nearly impossible, especially in older size classes, due to overlap in size and variation in growth rates of each cohort (A. Brumo, pers. obs., Beamish and Medland 1988). Aging of ammocoetes using statoliths, a hard tissue found in lampreys that is analogous to an otolith, has been attempted with some success, but is a tedious process and prone to error (Beamish and Medland 1988).

Quantity and quality of ammocoete rearing habitat in the Eel River and tributaries is for the most part undocumented. On an approximately six-mile reach of the South Fork Eel River between Benbow State Park and Garberville, rearing habitat appears to be restricted to small, isolated pockets on the river margins, typically in eddies formed by boulders or wood (A. Brumo, pers. obs.). A few more extensive rearing areas were observed in side-channels and alcoves, but these features were relatively rare in this reach. Quantifying ammocoete rearing habitat availability and rearing densities in the basin is a key step in understanding Pacific lamprey habitat limitations and population dynamics.

### 2.2.3 Macropthalmia

Very little recent information is available regarding abundance or outmigration timing of macropthalmia in the Eel River basin. In most river basins, data on Pacific lamprey outmigration is derived from downstream migrant traps targeting salmon or steelhead smolts. In recent years, outmigrant trapping for steelhead has been conducted in the South Fork Eel basin during April and May on Redwood and Sproul creeks to monitor steelhead smolt. Macropthalmia were captured periodically during these months, sometimes in large pulses (S. Downie, CDFG, pers. comm.). More information on these data may be available from the Eel River Salmon Restoration Project (S. Downie, CDFG, pers. comm.). It is important to note that these traps were only operated for a short window of time during the spring salmon and steelhead outmigration and can have very low capture efficiencies for lampreys; thus, they do not adequately describe annual patterns in lamprey outmigration timing or abundance. To effectively determine macropthalmia outmigration timing it would be necessary to sample during the full lamprey outmigration period.

During year-round trapping in the Upper Eel River (upstream of Outlook Creek), macrophalmia were captured in low numbers in all months (Ebert 2008). Downstream movement was concentrated in late winter and spring, with a pulse of movement typically occurring between mid-December and early February, and a second pulse occurring in mid-February to late May. Pulses of movement were almost always coincident with large increases in flow (Ebert 2008).

Besides data from outmigrant trapping, eyed individuals that were likely still undergoing metamorphosis prior to outmigration have been captured during electrofishing surveys in the summer and fall in various Eel River tributaries (S. Harris, CDFG, pers. comm.; Figures 3 through 9)

More research on the timing of lamprey outmigration throughout the basin, and how it relates to factors such as river flow and water quality, could help in evaluating and possibly quantifying mortality of downstream migrants caused by such factors as predation by non-native Sacramento pikeminnow.

### 2.2.4 Adult ocean stage

No information was located concerning use of marine habitats by Pacific lampreys originating in the Eel River basin. Much remains unknown about this part of the Pacific lamprey life cycle, such as where outmigrants go upon entering the ocean, how long they remain in the marine environment before returning to spawn, and factors affecting their survival. The proportion of lampreys from the Eel River basin that return to spawn there versus other basins is also unknown.

### 2.2.5 Adult migration and holding

Interviews with Wiyot Tribal members and eelers indicate that, based on harvest conducted at the mouth of the Eel River, adult Pacific lampreys typically enter the lower river from the ocean between January and at least into June. Historically eelers continued to capture lampreys further upstream in the mainstem Eel and South Fork Eel rivers later in the summer as the run season progressed (e.g., July at Benbow Dam on the South Fork Eel), indicating that upstream movement likely continues through the summer. It appears that most individuals continue migrating upstream into various tributaries or the upper mainstem until they reach suitable holding habitat, where they likely become dormant until just before spawning the following spring.

Various biologists working in the basin have captured sexually immature lampreys (in good condition and without secondary sexual characteristics) during summer and fall salmonid electrofishing surveys in the upper mainstem Eel River (P. Steiner, Steiner Environmental Consulting, pers. comm.), its tributaries (S. Harris, CDFG, pers. comm.), and tributaries to the South Fork Eel River (S. Harris, CDFG, pers. comm.; S. Downie, CDFG, pers. comm.; B. Trush, McBain & Trush, pers. comm.). In addition, numerous sexually immature adults are observed annually in late September to mid-October during dewatering of the ladder at Van Arsdale Fish counting station. All of these individuals appear to be holding, which suggests that the initial upstream adult migration ceases sometime in the late summer or fall. Holding adults have also been found in several very small streams, such as Fox and Rock creeks in the South Fork Eel subbasin and Ryan Creek, a tributary to Outlet Creek, suggesting that holding individuals utilize a variety of streams sizes. Refer to Section 3 below for additional locations where adults have been documented holding in each subbasin.

Observations of a pulse of adults passing the Van Arsdale Fish Counting station in May (A. Grass, CDFG, pers. comm.) suggest that some individuals undergo a secondary migration from fall and winter holding areas to spawning areas in the spring. This is consistent with findings from other basins (e.g., Bayer et al. 2001, Fox and Graham 2008).

Other noteworthy information related to Pacific lamprey migration obtained from Wiyot Tribal interviews includes the following:

- Alan Miller mentioned capturing primarily females while eeling in the lower mainstem Eel River and suggested that there is a difference in run timing between the sexes. He also indicated that lamprey tend to run in schools or migrate in pulses.
- Alan Miller suggested that adult migration is sensitive to water temperature, particularly the difference between river and ocean temperatures.
- Eeling within the Eel River historically occurred almost exclusively at night, which suggests that most upstream migration liked occurs at night (Appendix B, Wiyot Tribal Interviews).

## 2.3 Other Lamprey Species

As noted above, the western brook lamprey, a smaller, non-migratory, and non-parasitic species, has also been documented in the Eel River basin. Little is known about their distribution or abundance because very few biologists look for them, they are small (approximately 150–180 mm as adults), they rarely come out of their burrows except during a brief adult phase, and they are nearly indistinguishable from Pacific lampreys during the ammocoete phase. The only definitive accounts of western brook lamprey identified during this review came from Scott Harris (CDFG, pers. comm.), who has captured adults in Broaddus, Mill, Baechtal, and Davis creeks, which are tributaries to Outlet Creek in the upper mainstem Eel River drainage. He also noted variation in dorsal pigmentation of ammocoetes found in the Eel River basin, suggesting that more than one species is present (Goodman et al. 2009). In other river systems where both species occur, western brook lampreys typically spawn and rear in smaller tributaries than Pacific lampreys, but their freshwater distribution does overlap considerably (Brumo et al. 2009, Luzier et al. 2006, Gunckel et al. 2009).

River lamprey, an intermediate-sized, parasitic species, also occurs in the Eel River basin, but appears to be very rare. To our knowledge, only one adult has been documented in the basin, at Cape Horn Dam (Moyle et al. 2009).

Because most biologists do not have the training to identify lamprey ammocoetes to species, all records of lamprey ammocoetes should be interpreted with caution, assuming they could be any of the three species. Refer to Goodman et al. (2009) for more information on the distinguishing characteristics of the ammocoete phase of the three species.

# 3 DISTRIBUTION

Information on Pacific lamprey distribution was derived from a wide variety of sources including peer-reviewed literature and reports, Tribal interviews (Appendix B), CDFG databases, phone or email interviews with knowledgeable biologists or other stakeholders in the basin (Table 1), and museum records (Table 2).

**Table 1.** Individuals contacted to request information on Pacific lamprey in the Eel River basin.

| Name of contact | Organization | Position | Contact reached? | Notes |
|---|---|---|---|---|
| Alan Grass | California Department of Fish and Game | Biologist | yes | Now retired, but used to run the Van Arsdale Fisheries Station and ladder at Cape Horn Dam. |
| Andrew Kinziger | Humboldt State University | Fisheries Professor and Fish Collection curator | yes | Provided information on HSU Fish Collection |
| Bill Trush | McBain & Trush / Humboldt State University | Aquatic Ecologist / Adjunct Fisheries Professor | yes | In the mid-1980s he did research on steelhead in the South Fork Eel River and tributaries near Angelo Coast Range Reserve. Made extensive observations of spawning lampreys and redds. |
| Brett Harvey | Humboldt State University / U.S. Forest Service Redwood Sciences Lab | Fisheries Professor | yes | Has done extensive research in the Eel River basin including projects on pike minnow diet and larval fish distribution. |
| Damon Goodman | U.S. Fish and Wildlife Service | Fisheries Biologist and lamprey specialist. | yes | Did master's thesis on lamprey genetics and systematics and has extensive knowledge of various lamprey species. |
| Demian Ebert | PBS&J consulting | Fish and Wildlife Biologist | yes | Gave presentation on timing of adult and juvenile Pacific lamprey movements in the upper Eel River. Has additional data and reports. |
| Ernie Branscombe | local landowner near Garberville | n/a | yes | Grew up near, and spent a lot of time on, the South Fork Eel River. Runs website devoted to the history of the Eel River and provided some of his observations on lampreys. http://ernielb.blogspot.com/ |
| Nadananda | Friends of the Eel River | Executive Director | yes | |
| Larry Brown | U.S. Geological Survey | Research Biologist | yes | Has done extensive research on fish distribution in California. |
| Park Steiner | Steiner Environmental Consulting | Fisheries Biologist | yes | Has done extensive fisheries work in the Upper Eel River basin as part of the Potter Valley Project relicensing. Provided numerous observations of lampreys. |
| Scott Downie | California Department of Fish and Game | Senior Fisheries Biologist | yes | Grew up near South Fork Eel River and has considerable knowledge of streams and fish in the Eel River basin, including lampreys. |
| Scott Harris | California Department of Fish and Game | Fisheries Biologist | yes | Has done numerous fish surveys throughout the Eel Basin and provided several lamprey observations and records from a CDFG database. |
| Stephanie Britton | Round Valley Indian Tribes | Natural Resources Department Manager | yes | Had no knowledge of tribal use of lampreys in the Middle Fork Eel River. Recommended we contact Warren Mitchell. |
| Wendy Palen | Simon Fraser University | Biology professor | yes | Has done research on the impact of sediment on salmon and ammocoetes in the Angelo Coast Range Reserve. Collaborated with Michael Limm. |
| Michael Limm | UC Berkeley | Doctoral student in Mary Power Lab | no | Did research in the South Fork Eel River near the Angelo Coast Range Reserve, including study examining interactions between ammocoetes and freshwater mussels. |
| Warren Mitchell | Round Valley Indian Tribes | Fisheries Biologist | no | |

**Table 2.** Databases searched for Pacific lamprey records in the Eel River basin.

| Museum or online database searched | Records of Pacific lamprey in the Eel River basin | Relevant notes |
|---|---|---|
| California Academy of Sciences | 5 | |
| Smithsonian Museum of Natural History | 6 | Records referred to EPA EMAP surveys. |
| Humboldt State University Fish Collection | 1 | |
| FishNet | 6 | Records were the same as the Smithsonian records. |
| UC Davis Museum of Wildlife and Fish Biology | 1 | |
| The Museum of Vertebrate Zoology at UC Berkeley | 0 | |

## 3.1 Interpretation of Distribution Maps

For the purpose of displaying distribution data, the Eel River basin was divided into the following subbasins: Lower Eel River and Estuary, Van Duzen River, South Fork Eel River, Middle Main Eel River, North Fork Eel River, Middle Fork Eel River, and Upper Mainstem Eel River (Figure 1). Figures 3 through 9 show records of lamprey capture or observation by life stage for each subbasin. Importantly, these maps show only documented lamprey records obtained during this review and do not necessarily represent actual distribution, which is likely much more widespread. Moreover, the presence of the ammocoete life stage does not definitively indicate Pacific lamprey presence. As discussed above, these records could be other lamprey species. In addition to showing records of ammocoetes, macropthalmia, spawning adults, redds, and carcasses, the maps also indicate (with the letter "D") ammocoetes captured during studies of larval fish drift (Harvey et al. 2002, White and Harvey 2003). Since drift nets were typically placed at both tributary mouths and just upstream in the mainstem, in some cases these records appear on the maps as closely-spaced pairs in the main channel, but one point in each pair indicates ammocoete presence in the nearest tributary. Since age-0 ammocoetes and even older individuals are poor swimmers, and do not likely move upstream considerable distances, their presence indicates that spawning occurred upstream. Finally, Appendix A lists all tributaries to the Eel River in which each life stage of lamprey has been documented and should be used in conjunction with Figure 3 through 9 to help identify names of tributaries where lampreys have been documented.

## 3.2 Lower Eel River and Estuary

For this review, the Lower Eel River and Estuary subbasin includes the mainstem Eel River and tributaries from the mouth upstream to the confluence with the South Fork (Figures 1 and 3). Key sources of lamprey records in the Lower Eel River and Estuary include the Coastal Watershed Planning and Assessment Program - Lower Eel River Basin Assessment (CDFG 2010), Harvey et al. (2002), Alan Miller (Wiyot Tribe, pers. comm.), and collection records from the Smithsonian Museum of Natural History. Locations of adult collections by tribal eelers are not included on the map as it is known that adult lampreys utilize the entire lower mainstem Eel River as a migratory corridor.

Although there have been no systematic assessments of lamprey distribution in the subbasin, this review indicates that lamprey ammocoetes are likely relatively widespread in tributaries across the subbasin (Figure 3). Recent CDFG surveys indicated presence of ammocoetes in Palmer, Rohner, Strongs, Price, Oil, Howe, Atwell, and Larabee creeks (CDFG 2010, Appendix A). In addition, Alan Miller (Wiyot Tribe, pers. comm.) reported the presence of large numbers of ammocoetes of various sizes in the “mud banks” just downstream of Fernbridge. The role of these relatively large areas of ammocoete rearing habitat in the mainstem Lower Eel warrants further investigation. While available data indicates a widespread distribution in this subbasin, there are numerous small tributaries in which lamprey presence is unknown and there is very little understanding of how lampreys use the estuary and sloughs during each life stage. Electrofishing surveys that include ammocoete species identification could be used to better describe distribution and relative abundance within various tributaries, the lower mainstem Eel River and the estuary. Additional ammocoete distribution records for this subbasin are likely available in CDFG Stream Inventory Reports, or on data sheets filed at the CDFG office in Fortuna (S. Downie, CDFG, pers. comm.).

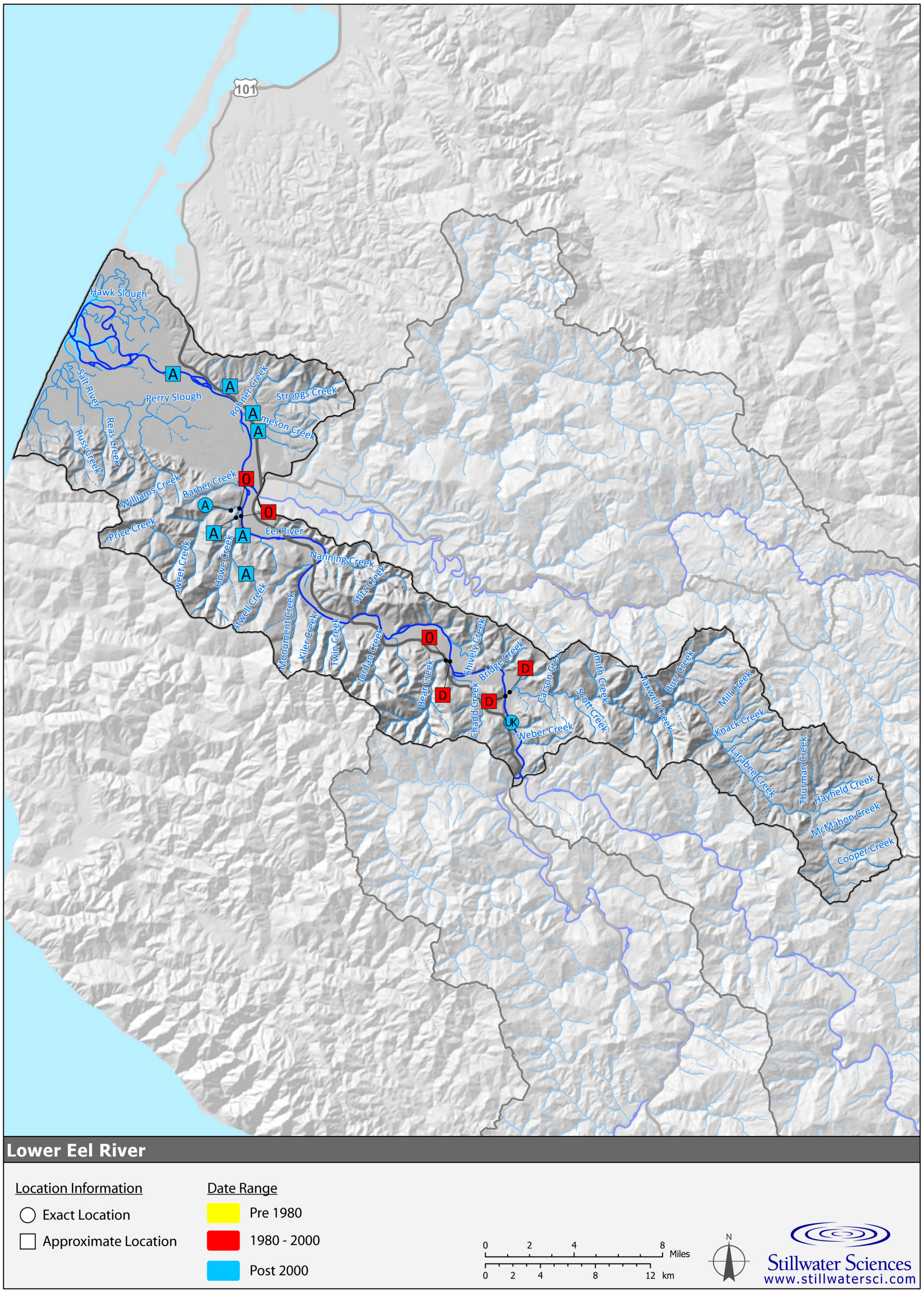


**Figure 3.** Records of Pacific lamprey in the Lower Eel River subbasin and estuary. A = ammocoete, D = ammocoetes captured in drift net samples; O = drift net samples in which no ammocoetes were captured; UK = unknown life stage. (Ammocoete records are not definitively Pacific lampreys and could be other lamprey species.)

## 3.3 Van Duzen River

Key sources of lamprey records for the Van Duzen River subbasin include Harvey et al. (2002), White and Harvey (2003), CDFG (2010), and the Smithsonian Museum Collection. No systematic assessments of lamprey distribution have been done for the subbasin and documented records are relatively sparse (Figure 4). In addition to being documented in several sites on the mainstem Van Duzen River, ammocoetes have been found in Wolverton Gulch, Yager Creek, and Grizzly Creek (Figure 4, Appendix A). Ammocoetes have been documented in the mainstem Van Duzen River as far upstream as Mill Creek, near Dinsmore (Figure 4). It is possible that additional ammocoete distribution records for the Van Duzen River are available in CDFG Stream Inventory Reports or on data sheets filed at the CDFG office in Fortuna (S. Downie, CDFG, pers. comm.).

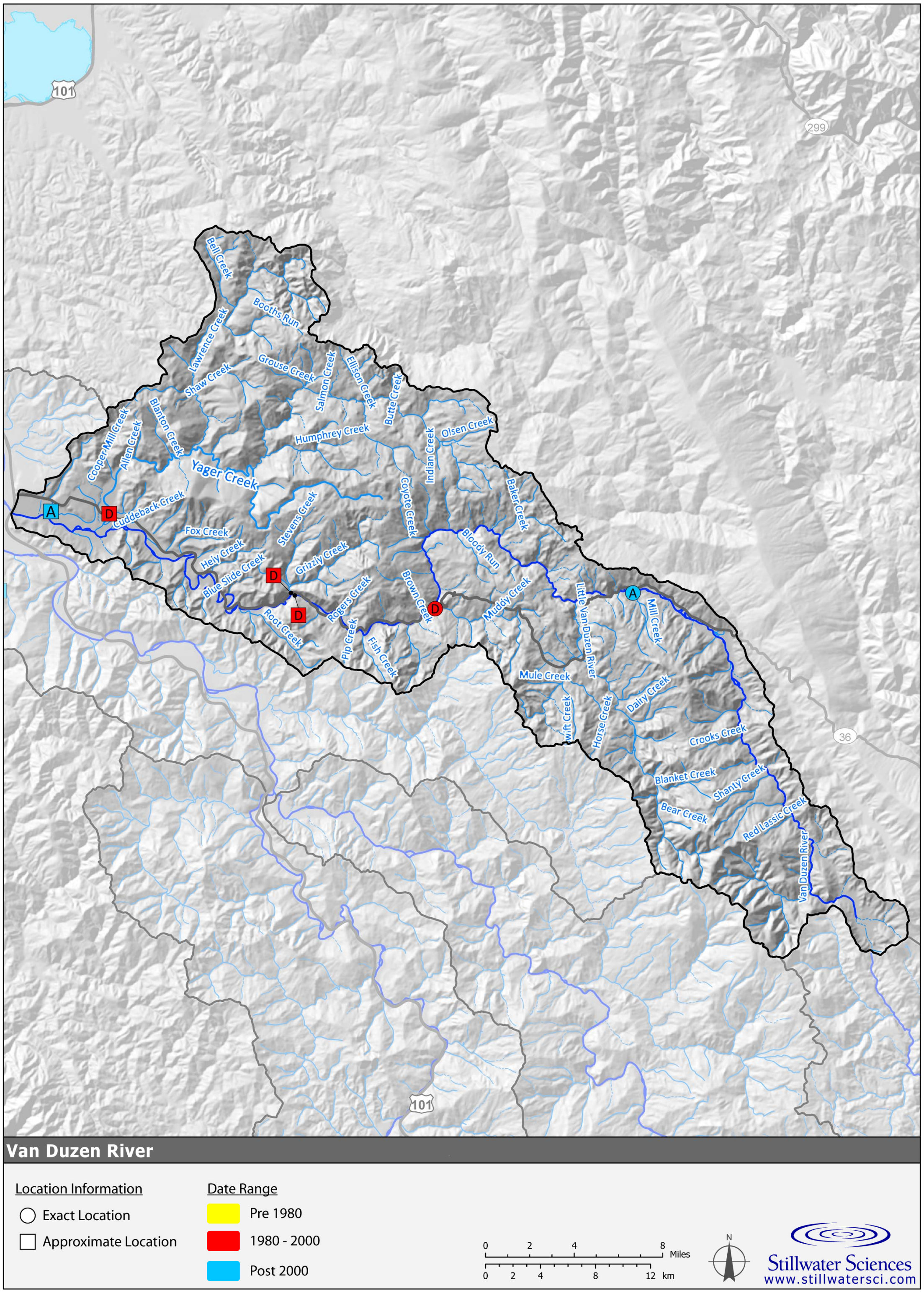


**Figure 4.** Records of Pacific lamprey in the Van Duzen River subbasin. A = ammocoete; D = ammocoetes captured in drift net samples. (Ammocoete records are not definitively Pacific lampreys and could be other lamprey species.)

## 3.4 South Fork Eel River

Key sources of lamprey records for the South Fork Eel River subbasin include Harvey et al. (2002), White and Harvey (2003), Scott Downie (CDFG, pers. comm.), Scott Harris (CDFG, pers. comm.), Bill Trush (McBain & Trush, pers. comm.), the Smithsonian Museum Collection, and an electrofishing survey database maintained by the CDFG office in Willits, CA. It is possible that additional lamprey distribution records are available in CDFG Stream Inventory Reports. While, no systematic assessments of lamprey distribution have been done for the South Fork Eel River or its tributaries, distribution records are relatively numerous and widespread (Figure 5), which is likely due to the comparative accessibility of the subbasin. In addition to numerous records of ammocoetes, adult and/or macropothalmia life stages have recently been located in several tributaries, indicating the unambiguous presence of Pacific lamprey (Figure 5, Appendix A). These tributaries include Bull Creek, Salmon Creek, Redwood Creek, West Fork Sproul Creek, Hollow Tree Creek, Bond Creek, Rattlesnake Creek, Elder Creek, Fox Creek, and Rock Creek. Several of these tributaries, such as Fox and Rock creeks, are quite small, which suggests that Pacific lamprey utilize small streams as well as larger streams in the basin. Furthermore, Pacific lamprey distribution extends into the upper reaches of the subbasin, as evidenced by the presence of macropthalmia in upper reaches of Hollow Tree Creek (Figure 5).

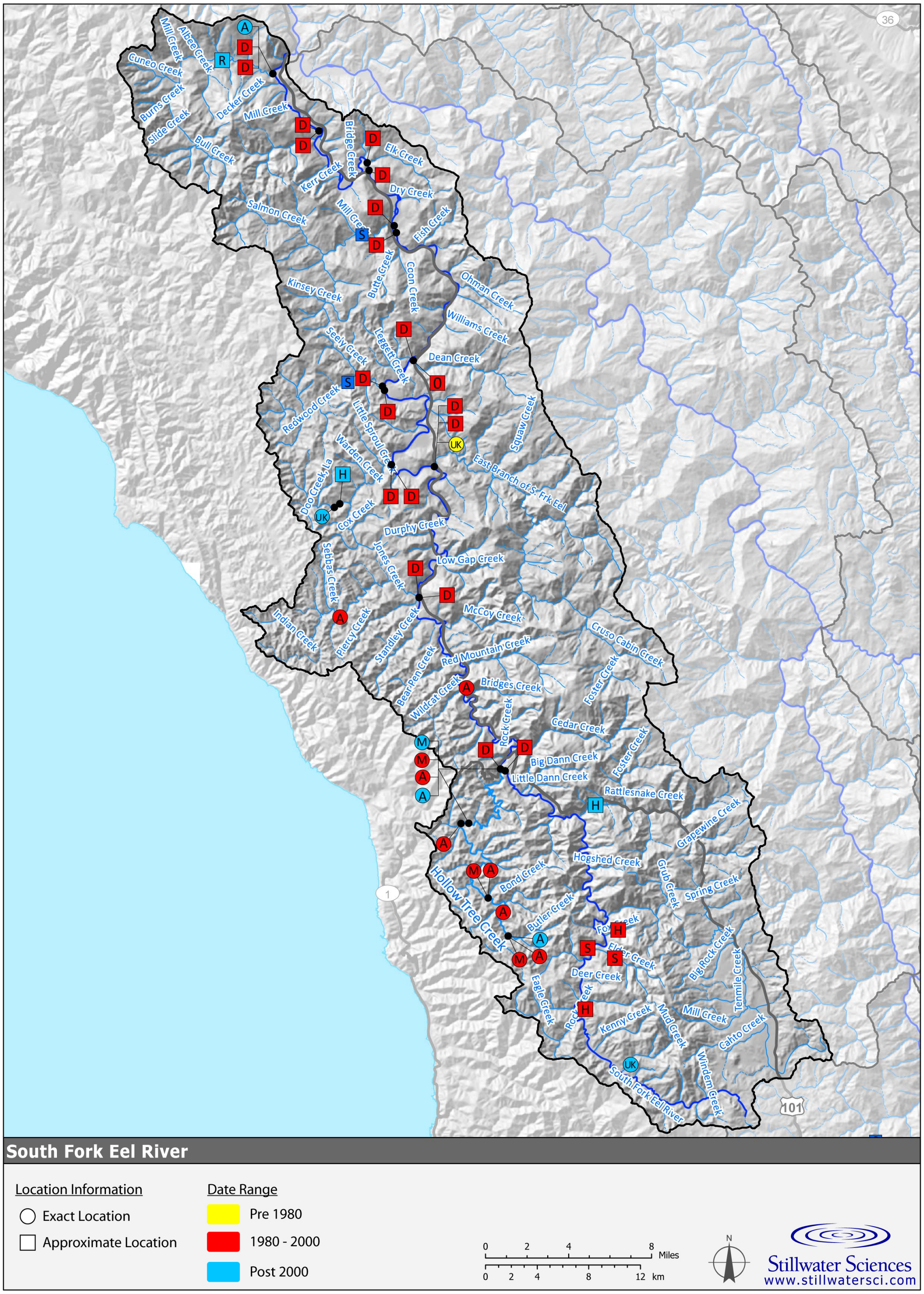


**Figure 5.** Records of Pacific lamprey in the South Fork Eel River subbasin. A = ammocoete; D = ammocoetes captured in drift net samples; H = Adult Holding; S = spawning adults; UK = unknown lifestage. (Ammocoete records are not definitively Pacific lampreys and could be other lamprey species.)

## 3.5 Middle Main Eel River

For this review, the Middle Main Eel River subbasin encompasses the mainstem Eel River and its tributaries from the confluence with the South Fork Eel River upstream to the Middle Fork Eel River confluence, not including the North Fork Eel River watershed (Figures 1 and 6). Very little information on Pacific lamprey was available for this subbasin: only one distribution record—a collection of ammocoetes near the South Fork Eel confluence—was obtained during this review (Figure 6). The lack of data is most likely due to the rugged and inaccessible nature of the subbasin. The documented presence of various life stages of Pacific lamprey in upstream reaches and tributaries indicates that, at a minimum, adults utilize the mainstem Eel as a migratory corridor. However, it is likely that spawning and rearing occurs in the mainstem and larger tributaries of the subbasin. Ammocoete distribution surveys in the subbasin could be used to fill this conspicuous gap in distribution data. It is also possible that additional lamprey distribution records for this subbasin are available in CDFG Stream Inventory Reports or on data sheets filed at the CDFG office in Fortuna (S. Downie, CDFG, pers. comm.).

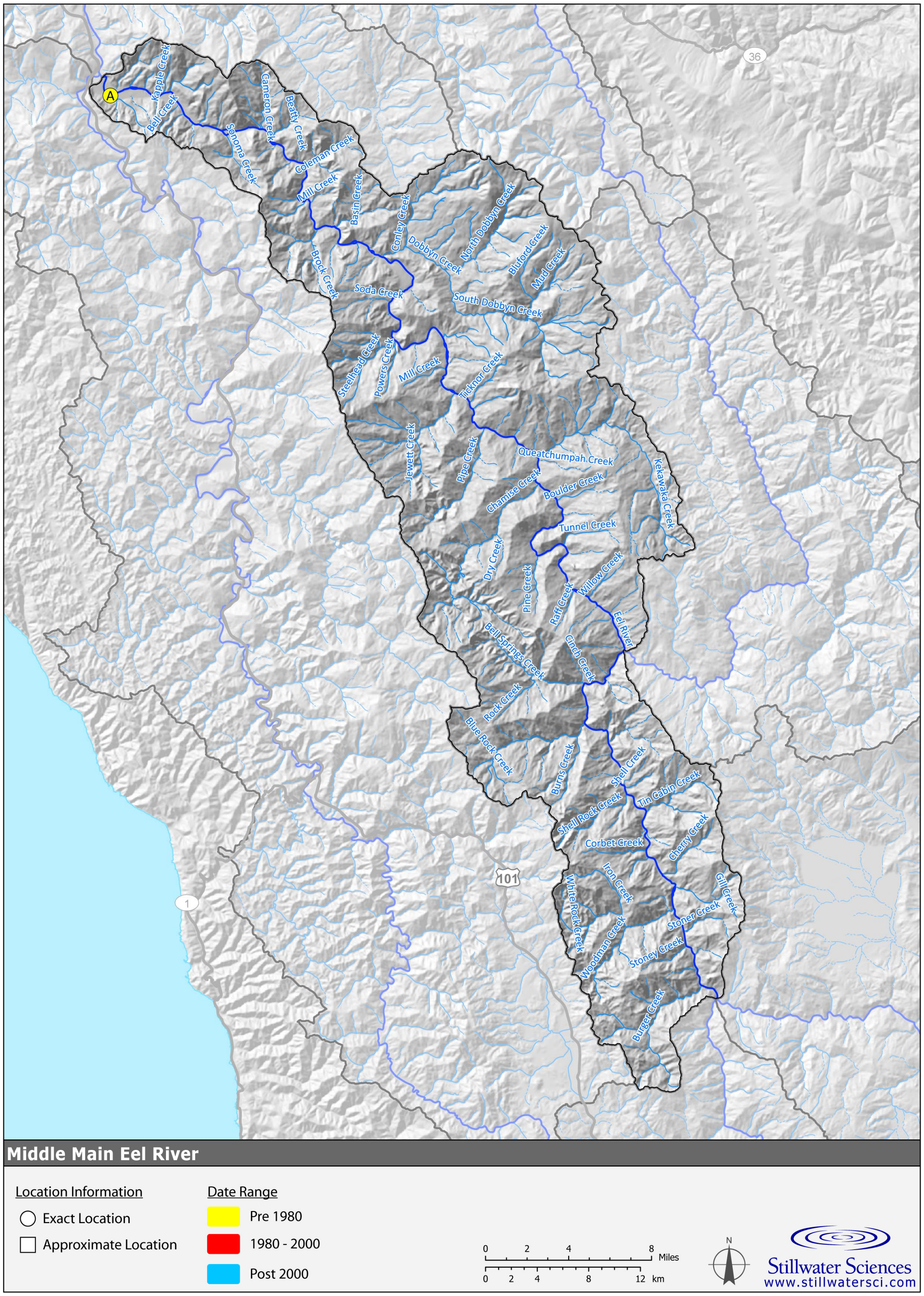


**Figure 6.** Records of Pacific lamprey in the Middle Main Eel River subbasin. A = ammocoete. (Ammocoete records are not definitively Pacific lampreys and could be other lamprey species.)

### 3.6 North Fork Eel River

Very little information on Pacific lamprey distribution was readily available for the North Fork Eel River subbasin (Figure 7). The only distribution records come from observations of redds and carcasses made during summer steelhead snorkel surveys (Scriven 2002). It is possible that additional observations of lampreys have been reported in other summer steelhead snorkel survey reports for the North Fork Eel River. Additional potential sources of lamprey distribution records include CDFG Stream Inventory Reports, notes on data sheets filed at the CDFG office in Fortuna, or U.S. Forest Service offices in the subbasin.

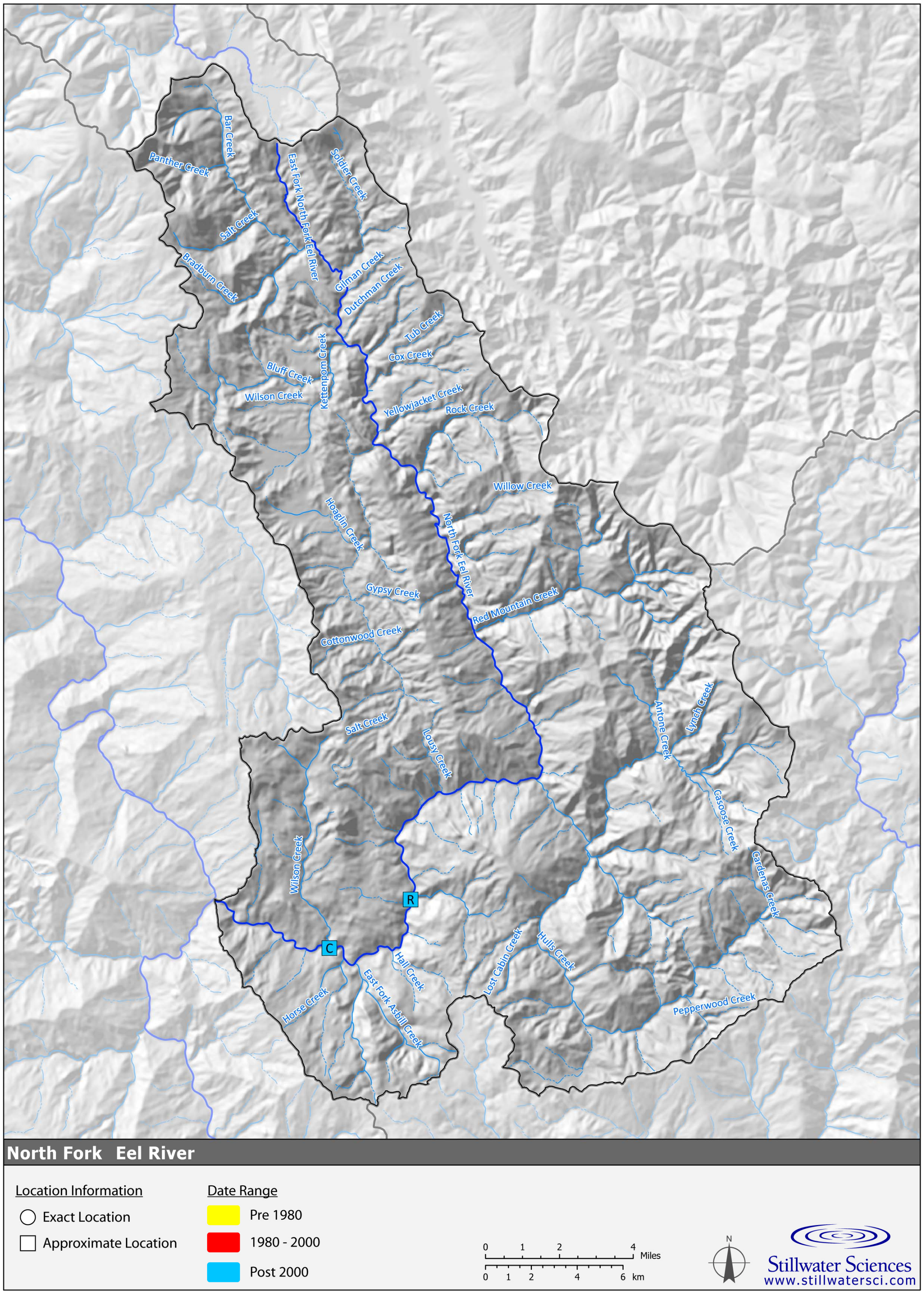


**Figure 7.** Records of Pacific lamprey in the North Fork Eel River subbasin. C = carcasses; R = redd.

## 3.7 Middle Fork Eel River

Very little information on Pacific lamprey distribution was available for the Middle Fork Eel River subbasin (Figure 8). Ammocoetes were captured near the confluence with the mainstem Eel River during CDFG electrofishing surveys in the 1980s and 1990s. In addition, Scott Harris reported seeing Pacific lamprey redds during summer steelhead dive surveys and noted that he has seen them as far upstream as the Yolla Bolly-Middle Eel Wilderness (CDFG, pers. comm.). Further discussions with Scott Harris and obtaining summer steelhead snorkel survey reports would help expand understanding of lamprey distribution in the subbasin. It is also possible that additional distribution records are available from CDFG Stream Inventory Reports, on data sheets filed at the CDFG office in Fortuna, or through U.S. Forest Service offices in the subbasin.

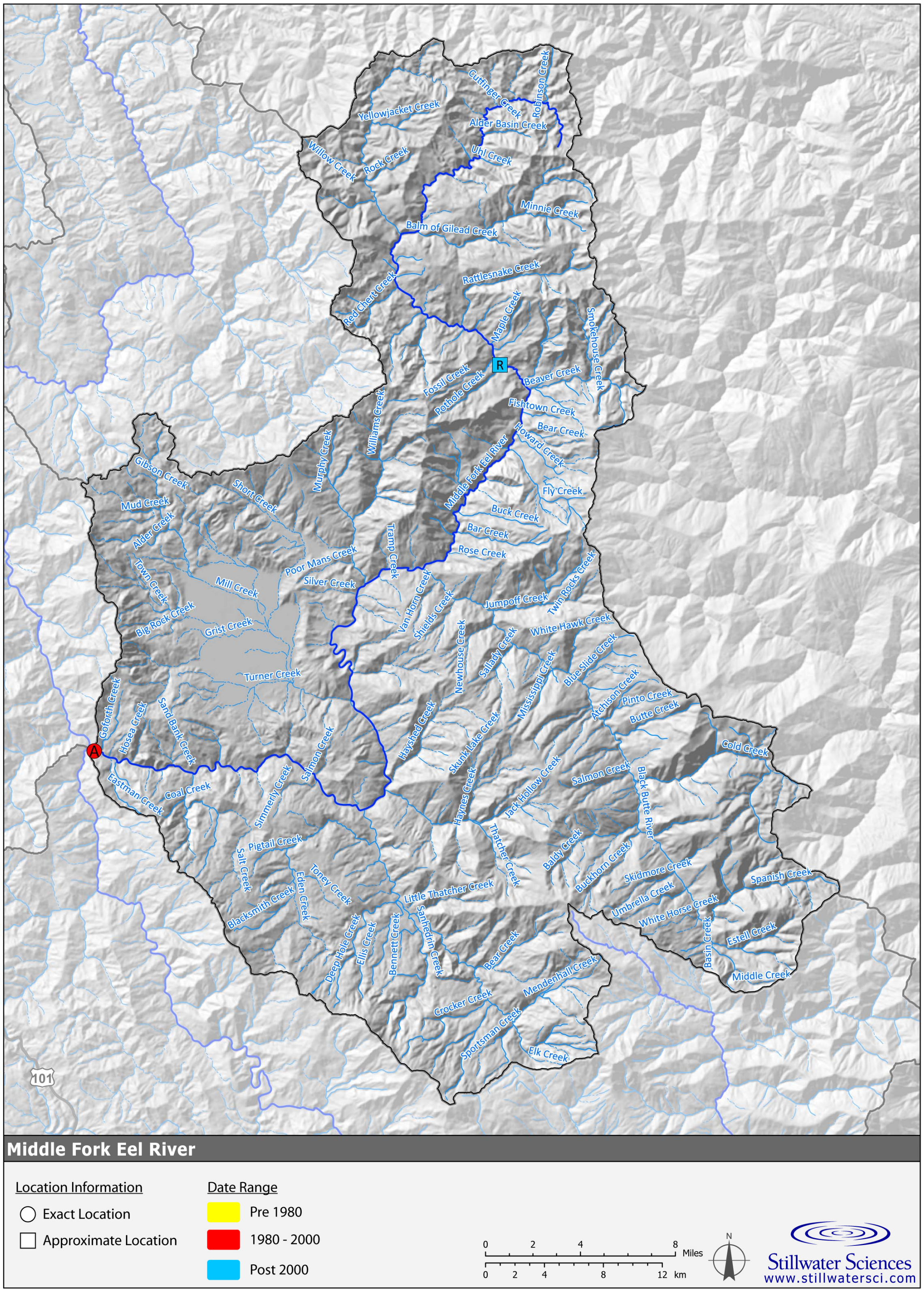


**Figure 8.** Records of Pacific lamprey in the Middle Fork Eel River subbasin. A = ammocoete, R = redd. (Ammocoete records are not definitively Pacific lampreys and could be other lamprey species.)

## 3.8 Upper Mainstem Eel River

The Upper Mainstem Eel River subbasin includes the mainstem Eel River and its tributaries upstream from the confluence with the Middle Fork Eel River. Key sources of lamprey records for the subbasin include Scott Harris (CDFG, pers. comm.), an electrofishing survey database maintained by the CDFG office in Willits, Alan Grass (CDFG, pers. comm.), Park Steiner (Steiner Environmental Consulting, pers. comm.), and the California Academy of Sciences museum collection database.

Available data suggests that Pacific lamprey distribution is relatively widespread in the Upper Mainstem Eel River subbasin (Figure 9). Distribution records were particularly concentrated in the Outlet Creek drainage near the town of Willits. In addition to the mainstem of Outlet Creek, definitive Pacific lamprey presence (non-ammocoete records) has been documented in Ryan, Willits, and Broaddus creeks. Ammocoetes, macropthalmia, holding adults, and carcasses have all been observed in the mainstem Eel River at Scott Dam (Figure 9; A. Grass, CDFG, pers. comm.). In addition, holding adults have been observed in the mainstem Eel near its confluence with the Middle Fork Eel and near Fish Creek (Figure 9; P. Steiner, Steiner Environmental Consulting, pers. comm.). Pacific lamprey redds have also been observed in Tomkai Creek during salmon spawning surveys (P. Steiner, Steiner Environmental Consulting, pers. comm.). Notably, ammocoetes and macropthalmia have been documented in Bucknell and Mill creeks, respectively, which are both upstream of Scott Dam. Since Cape Horn Dam is a barrier to migration, no migratory Pacific lampreys are found upstream. Additional potential sources of lamprey distribution records include CDFG Stream Inventory Reports, U.S. Forest Service offices in the subbasin, and fisheries reports associated with Potter Valley Project relicensing (P. Steiner, Steiner Environmental Consulting, pers. comm.).

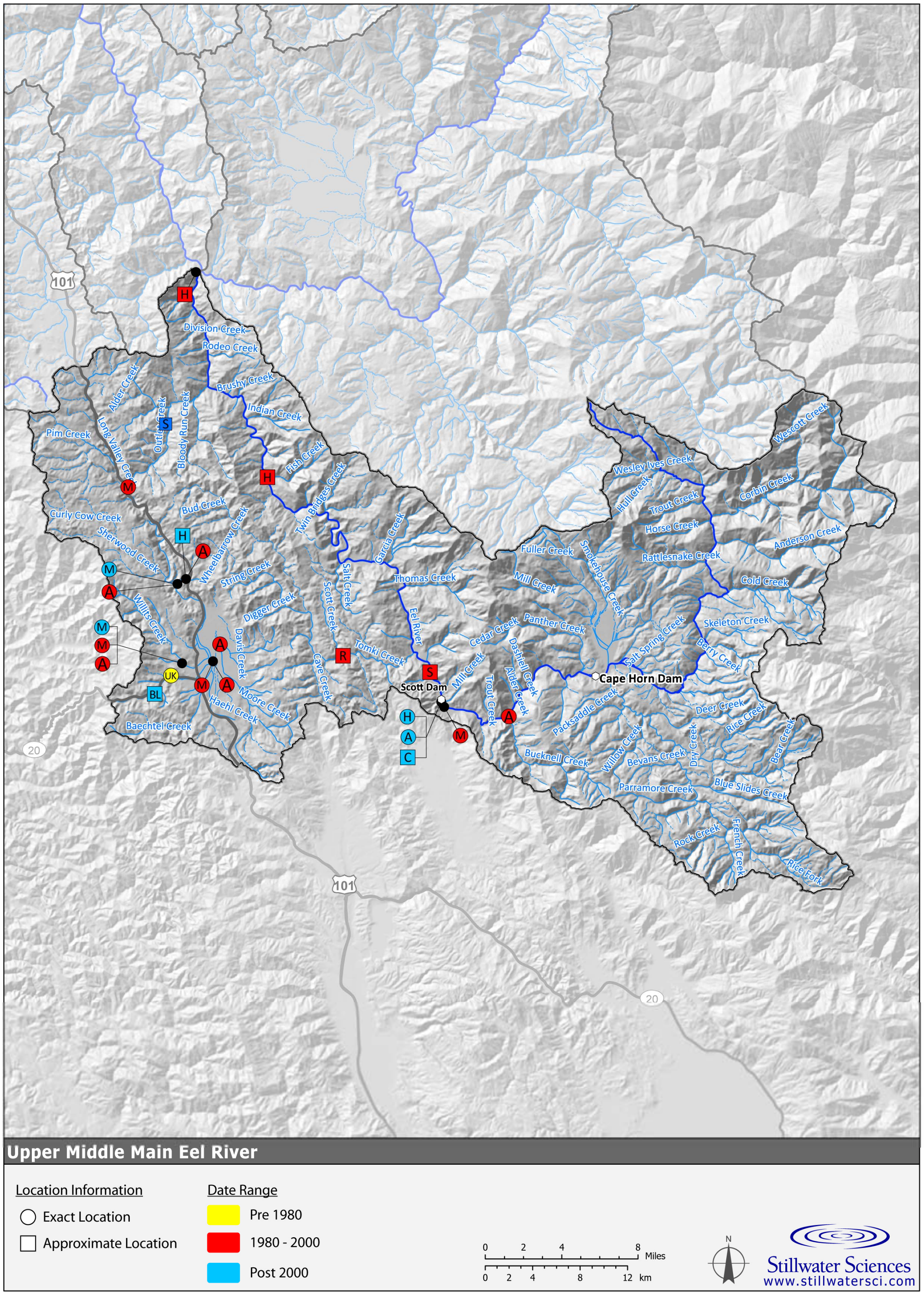


**Figure 9.** Records of Pacific lamprey in the Upper Mainstem Eel River subbasin. A = ammocoete; M = macropthalmia; H = Adult Holding; S = spawning adult; UK = unknown lifestage; BL = Brook lamprey. (Ammocoete records are not definitively Pacific lampreys and could be other lamprey species.)

# 4 ECOLOGY

In addition to being an important food source and cultural resource for Native Americans, the Pacific lamprey plays a key role in both freshwater and saltwater ecosystems (Close et al. 2002, Petersen Lewis 2009). For the same reasons adult Pacific lampreys are desirable as a food for humans, they are also sought out by many aquatic and terrestrial animals: they are not strong swimmers and thus relatively easy to catch and they have a very high caloric content—two to five times higher per unit weight than Chinook salmon. Adult lampreys are preyed on by numerous fish, birds, and aquatic mammals. In the Eel River basin seals, sea lions, ospreys, blue herons, river otters, and bald eagles have all been observed feeding on Pacific lampreys. In the mid 1980s Bill Trush commonly observed families of otters hunting lampreys on the South Fork Eel River. They were so abundant and easy to catch that the otters would bite off the head and the tail and leave the middle.

A study of seals and sea lions on the lower Rogue River indicated that Pacific lampreys can make up a high percentage (92%–96%) of their diet seasonally (Bowlby 1981, Roffe and Mate 1984). It has been theorized that, when abundant, both migrating adult lampreys and macropthalmia provide a buffer against predation for salmon: i.e., the predators preferentially select the easy to catch and fatty lampreys over salmon. The following quote from a 1951 California Fish and Game Journal is telling (Bonnot 1951):

> ....Many years ago two half-grown Steller sea lions were shot from the cannery dock in the estuary of the Klamath River "because they were killing salmon." It was evening and salmon were rolling and jumping in considerable numbers so the conclusion seemed justified. The next morning the two dead sea lions were found on the opposite shore, stranded by the tide. As a matter of interest they were cut open "to see how many salmon they had eaten." No salmon were found. Both were full of lampreys....

Like salmon (Wipfli et al.1998), migrating Pacific lampreys are a critical source of marine-derived nutrients that act to increase the productivity of otherwise nutrient poor stream ecosystems (Beamish 1980). Carcasses and eggs may be particularly important to river ecosystems, because they are available during spring, long after salmon carcasses are gone, and during the spring growth period for many aquatic species. Carcasses and eggs are eaten by resident fish species, aquatic invertebrates, and various scavengers such as vultures (Brumo 2006, Peterson Lewis 2009). In addition, snorkeling observations on the South Fork Coquille River revealed that vigorous movement of stones by Pacific lampreys during redd construction dislodged stream insects. Salmonid parr and larger cutthroat trout (*O. clarki clarki*) were commonly observed congregating and feeding immediately downstream of actively digging lampreys. On the upper mainstem Eel River, dying lampreys and their carcasses appear to be an important food source for the resident bald eagle population, which are observed feeding on them each summer (A. Grass, CDFG, pers. comm.). Investigation into the role of marine-derived nutrients supplied by anadromous lampreys is lacking, but vital for understanding the ecological consequences of their population decline.

Lamprey ammocoetes can make up a large portion of the benthic biomass in streams where they are abundant and play an important role in processing, storing, and cycling nutrients (Kan 1975). Interestingly, ammocoete habitat often overlaps with native freshwater mussel habitat (Betasso and Goodman 2008), and recent studies on the South Fork Eel River indicated that ammocoetes grew faster in the presence of mussels (Limm et al. n.d.; W. Palen, Simon Fraser University, pers. comm.). The ecological role of all life stages of the Pacific lamprey in the Eel River basin warrants further investigation.

# 5 ABUNDANCE AND STATUS

Very few data are available on historical or current Pacific lamprey abundance in the Eel River basin because the population has never been systematically monitored. However, there are widespread and consistent reports of a considerable decline in abundance of migrating and spawning adults and carcasses in the basin. Interviews with biologists, Wiyot Tribal eelers and elders, and other stakeholders living or working in the basin all indicate a decline in the Eel River Pacific lamprey beginning around the 1950s. Observations of migrating adults at Cape Horn Dam also point toward a significant decline since the late 1980s when hundreds of adults were commonly observed in the fish ladder and on the dam (A. Grass, CDFG, pers. comm.).

Responses from Wiyot Tribe member interviews and questionnaires consistently indicated a precipitous decline in Pacific lamprey populations based on their availability for harvest in the lower river (Appendix B). Several of the older respondents mentioned they were extremely plentiful before the major flood of 1955 and that they have continued to decline in recent years. Several respondents indicated that Tribal eelers used to capture “gunny sacks full” and now they are fortunate to get a couple in any given night (Appendix B).

Scott Downie, a CDFG biologist who grew up near the South Fork Eel River, echoed the tribal responses. Before the 1955 flood, he used to see lots of carcasses in the summer, but many fewer after the flood. Ernie Branscombe, a local landowner who also grew up on the South Fork Eel River near Garberville stated the following:

> “My father asked a person that used to catch Eels, if he would bring him some. As a joke, the man brought him a whole gunny sack full. Probably around ninety pounds, so they were abundant in the ’50s.”

One biologist, Scott Harris (CDFG, pers. comm.), said that he has not observed an obvious decline in ammocoete distribution or relative abundance as indicated by salmonid electrofising surveys throughout the South Fork Eel basin since the early 1990s, which suggests that the population in some areas could be relatively stable. However, it is unclear how ammocoete abundance and distribution today compares to years past. In mid-1980, Bill Trush (McBain & Trush, pers. comm.) observed seemingly high densities of Pacific lampreys and redds in the upper South Fork Eel and tributaries. We were unable to obtain more recent data, but it would be useful to compare his redd density data with present-day surveys.

Additional research into historical abundance and targeted monitoring of current populations is needed to better understand Pacific lamprey status in the Eel River basin.

## 5.1 Causes of Decline and Threats to the Population

The root causes of lamprey population decline are unknown, but are in all likelihood, multifaceted. Due to similarity in habitat requirements and life histories between the Pacific lamprey and anadromous salmonids, as well as some parallels in the timing of their population collapse (i.e., following the 1955 and 1964 floods), it is likely that many of the same factors led to their decline. Dams, diversions, grazing, urban development, mining, estuary modification, decline in prey abundance, and non-native species have all been postulated as factors limiting Pacific lamprey abundance across their range (Nawa 2003, Moyle et al. 2009). Little direct evidence of specific factors limiting abundance in the Eel River basin exists. However, likely factors including the Potter Valley Project dams and water withdrawals, migration obstructions affecting upstream passage to historical spawning areas, the effects of the large floods of 1955 and 1964, forest management and roads, and non-native species are discussed below.

The migration of anadromous species, including Pacific lampreys, to the headwaters of the mainstem Eel River has been blocked since the construction of Scott Dam in 1922. Over 100 miles (161 km) of stream reaches containing spawning habitat for anadromous salmonids, which have similar habitat requirements to lampreys, exists above Scott Dam (NMFS 2002). The Potter Valley Project dams and the transfer of large volumes of water from the Eel River to the Russian River are widely recognized to have adverse impacts on downstream fish populations, very likely including Pacific lamprey (NMFS 2002). Potential impacts from the dams and altered flow regimes on lampreys include delayed or altered adult and macropthalmia migration, decreased water quality, and increased suitability of habitat for predators such as Sacramento pikeminnow. In addition, the fish passage system and screening apparatus installed at Cape Horn Dam in 1995 were designed for salmonids, and could be impairing upstream passage of adults and the survival of outmigrating macropthalmia. Research into these and other potential impacts of the Potter Valley Project on lampreys is needed.

In addition to loss of historic spawning habitat above Scott Dam, numerous smaller barriers to lamprey migration, such as poorly designed culverts, exist. While many culverts have been retrofitted to aid in passage of salmon and steelhead, lamprey passage criteria, which are different than those of salmonids, are often ignored in these retrofits (CCC 2004). Numerous other culverts or road crossings acting as total or partial barriers to migrating lampreys likely exist. Identification of potential problem culverts, evaluation of their impact on lamprey passage, and quantification of suitable upstream habitat are critical for prioritizing culverts for removal for recovery of the species.

Destructive land use practices in the basin in the early 20$^{th}$ century (e.g., logging, mining, grazing) followed by the massive floods of 1955 and 1964 in a naturally erosive basin, very likely had a large and detrimental effect on lampreys and their habitat due to the extreme aggradation of the stream bed and destruction of riparian vegetation that occurred (NMFS 2002). Wiyot Tribal accounts and those of biologists and landowners who had experience in the basin prior to the floods, point to a major decline in the Pacific lamprey following the floods.

Non-native species, particularly the predatory Sacramento pikeminnow, have likely contributed to the decline of lampreys and will likely continue to hinder their recovery in the Eel River basin. Around 1979, pikeminnow were illegally introduced into Pilsbury Reservoir and within a decade had expanded throughout the mainstem Eel River and most major tributaries (Brown and Moyle 1997). The species is a voracious predator that consumes all lamprey life stages, including adults (Nakamoto and Harvey 2003). Remarkably, Nakamoto and Harvey (2003) documented a 470-mm pikeminnow that had consumed a 600-mm Pacific lamprey. In the same study, Pacific lamprey ammocoetes were found to be prominent prey item for both juvenile and larger pikeminnow, in some cases comprising the largest part of their diet. Smaller tributaries in which pikeminnow are not found have likely become important refuge habitats for lamprey ammocoetes and other native fishes eaten by pikeminnow (White and Harvey 2001). Other documented non-native species that could adversely impact lampreys green sunfish and largemouth bass in Willits Creek, a tributary to the upper mainstem Eel River.

# 6 ADDITIONAL DATA SOURCES

Due to the sheer size of the Eel River basin and the limited scope of this report, there are likely other sources of information on Pacific lamprey that were not discovered or included. These sources could help fill in gaps in our understanding of Pacific lamprey distribution and possibly status, which would be useful for designing future studies. Some potentially useful sources were identified during this review, but were unable to be obtained or thoroughly explored due to limited time or lack of response from key contacts (Table 3).

**Table 3.** Potential sources for additional information on Pacific lamprey in the Eel River basin.

| Data source | Organization | Key contacts | Notes |
|---|---|---|---|
| Electrofishing survey data sheets | CDFG—Fortuna office | Allan Renger | Records of ammocoete distribution associated with salmonid electrofishing surveys are available, but not in an electronic database. We can arrange to view the hard copy data forms if needed. |
| Outmigrant trapping data for South Fork Eel River tributaries | Eel River Salmon Restoration Project | Harry Vaughn / Bill Eastwood | Multiple years of data exist for Sproul, Redwood, and Leggett creeks and possibly others. |
| Outmigrant trapping data in the Outlook Creek drainage | CDFG—Willits office | Scott Harris | Scott Harris has operated various smolt traps, primarily in the Outlet Creek drainage. He likely has capture data on ammocoetes and macropthalmia. |
| Fisheries reports associated with Potter Valley Project relicensing | Steiner Environmental Consulting | Park Steiner | Multiple years of reports summarizing fish surveys associated with the Potter Valley Project relicensing are available and contain records of lamprey capture in the upper mainstem Eel and various tributaries. Hard copies are available from Steiner Environmental Consulting and through FERC. |
| Summer steelhead dive survey reports | unknown | unknown | Summer steelhead dive surveys have been done for multiple years on the North Fork and Middle Forks of the Eel River and may contain lamprey observations. These reports can likely be obtained. |
| EMAP survey data showing records of ammocoete capture | U.S. Environmental Protection Agency | unknown | EMAP surveys for various streams in the Eel River basin were referred to in collections records at Smithsonian Museum database. It is likely that these survey data are available for numerous streams. |
| CDFG Habitat Inventory Reports | CDFG, Fortuna office | Scott Downie | Habitat inventories have been carried out for numerous tributaries in the basin and may contain relevant information on lampreys or their habitats. |
| Various studies and observations of lampreys at Angelo Coast Range Reserve on the SF Eel River. | UC Berkeley | Wendy Palen/ Michael Limm | They have done various studies involving lampreys at Angelo Coast Range Reserve on the SF Eel River. Limm has a paper in press involving the ecological interactions between lamprey ammocoetes and freshwater mussels, but was not reachable. |
| Physical characteristics and density of redds | McBain & Trush | Bill Trush | Bill Trush data on Pacific lamprey redd depth and velocity and redd abundance in a ~1,000-m study reach in the mainstem SF Eel near Elder Creek confluence. Data are available upon request. |

| Data source | Organization | Key contacts | Notes |
|---|---|---|---|
| CDFG diaries from Benbow Dam on the SF Eel River | CDFG—Fortuna office | Scott Downie | Bill Trush had a copy of the diaries and gave it to CDFG in Fortuna. The diaries start on Jan 1. 1938 when the dam was built. Will likely provide information on historical population. |
| Lamprey observations and land access information | Eel River Watershed Improvement Group | Ruth Goodfield | Scott Downie recommended her as a contact. She has extensive knowledge of tributaries to the South Fork Eel River and land access issues. |
| Lamprey observations | unknown | Sarah Kupferberg | Did research in the South Fork Eel River near the Angelo Coast Range Reserve. Bill Trush indicated that Kupferberg may have observations of lampreys from the 1990s. |
| Distribution data | U.S. Forest Service | unknown | It is likely that various U.S. Forest Service offices working the subbasins have observations and/or records of Pacific lamprey distribution. |
| Adult and macropthalmia migration | PBS&J consulting | Demian Ebert | Has data on timing of adult and juvenile Pacific lamprey movements in the upper Eel River associated with Potter Valley Project Relicensing studies |

# 7 DATA GAPS AND FUTURE RESEARCH

While this review brought to light a great deal of information on Pacific lampreys across the Eel River basin, it also highlighted several fundamental gaps in our understanding of the species' life history, distribution, and status. Table 4 lists some of the key research and monitoring needs identified during this review and potential steps to address them. A further logical step for filling these data gaps is to expand on this relatively limited review by pursuing the additional data sources listed in Table 3 above, conducting additional interviews with knowledgeable Wiyot Tribal members (particularly elders and eelers), and searching for other existing sources of information.

**Table 4.** Key research needs for Pacific lamprey in the Eel River basin.

| Key research need | Potential research, monitoring, or restoration approaches |
|---|---|
| Adult population trends | Annual creel surveys to estimate harvest and catch-per-unit effort |
| | Annual index reach spawning surveys to estimate relative abundance between years and stream reaches. |
| | Obtain, set up, and run a DIDSON to monitor the adult population near the mouth of the Eel River or major tributaries of interest. |
| Barriers to adult passage | Identify potential problem culverts or other barriers using the California Passage Assessment Database and other existing resources. |
| | Evaluate potential problem culverts and prioritize removal/retro-fit based on suitability and quantity of upstream habitat. |
| | Modify passage barriers, provide lamprey-specific fishways or bypasses, and monitor lamprey passage at each site. |
| Pacific lamprey distribution | Standardized electrofishing surveys for ammocoetes, including species identification, designed to fill in gaps in understanding of distribution and to estimate relative abundance between stream reaches. |
| | Focus on sub-basins such as the North Fork and Middle Fork, where little information appears to exist. |
| | Pursue potential additional sources of information described in Table 1. |
| Ammocoete life history | Design studies to understand ammocoete movement and time spent in freshwater. |
| Habitat quantity and quality | Estimate area of suitable habitat for spawning and rearing in index reaches and identify key reaches or tributaries for conservation and restoration priority. |
| Macropthalmia life history timing | Obtain existing information from salmonid outmigration projects. |
| | Design and implement lamprey-specific outmigrant traps to aid in research and population monitoring. |
| Impact of Potter Valley Project | Assess the impact of water diversion and reduced flows on all life stages of Pacific lamprey. |
| | Quantify the amount of lost spawning and rearing habitat above Scott Dam. |
| | Evaluate adult passage efficiency at the Van Arsdale Fish ladder at Cape Horn Dam. |
| | Evaluate effectiveness of screening apparatus at Cape Horn for avoiding entrainment of ammocoetes and macropthalmia. |
| Factors limiting lamprey production and abundance | Analysis of factors limiting the population through development of a conceptual life cycle model, characterization of available habitat for each life stage, collection of density data for each life stage, generation of hypotheses based on existing data and the conceptual model, and implementation of targeted research and population models to test each hypothesis. |

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# Appendices

# Appendix A

# List of Tributary Streams in the Eel River Basin in which Pacific Lampreys Have Been Documented and Year of Capture by Life Stage

**Table A-1.** Tributary streams in the Eel River basin in which Pacific lampreys have been documented. Tributaries are ordered from downstream to upstream. For each stream, only the most recent record of each life stage documented is shown. A = ammocoete; M = macropthalmia; H = Adult Holding; R = redd, S = spawning adult; C = Carcasse; UK = unknown lifestage. (Ammocoete records are not definitively Pacific lampreys and could be other lamprey species.)

| Stream | Tributary to | Year | Life stage | Source[1] |
|---|---|---|---|---|
| Palmer Creek | Eel River | 2003 | A | CDFG (2010) |
| Rohner Creek | Eel River | 2003 | A | CDFG (2010) |
| Strongs Creek | Eel River | 2003 | A | CDFG (2010) |
| Van Duzen River | Eel River | 2001 | A | Smithsonian Museum Collection |
| Wolverton Gulch | Van Duzen River | 2003 | A | CDFG (2010) |
| Yager Cr. | Van Duzen River | 1997 | A | White and Harvey (2003) |
| Grizzly Creek | Van Duzen River | 1997 | A | White and Harvey (2003) |
| Price Creek | Eel River | 2000 | A | Smithsonian Museum Collection |
| Oil Creek | Eel River | 2002 | A | CDFG (2010) |
| Howe Creek | Eel River | 2003 | A | CDFG (2010) |
| Atwell Creek | Howe Creek | 2003 | A | CDFG (2010) |
| Larabee Creek | Eel River | 1997 | A | Harvey et al. (2002) |
| SF Eel River | Eel River | 1985 | S | Bill Trush, McBain & Trush |
| SF Eel River | Eel River | 2010 | A | Abel Brumo |
| SF Eel River | Eel River | 2010 | R | Abel Brumo |
| Bull Creek | South Fork Eel River | 1997 | A | Harvey et al. (2002) |
| Bull Creek | South Fork Eel River | recent years[2] | S | Scott Downie, CDFG |
| Canoe Creek | South Fork Eel River | 1997 | A | Harvey et al. (2002) |
| Elk Creek | South Fork Eel River | 1997 | A | Harvey et al. (2002) |
| Salmon Creek | South Fork Eel River | 1997 | A | Harvey et al. (2002) |
| Salmon Creek | South Fork Eel River | recent years[2] | S | Scott Downie, CDFG |
| Redwood Creek | South Fork Eel River | 1997 | A | Harvey et al. (2002) |
| Redwood Creek | South Fork Eel River | recent years[2] | S | Scott Downie, CDFG |
| Sproul Creek | South Fork Eel River | 1997 | A | Harvey et al. (2002) |
| West Fork Sproul Creek | Sproul Creek | recent years[2] | H | Scott Downie, CDFG |
| West Fork Sproul Creek | Sproul Creek | 2001 | UK | Smithsonian Museum Collection |
| East Branch of South Fork | South Fork Eel River | 1997 | A | Harvey et al. (2002) |
| Indian Creek | South Fork Eel River | 1997 | A | Harvey et al. (2002) |
| Wildcat Creek | South Fork Eel River | 1987 | A | CDFG database |
| Hollow Tree Creek | South Fork Eel River | 2001 | A | CDFG database |
| Hollow Tree Creek | South Fork Eel River | 2000 | M | CDFG database |
| Bond Creek | Hollow Tree Creek | 1990 | A | CDFG database |
| Bond Creek | Hollow Tree Creek | 1983 | M | CDFG database |
| Waldron Creek | Hollow Tree Creek | 1991 | A | CDFG database |
| Rattlesnake Creek | South Fork Eel River | 2009 | H | Scott Harris |

| Stream | Tributary to | Year | Life stage | Source[1] |
|---|---|---|---|---|
| Elder Creek | South Fork Eel River | 1985 | S | Bill Trush, McBain & Trush |
| Fox Creek | South Fork Eel River | 1985 | H | Bill Trush, McBain & Trush |
| Moody Creek | South Fork Eel River | 1987 | A | CDFG database |
| Mud Creek | South Fork Eel River | 2001 | UK | Smithsonian Museum Collection |
| Rock Creek | South Fork Eel River | 1985 | H | Bill Trush, McBain & Trush |
| North Fork Eel River | Eel River | 2002 | C | Scriven (2002) |
| North Fork Eel River | Eel River | 2002 | R | Scriven (2002) |
| Middle Fork Eel River | Eel River | 2001 | A | CDFG database |
| Middle Fork Eel River | Eel River | recent years[2] | R | Scott Harris, CDFG |
| Outlet Creek | Eel River | recent years[2] | A | Scott Harris, CDFG |
| Outlet Creek | Eel River | 1989 | M | CDFG database |
| Ryan Creek | Outlet Creek | 2001 | A | CDFG database |
| Ryan Creek | Outlet Creek | 2000 | M | CDFG database |
| Ryan Creek | Outlet Creek | 2002[2] | H | Scott Harris, CDFG |
| Willits Creek | Outlet Creek | 1999 | A | CDFG database |
| Willits Creek | Outlet Creek | 2000 | M | CDFG database |
| Broaddus Creek | Outlet Creek | 1990 | A | CDFG database |
| Broaddus Creek | Outlet Creek | 1989 | M | CDFG database |
| Davis Creek | Outlet Creek | 1988 | A | CDFG database |
| Tomki Creek | Eel River | 1990[2] | R | Park Steiner, SEC |
| Bucknell Creek[3] | Eel River | 1994 | A | CDFG database |
| Mill Creek[3] | Eel River | 1994 | M | CDFG database |

1 The listing of a name and affiliation indicates this information was based on personal communication or observation.
2 Indicates approximate year based on correspondence with source.
3 These streams are located upstream of Scott Dam.

# Appendix B

# Wiyot Tribal Interviews

B-1

Appendix B contains potentially sensitive tribal information and thus is not included in this report. It is contained in a stand alone document that may be requested from the Wiyot Tribe.

# Appendix C

# Phone Questionnaire for Wiyot Tribal Interviews

Appendix C contains potentially sensitive tribal information and thus is not included in this report. It is contained in a stand alone document that may be requested from the Wiyot Tribe.

# Appendix D

# Abbreviated Questionnaire Included in Wiyot Tribal Newsletter

Appendix D contains potentially sensitive tribal information and thus is not included in this report. It is contained in a stand alone document that may be requested from the Wiyot Tribe.