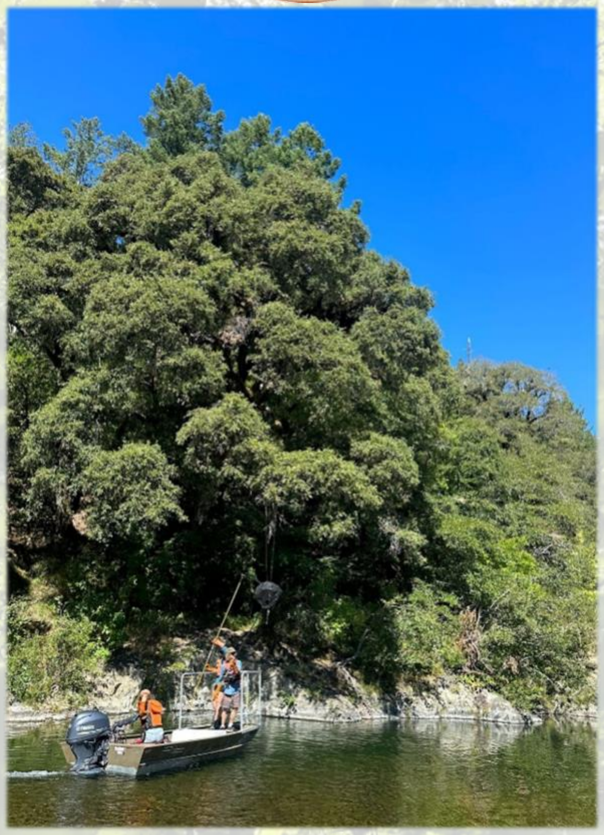
Wiyot Tribe Natural Resources Department

Lhou'lhaqh (South Fork Eel River) Sacramento Pikeminnow Management Plan



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Cover photo: Jon boat equipped with an electrofishing throw anode set-up.

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Acronyms and Abbreviations

BLM	U.S. Department of the Interior, Bureau of Land Management
BPA	Bonneville Power Administration
CalTrout	California Trout
CDFW	California Department of Fish and Wildlife
CPH	Cal Poly Humboldt
CPUE	Catch per unit effort
ERRP	Eel River Recovery Project
ESU	Evolutionary Significant Unit
FL	Fork length
FOER	Friends of the Eel River
FY	Fiscal year
GRTS	Generalized Random Tessellation Stratified
NMFS	National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
PG&E	Pacific Gas and Electric Company
PSMFC	Pacific States Marine Fisheries Commission
RKM	River kilometer
SHaRP	Salmonid Habitat Restoration Priorities
SL	Standard length
SRA	State Recreation Area

SWS	Stillwater Sciences
USEPA	US Environmental Protection Agency
USFWS	US Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WNRD	Wiyot Tribe Natural Resources Department

Acknowledgements

The Wiyot Tribe's Natural Resources Department would like to acknowledge that the vast amount of work presented in this document was conducted on ancestral lands and waters of the Wailaki people. Many project partners including Wiyot tribal members, non-profit organizations, state and federal agencies, academic institutions, consultant groups, Watershed Stewards Program Corpsmembers, and members of the public have contributed to this project, and we extend a heartfelt thank you to all those people and groups.

WNRD extends a special thank you to past employees who were pivotal in spearheading the initial work that has been passed on and adopted by current employees. These early efforts involved collaboration with Stillwater Sciences, who have helped develop and guide pikeminnow monitoring, data analysis, and research. The local community has spent many years using this fish as a scapegoat for native species decline that WNRD and Stillwater Sciences saw the opportunity to learn more about the fish. WNRD also recognizes this was not the fault of the fish for being invasive, but the fault of humans; and further recognizes this fish has cultural significance and its own ecosystem niche elsewhere in other basins.

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Executive Summary

This management plan is focused on non-native Sacramento pikeminnow in *Lhou'lhaqh* or the South Fork of the Eel River. *Lhou'lhaqh* is the Soulatluk word for the South Fork of the Eel River, which is the language of the Wiyot Tribe. Sacramento pikeminnow will be referred to as pikeminnow unless otherwise specified, and the South Fork Eel River will be referred to as SF Eel River. This plan is intended to be an information source for restoration practitioners in the SF Eel River, but also sets implications for the entire Eel River basin.

Section 1 gives a brief background of Eel River fisheries, overarching management objectives of the plan, and the project's geographical focus. Section 2 provides a species description and distribution along with new insights into age structure, size, and diet. Section 3 describes WNRD monitoring and suppression efforts along with results from those efforts; monitoring and suppression efforts done by other entities in the SF Eel River and other parts of the basin; and information sharing and coordination. Section 4 is supplemented by the previous section to create and suggest management actions, addresses data gaps, research needs and questions, and concludes with an adaptive management framework. There are appendix items as well: Appendix A shares the Technical Advisory Committee members by name and affiliation, the authors, as well as the many individuals who have contributed in one way or another by name and affiliation; Appendix B contains raw data of pikeminnow and juvenile steelhead counts by sub-reach for 2018 - 2023; Appendix C contains a summary of sub-reaches snorkeled and their associated habitat data for 2018 - 2023; and Appendix D provides a brief description of preliminary movement data on pikeminnow and salmonids.

1 Introduction

1.1 Background and Need

The Wiyot Tribe shares its name with its ancestral river, *Wiya't*. A significant aspect of this river's abundance is the *gou'daw*, Pacific lamprey (*Entosphenus tridentatus*) – commonly called *eels*, which inspired the river's English name, *Eel River*. The Eel River watershed is the third largest in California and was one of the most productive fisheries in the state hosting abundant runs of Chinook salmon, Coho salmon, steelhead, sturgeon, and Pacific lamprey—all of which are important for tribal subsistence and culture. During the late 19th and early 20th centuries, cannery records suggest Chinook salmon runs probably ranged between 100,000 and 800,000 fish per year (Yoshiyama and Moyle 2010). However, the Eel River basin has endured a long history of abusive land use by Euro-Americans which devasted the watershed and its fishes (Yoshiyama and Moyle 2010). In the mid-1800s, gold and timber exploitation brought European settlers to northwest California, resulting in a near decimation of the Wiyot population and culture. Numerous impacts, including water diversions, dams, invasive predators, logging, overgrazing by livestock, flooding, and sedimentation, have led to significant ecological and habitat degradation and diminished native fish populations that are important to the Wiyot Tribe. This river basin holds immense cultural significance for the Wiyot Tribe, as most of ancestral territory spans across the lower reaches of this basin. In recent years the Wiyot Tribe has been a driving force for activities aimed at restoring native fishes.

Fisheries restoration and conservation efforts in the Eel River basin have focused on improving and protecting stream habitats, and in recent years, a focus on non-native aquatic species has been added. The

Sacramento pikeminnow (*Ptychocheilus grandis*) is a large piscivorous cyprinid that was introduced into Lake Pillsbury in the upper mainstem Eel River around 1979 (three or four fish) and has since expanded its distribution into much of the basin (SEC 1998, Brown 1990, Brown and Moyle 1997, Harvey et al. 2002, Kinziger et al. 2014). Pikeminnow occur at very high densities in many parts of the watershed (e.g., White and Harvey 2001, Higgins 2020, PG&E 2020a) and therefore have the potential to fundamentally alter the aquatic ecosystem and negatively impact native species. Of concern are anadromous species, which must migrate from headwater streams through the mainstem to reach the estuary and ocean and eventually return to freshwater. Federal and California Endangered Species Act salmonid recovery plans for Coho salmon, Chinook salmon, and steelhead describe the deleterious effect of pikeminnow to Eel River listed salmonid populations and recommend suppression or eradication of pikeminnow in the Eel River (NMFS 2014, 2016). Numerous studies indicate that pikeminnow compete with, prey on, or alter the behavior of juvenile salmonids, lampreys, and other native fishes in the Eel River basin (e.g., Brown and Moyle 1997, White and Harvey 2001, Reese and Harvey 2002, Nakamoto and Harvey 2003, Georgakakos 2020). The non-predation impacts of pikeminnow are speculated to cause alteration of the life history expression of native fish (e.g. some life histories may be extirpated or severely reduced by the presence of pikeminnow) and mainstem rearing (for juvenile salmonids, lamprey and to some extent Sacramento suckers). While predation by novel, introduced predators may not be the cause of initial declines, continued predation might prevent the recovery of diminished salmonid populations and be exacerbated by human activities and increased warming due to climate change (Falkegard et al 2023; Georgakakos et al 2023). Furthermore, pikeminnow impacts under warmer conditions will be more prolonged and more spatially extensive; earlier arrivals in upstream reaches will expand and lengthen pikeminnow co-occurrence with native species (Georgakakos et al. 2023). Species that tolerate warmer water temperatures such as Pacific lamprey, Sacramento sucker, and sculpin species tend to have a higher degree of overlap with pikeminnow during the summer and may be more vulnerable to predation (Brown and Moyle 1991, White and Harvey 2001, Stillwater Sciences 2014).

Understanding and mitigating the adverse impacts of non-native aquatic species is vital for tribal fisheries resources including California Coastal Chinook salmon Evolutionary Significant Unit (ESU) (threatened), Northern California Steelhead Distinct Population Segment (threatened), Southern Oregon/Northern California Coho salmon ESU (threatened), and Pacific lamprey. To address these needs, the Wiyot Tribe has taken measures to develop and implement a holistic and coordinated strategy to minimize pikeminnow impacts on native species in the basin in coordination with local, state, and federal agencies, academic institutions, NGOs, and private consultants.

1.2 Management Objectives

The first phase of this ongoing effort – conducted between 2017 and 2020 with funding from a USFWS Tribal Wildlife Grant – included (1) developing and evaluating various pikeminnow suppression approaches, (2) designing and implementing an approach to monitor the pikeminnow population in the SF Eel River, (3) describing pikeminnow summer diet, and (4) making initial recommendations to guide future research, monitoring, and suppression efforts.

Building on this work, WNRD implemented the current project between 2021 and 2023, with these objectives:

(1) Remove a sufficient number of invasive pikeminnow from the SF Eel River to result in a population decline that will result in an increase in survival and abundance of tribally important and federally listed native fish populations;

(2) Improve pikeminnow management by filling basic biological data gaps, including seasonal impacts of pikeminnow predation on native fish and their age and growth patterns in the Eel River;
(3) Further evaluate and refine population control methods and management strategies;
(4) Foster collaboration amongst Eel River stakeholders, including State and Federal partners, in addressing the adverse impacts of pikeminnow;
(5) Build Wiyot tribal capacity to conduct fisheries research, monitoring, and restoration projects in the Eel River basin.

The outcome of this work is summarized in this Management Plan. In addition to drawing from the Wiyot Tribe's funded projects in the SF Eel River, this Plan integrates relevant information from other pikeminnow research, monitoring, and management efforts in the Eel River and beyond. A suite of methods has been identified to remove large numbers of pikeminnow from the SF Eel River and monitor population response to gauge success and adapt strategies. These efforts aim to protect imperiled native salmonid and lamprey populations while also collecting biological data to help fill key gaps in understanding to inform future management.

Importantly, this Plan should be viewed as an iterative and will be refined and expanded geographically in coordination with partners as more information becomes available.

1.3 Geographical Focus

This iteration of the plan is focused on the SF Eel River where funded activities occurred (Figure 1) but includes information from and recommendations for other parts of the Eel River watershed. In a future iteration, additional details and recommendations for the larger watershed would be included.

The SF Eel River has a contributing drainage area of 1,785 km^2 (689 mi^2) and is a major tributary to the Eel River. The drainage is unique among the tributaries of the Eel, differing in form, climate, vegetation types, and underlying rock (Brown and Ritter 1971). The Wiyot Tribe has lived in the lower portions of the Eel River basin for millennia and has an interconnected relationship with the waters and fish of the *Wiya't* (Eel River). The Eel River is extremely important to the Tribe, as ancestral territory encompasses its lower reaches.

The climate in this region is described as Mediterranean with the lower portion, closer to the coast, known for its "fog belt," influenced by moist airmasses over the ocean which produce onshore winds, cool foggy summers, and mild wet winters (Brown and Ritter 1971). Further inland it's less moist than that along the coast (Brown and Ritter 1971). The SF Eel River is low gradient and consists of pools with warm summer water temperatures. Annual precipitation in the SF Eel River basin typically ranges from about 140 cm (55 in) in lower elevations to over 204 cm (80 in) at some higher elevation locations (PRISM Climate Group 2020). The rainfall pattern in the basin is characterized by wet winters and dry summers.

Recent land uses in the watershed include grazing, timber management, rural and residential development, gravel extraction, and widespread marijuana cultivation. These activities, along with historical widespread disturbance of the landscape from intensive logging and road building, followed by large floods in the 1955 and 1964, have caused extensive changes to much of the basin, including widespread landslides, channel aggregation, and loss of riparian vegetation that have contributed to habitat simplification in increased water temperatures (CDFW 2014). The SF Eel River is listed as an impaired water body due to excessive sediment and high summer water temperature (USEPA 1999).

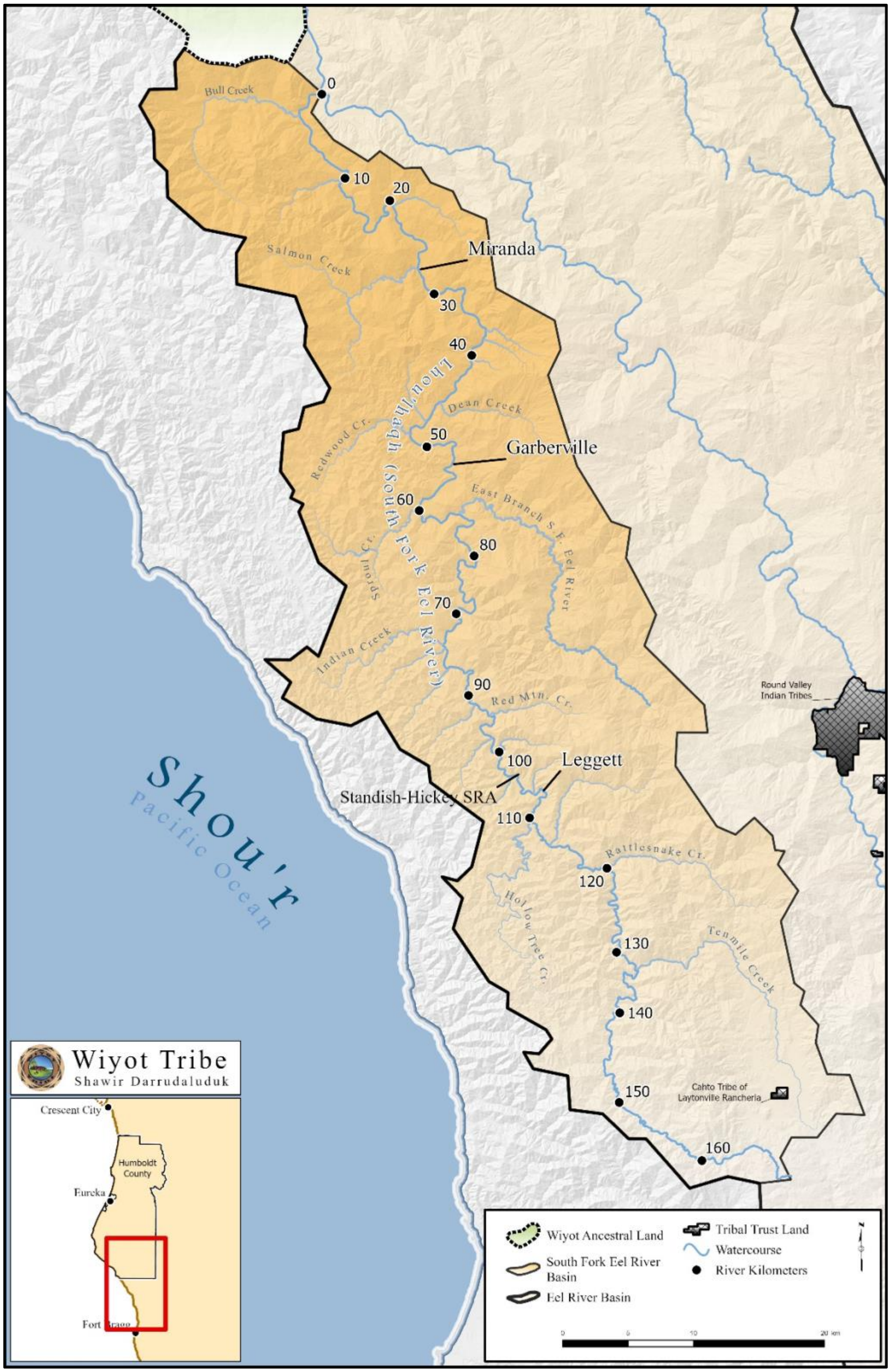

Figure 1. Overview of Lhou'lhaqh or South Fork of the Eel River.

2 Species Description

2.1 Life History and Habitat Requirements

The Sacramento pikeminnow is a large, piscivorous, cyprinid fish species with complex habitat utilization that varies diurnally and seasonally (Nobriga and Feyrer 2007). During the daytime, adult pikeminnow prefer pool and deeper run habitats with abundant cover such as boulder ledges, overhanging riparian branches, undercut banks, or large wood, and are generally absent in riffles (Brown 1990, Moyle 2002, Gard 2005). Adults can be found in small schools, but the largest individuals are often solitary (Grant 1992, as cited in Moyle 2002). Adult pikeminnow are more active at dusk and dawn and may move into shallower water at night (Brown and Moyle 1981, Harvey and Nakamoto 1999).

There is little known about pikeminnow spawning in the Eel River. The information presented here is taken from other watersheds where they are native such as the Sacramento-San Joaquin basin. Pikeminnow can spawn annually but only spawn when conditions are favorable. Typical fecundity is around 20,000 eggs, but large females can produce as many as 40,000 eggs (Wang 1986; Mulligan 1975, as cited in Moyle 2002). Individuals in larger rivers or reservoirs are thought to move into tributaries to spawn, while fish in smaller streams may spawn locally (Taft and Murphy 1950, Mulligan 1975, Grant 1992; all as cited in Moyle 2002). Upstream movement associated with spawning has been documented to occur as early as March and as late as June (Wang 1986, Moyle 2002). Males are thought to gather in spawning areas prior to the arrival of females (Mulligan 1975, as cited in Moyle 2002). Spawning occurs when water temperatures exceed approximately 14°C (57°F) and is thought to take place at night (Wang 1986; Mulligan 1975, as cited in Moyle 2002). Spawning occurs in riffles or pool tail outs, where eggs released by females are fertilized by one or more males before sinking to the bottom and adhering to gravel and cobble substrate (Wang 1986, Moyle 2002). Eggs of Northern pikeminnow (*Ptychocheilus oregonensis*), a closely related species, hatch in 47 days at 18°C (64°F) (Burns 1966, as cited in Moyle 2002).

Newly hatched larvae, which are approximately 9 mm (0.35 in) long, remain in spawning gravels for a short time before dispersing to shallow backwater habitats or margins of pools (Moyle 2002). As they grow into the juvenile stage, pikeminnow typically inhabit shallower portions of pools and flatwater habitats often forming large mixed schools with Northern Coastal Roach (*Hesperoleucus venustus navarroensis*) (Moyle 2002, Gard 2005). Young-of-the-year pikeminnow can disperse widely, typically moving downstream (Moyle 2002).

Pikeminnow and other minnow species have a unique alarm response to predation that triggers fearful behavior and escape in conspecifics. A pheromone-like substance, known as *schreckstoff* (German for fear or fright stuff) is released in response to mechanical trauma and injury – such as that inflicted by the teeth of predators (Stensmyr and Maderspacher 2012). The *schreckstoff* response has implications for efforts to remove pikeminnow, since it can limit capture with gear types that cause injury such as spearfishing and angling.

2.2 Distribution

The Sacramento pikeminnow is native to the Sacramento-San Joaquin River basin, the Pajaro, Salinas, Russian, Upper Pit rivers, and the Clear Lake Basin (Moyle 2002). In addition to the Eel River, the species has been introduced into Chorro and Los Osos creeks, which drain into Morro Bay in central California, and several reservoirs in southern California (Moyle 2002). In 2008, seven Sacramento pikeminnow were detected in Martin Slough, a tributary to Elk River, which flows into Humboldt Bay; however, it does not appear that the species has become established in that watershed (Kinziger et al. 2014). In general, pikeminnow are restricted to lower gradient streams with summer water temperatures of 18–28°C (64–82°F) (Brown and Moyle 1997, Harvey et al. 2002, Moyle 2002).

In 1986, just six or seven years after three or four pikeminnow were introduced to the Eel River, they had colonized the entire mainstem, the lower 47 km of the Middle Fork Eel River, the lower 56 km of the SF Eel River, and the lower 37 km of the Van Duzen River (Brown and Moyle 1997). During initial monitoring efforts in 2018 they were found in high concentrations, with a mean density estimated at around 750 fish/km (size class >450 mm) in the SF Eel River (Stillwater Sciences and WNRD 2020). Pikeminnow are highly mobile with noted migrations of up to 432 km between 69 to 745 days across the northern Sacramento-San Joaquin Delta and 300 km within a year in their native range (Valentine et. Al. 2020). In the Eel River, pikeminnow were tracked up to 92 km within a year (Harvey and Nakamoto 1999).

In the SF Eel River large-scale seasonal movements of adult pikeminnow have been documented, with individuals tagged in the upper reaches moving downstream approximately 25 km (15.5 mi) in the fall before and moving back upstream in the spring (Harvey and Nakamoto 1999). In the same study during summer months, adult pikeminnow that held in large pools during the day commonly moved through adjacent riffles into shallower pools or runs at night, before returning to the large pools the next day. In the same study, observations in October found that many fish occupied a pool body during the day and moved into either the pool head or pool tail at night. Recent multi-year research by Georgakakos (2020) documented annual spring and summer migrations of adult pikeminnow into the upper reaches of the SF Eel River. These studies, along with recent winter and spring snorkel observations by Georgakakos (pers. comm., 2021) and CDFW (S. Ricker, pers. comm., 28 February 2020), indicate that pikeminnow are largely absent from the upper SF Eel River (upstream of approximately Indian Creek) in the winter and early spring, and they migrate upstream in mid to late spring as juvenile salmonids are migrating downstream. Snorkel surveys and temperature monitoring between 2015-2019 on the SF Eel River suggest that monitoring temperature annually can help predict the timing of pikeminnow migration and is a good predictor of site-specific arrival times and spatial movements within a year (Georgakakos 2023).

2.3 Age Structure and Size

Pikeminnow are a long-lived and slow growing species. They can live up to at least 16 years and grow past 1,100mm (42 in) in their native habitat (Scoppetone 1988, Moyle 2002). For many years it was thought there was no size difference between males and females. However, all the pikeminnow captured in this study displayed sexual dimorphism where females grow larger than males. In the Eel River basin, they have been aged up to 10 years and measured up to 668 mm (26 in) fork length (Juan/Wiyot Tribe unpublished data). Females generally reach sexual maturity after 4-5 years of age, while males reach maturity after 2-3 years (Juan/Wiyot Tribe unpublished data). There is also some evidence suggesting possible sex-specific mortality in the species, with males having a higher mortality rate than females and therefore not surviving as long. A similar sex-specific variation in mortality is known to exist in Northern pikeminnow (*Ptychocheilus oregonensis*) (Beamesderfer 1992; Parker et al. 1995).

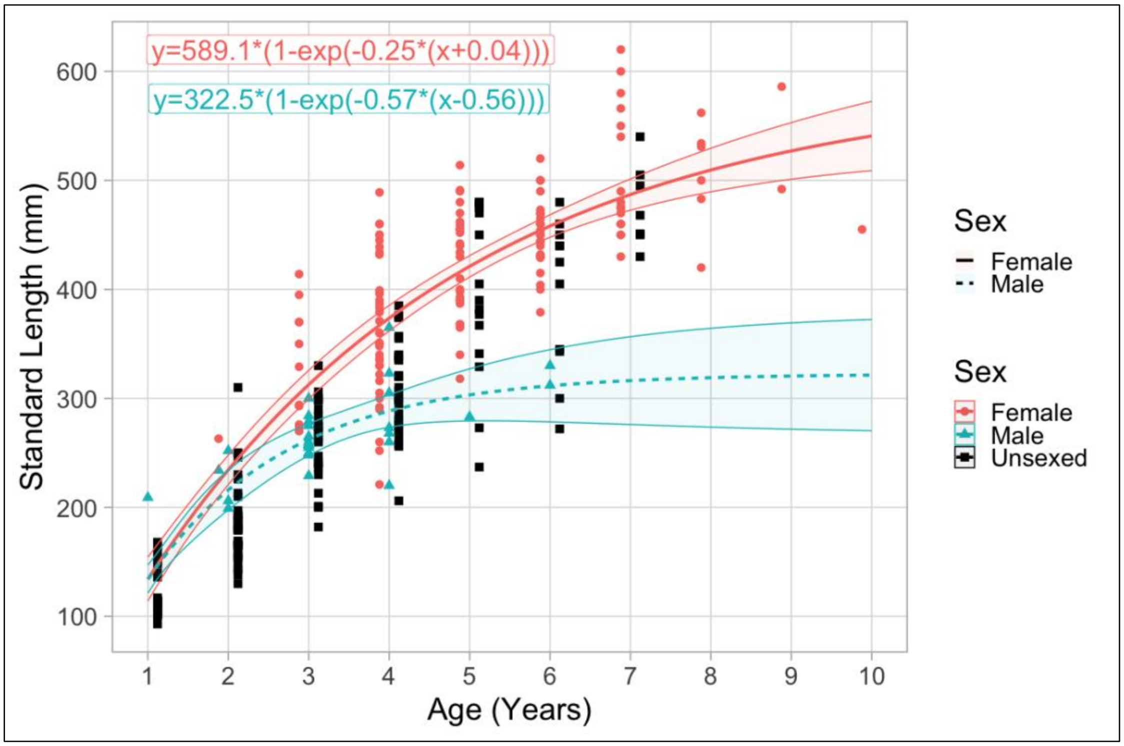

Figure 2: Scale aging results of South Fork Eel River pikeminnow, including Von Bertalanffy growth model fits for male and female fish. Both models were fit using all age-1 data points (male, female, and unsexed).

To investigate pikeminnow growth and age structure, scales were collected from pikeminnow in 2018, 2019, 2022, and 2023. Scales were removed either from the area under the tip of the pectoral fin or below the dorsal fin and stored in scale envelopes. In the CPH lab, scales were cleaned with soap and water, mounted between two glass slides, and imaged with a QImaging Retiga-2000R digital camera under a dissecting microscope at 4x or 2x magnification depending on the size of the scale. Ages were estimated by counting annuli. For scales collected in 2018, 2019, and 2022, two readers worked independently and then met to reach a consensus age for scales they disagreed upon. For scales collected in 2023, three readers were used following the same procedure. Only one reader was a member of both groups for a total of four readers.

Female pikeminnow were found to grow much larger than males. While the largest confirmed male pikeminnow in this study measured only 365 mm SL, the largest female measured 620 mm SL (Figure 2). In addition, many older female pikeminnow were found than males; while the oldest male was estimated to be 6 years old, 25 of 127 aged females were estimated to be older than this to a maximum of 10 years. This suggests sex-specific mortality differences may exist for Sacramento pikeminnow, but further investigation into this topic is recommended.

2.4 Diet

Pikeminnow are generalist predators, with Eel River diet studies suggesting they feed opportunistically on the most available prey items in their environment (Brown and Moyle 1997).

Stomach contents were collected from a subset of pikeminnow in each size class captured during 2019, 2022, and 2023 suppression efforts for visual examination of diet. A total of 221 diet samples were analyzed out of 1,170 euthanized pikeminnow. Various suppression methods were employed to obtain these samples which is further described in Section 3.1.2. Pikeminnow >150 mm were dissected and the entire digestive tract was excised (Nakamoto and Harvey 2003). Any prey items from the esophagus to the second S-shape digestive tract were removed for preservation and included in the analysis (Nakamoto and Harvey 2003). Lab analysis was performed in the CPH Ward Lab using a microscope, scale, trays, and a dissection kit. It's important to highlight that many findings in the stomachs consisted of fish parts that were challenging to identify therefore, they were carefully stored aside for potential future analysis.

Prey items were categorized as fish, insects, crustaceans, herptiles, and mollusks. In general, fish and insects were the most common prey items found while crustaceans, herptiles, and mollusks were comparatively rare. As pikeminnow size increased, the proportion of insects decreased while the proportion of crustaceans and herptiles increased. These findings are mostly consistent with those of Nakamoto and Harvey (2003), who found an increase in the proportion of fish and decrease in the proportion of insects consumed as size increased up to 400 mm. Notable finds included two frogs, a turtle, unidentifiable frog bones, crayfish, insects, and snails.

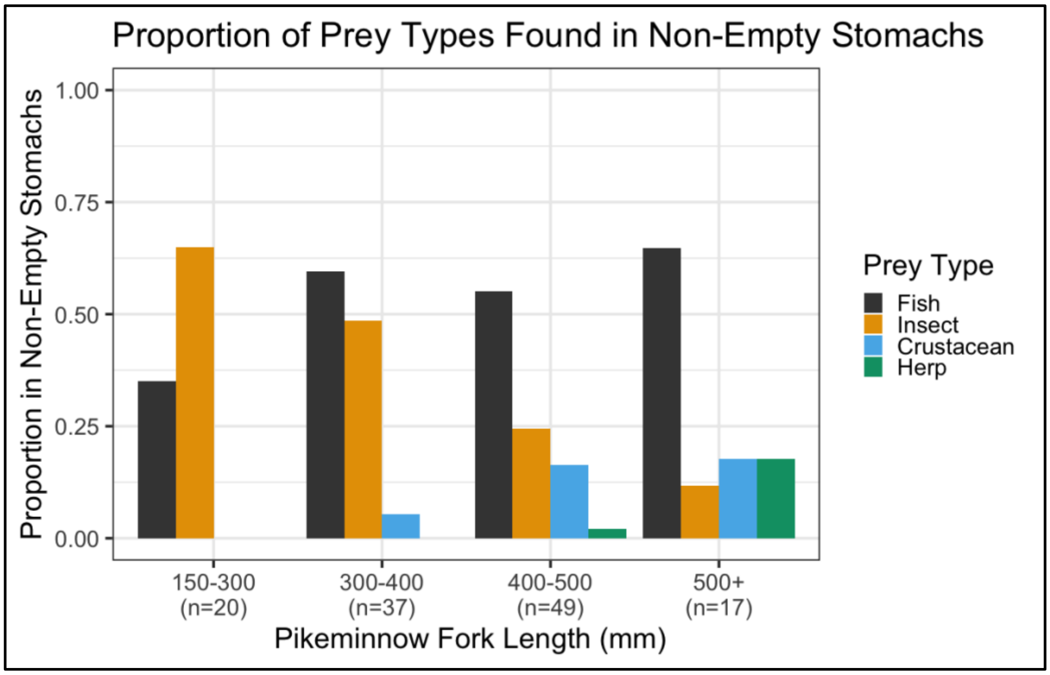

Figure 3. Proportion by total mass of prey types found in non-empty stomachs for different size classes of pikeminnow in 2019, 2022, and 2023.

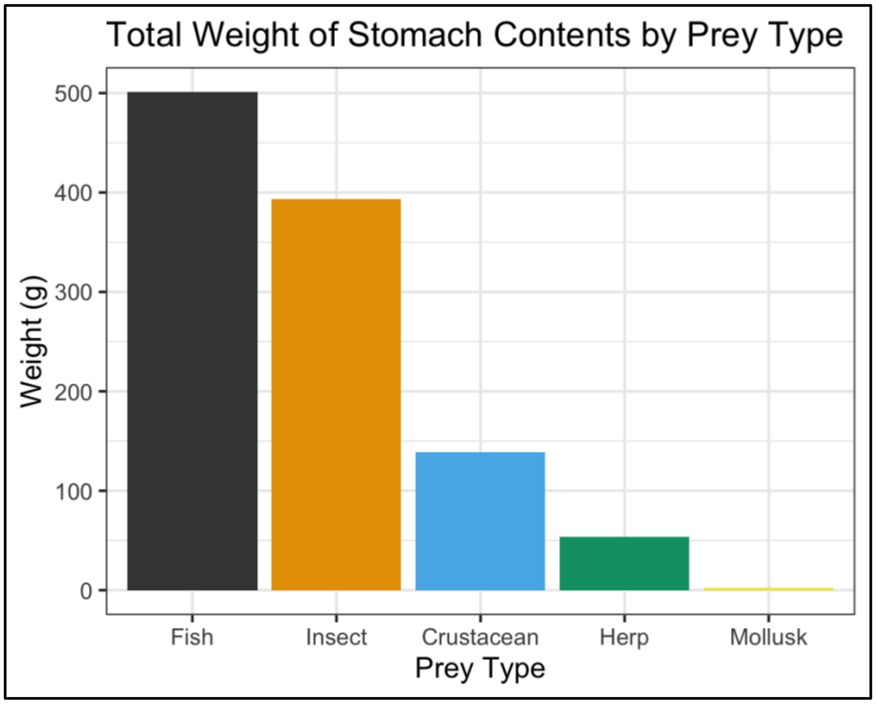

Figure 4. Total weight of each prey type found in South Fork Eel River pikeminnow stomachs in 2019, 2022, and 2023.

Muscle tissue was also collected from individuals sampled for gut contents for isotopic diet analysis. Muscle tissue samples came from euthanized pikeminnow in 2018, 2019, 2022, and 2023. Tissue was removed from below the dorsal fin near the lateral line using a scalpel knife, placed in a sealable bag with a unique ID, and immediately placed on ice in the field before being stored in a freezer. Tissue samples were later prepped in the CPH Ward Lab. Once tissues were thawed out, they were cut into smaller pieces and placed in dry vials in a drying oven at 35-40°C overnight. Samples in vials were then ground up into a fine homogenous powder. A total weight of 1.0g (+/- 0.2g) was measured out and stored in a pre-weighed tin boat and placed in a tray with a unique ID. In addition to collecting pikeminnow tissue, tissue samples from major prey items were collected to serve as reference isotopic signatures for these analyses. Non-lethal tissue samples were collected from a small number of juvenile salmonids, lamprey ammocoetes, and Northern Coastal Roach for the purpose of developing isotopic signatures for these species in the SF Eel River. Macroinvertebrates and crayfish were collected as prey items too. Table 1 shows the exact amounts of samples relative to each species collected for isotopic signatures.

Table 1. Number of samples analyzed for isotopic analysis listed by species group.

Species group	Number of samples
Sacramento pikeminnow	263
California roach	2
Lamprey (ammocoete)	2
Stickleback	2
Chinook salmon	1

Coho salmon	1
Steelhead	1
Sunfish	1
Clam	2
Mollosk	2
Crayfish	1
Coleoptera	1
Odonata	1
Trichoptera	1
Plecoptera	1
Ephemeroptera	1
Water boatman	2
Worm	1
Total	**286**

A total of 286 sample tissues were sent to UC Davis Stable Isotope Facility, where solid δ13C and δ15N (carbon and nitrogen) were analyzed using an EA-IRMS system. Measuring the ratios of the stable isotopes δ13C and δ15N in tissue samples allows for a description of the relative contribution of major prey items (e.g juvenile salmonids, lamprey ammocoetes, other fish, macroinvertebrates, and crayfish etc). Isotope diet analysis can show what trophic level pikeminnow are on the food web relative to their size. This data set is highly complex and requires further analysis.

3 Species Management and Monitoring

3.1 Existing Monitoring and Suppression Efforts

Monitoring, suppression, and research efforts of pikeminnow populations have been occurring throughout the Eel River basin over many years by various groups. This includes efforts by CDFW, PG&E, UC Berkeley, Eel River Recovery Project (ERRP), Stillwater Sciences, the Bureau of Land Management (BLM) Arcata Field Office, California Trout (CalTrout), and the WNRD, which have in recent years collaborated more closely to share information and support each other's efforts.

Past suppression efforts have occurred in the Eel River on smaller scales. There was a pikeminnow derby in the early 2000's as noted in a local non-profit's publication that encouraged members of the public to fish for pikeminnow (FOER, 2005). This derby was well-supported by members of the public but was shut down by the state.

More recent suppression efforts have taken place by various agencies and groups throughout the basin. The WNRD, Stillwater Sciences, CDFW, BLM, UC Berkeley, and CalTrout have contributed hours of service working towards restoring salmon, trout, and lamprey populations by monitoring and removing pikeminnow. Table 2 provides a brief overview of existing pikeminnow management measures, which entity conducts the work, geographic focus within the basin, and the time frame for those efforts.

Table 2. Summary of existing pikeminnow monitoring and suppression measures in the Eel River basin.

Entity	Location coverage	Monitoring Time frame	Suppression time frame
PG&E	Between Cape Horn and Scott Dams	1990 – present	2006, 2019 - present
CDFW	Eel River basin (varies)	~1991 - present	varies
UC Berkeley (Georgakakos)	Upper South Fork Eel River (Angelo Reserve)	2015 - present	2023 - present
Eel River Recovery Project	Upper South Fork Eel River (Rattlesnake Creek to Standish Hickey SRA)	2016 - present	none
WNRD	South Fork Eel River (confluence to Standish Hickey SRA)	2017 - present	2019 - present
BLM	North Fork Eel River	2017 - present	2018 - present
CalTrout	South Fork Eel River (Piercy)	2023 - present	2023 - present

3.1.1 Abundance Monitoring

WNRD Monitoring Efforts

The primary objective of population monitoring was to estimate abundance and describe the distribution of pikeminnow in the Monitoring Reach (Figure 5), a critical step for assessing their impacts on native fish populations. Data from this task also helped identify pikeminnow population "hot-spots" to inform selection of locations for suppression events. A secondary objective of the task was to improve understanding of summer distribution of juvenile salmonids, especially steelhead, to help avoid potential impacts to these species during suppression events.

Continuing long-term monitoring through summer snorkel counts, mark and recapture studies, and ongoing tagging initiatives is necessary to achieve management objectives. These efforts will continue to refine suppression methods to accurately pinpoint pikeminnow congregation areas, estimate abundance, and address existing biological data gaps.

It is important to note that a channel-spanning resistance board weir was installed in the SF Eel River in the summer of 2023. The weir was installed near the upstream end of sub-reach 46 (RKM 83). It is too early to assess how the weir affected monitoring results for 2023.

Methods

The Monitoring Reach begins at the confluence of the SF Eel River and the mainstem with the upstream end at Standish-Hickey State Recreation Area, located in Humboldt and Mendocino counties of Northern California. WNRD and Stillwater Sciences employed a spatially balanced sampling approach known as Generalized Random Tessellation Stratified (GRTS) to effectively sample this large stretch of river. The 105 km (65 mi) Monitoring Reach (Figure 5) was divided into 58 sub-reaches that made up the sampling frame from which a subset of sub-reaches was selected for conducting snorkel surveys. The sampling frame consisted of sub-reaches varying in length from 0.8 to 3.6 km (0.5 to 2.4 mi). At least 12 sub-reaches were selected each year using the R-package "SDraw" (R Core Team 2019, McDonald and McDonald 2020). The GRTS site selection approach provides a major advantage over both simple random sampling and systematic sampling: the sample is guaranteed to be spatially balanced (McDonald 2003).

Timeframe: Snorkel surveys were conducted in summer months during the daytime from 2018 -2023 (no sampling conducted in 2019). Each of the sub-reaches selected in the GRTS draws were sampled using single-pass, daytime snorkel surveys conducted between July 5 and August 1 in 2018; July 15 and 22 in 2020; June 24 and July 9 in 2021; June 14 and July 12 in 2022; and June 15 and July 20 in 2023. All diveable portions of selected sub-reaches were sampled in their entirety, starting downstream and working upstream in 2018, 2020, and 2021; and starting upstream and working downstream in 2022 and 2023.

Locations: Population monitoring was restricted to the 105-km (65-mi) reach downstream of Standish-Hickey State Recreation Area to avoid overlap with annual pikeminnow census snorkel surveys conducted by the ERRP. This 105-km reach is referred to as the "Monitoring Reach" (Figure 5). The Monitoring Reach was divided into numbered sub-reaches as described earlier in the Methods. These sub-reaches constituted the sampling frame for snorkel surveys and were also used to describe the locations of suppression efforts and other project activities.

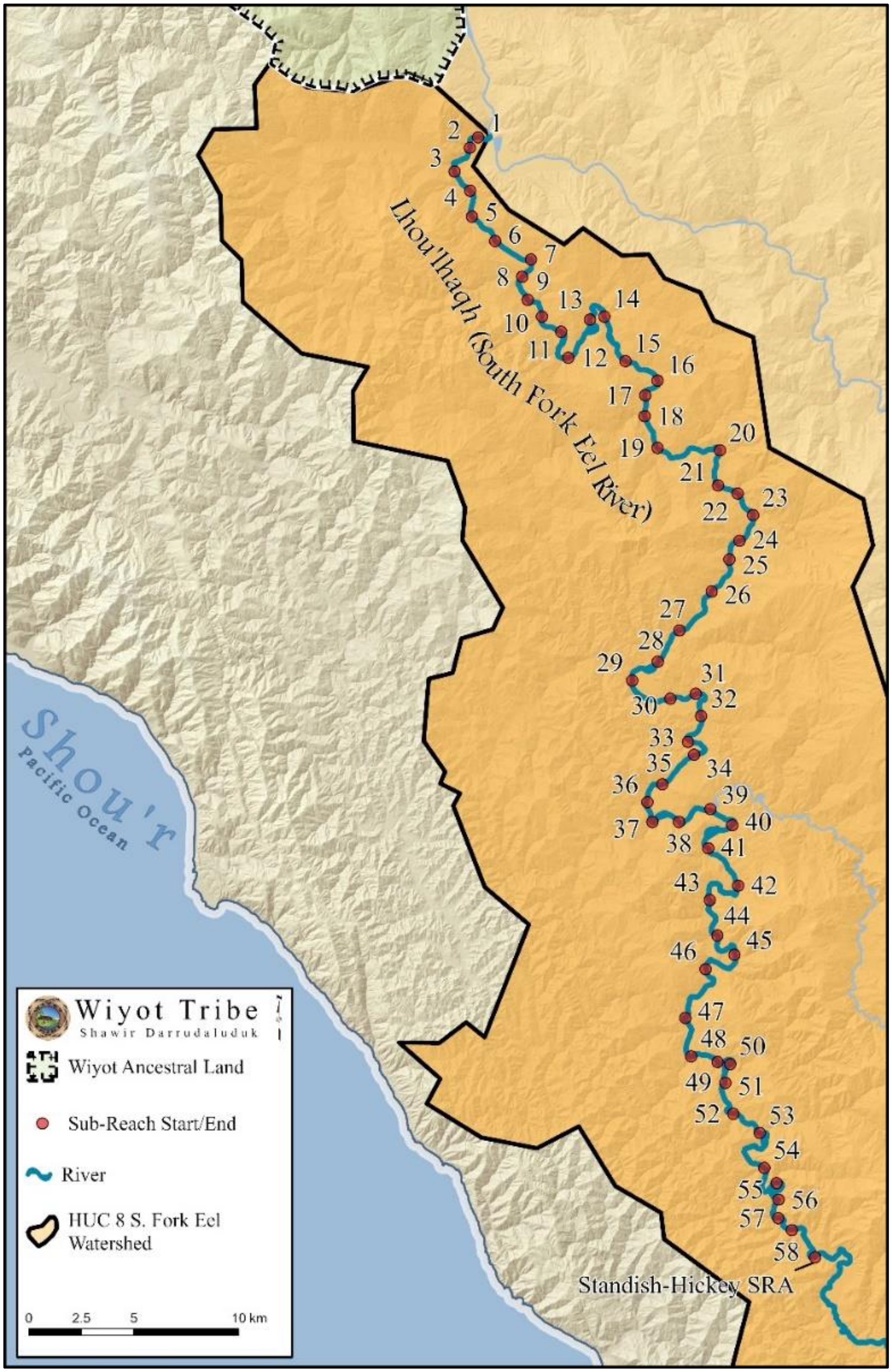

Figure 5. Monitoring Reach and sub-reaches in the South Fork Eel River.

Field methods: Snorkel surveys were primarily focused on pikeminnow observations that were assigned to the following size classes for subsequent summaries and analyses: 100 – 200 mm (4 – 8 in), 201 – 300 mm (8 – 12 in), 301 – 450 mm (12 – 18 in), and >450 mm (>18 in). Size classes were based on standard length. Pikeminnow smaller than 100 mm (4 in) were also counted in 2018 and 2020, but those counts are considered coarse estimates due to their high numbers, potential for misidentification with the co-occurring Northern Coastal Roach, and the focus on accurately counting larger size classes. Non-target fish species were also counted and assigned to 100 mm (4 in) size classes (juvenile steelhead counts in Appendix B; other species counts available upon request). Divers paid particular attention to detecting juvenile salmonids to help describe their summer distribution and inform efforts to avoid them during suppression efforts. Other relevant ecological observations such as lamprey redds were also noted.

Within each sub-reach, snorkel data were collected at the mesohabitat unit scale (pool, flatwater, riffle) to split surveys into manageable lengths and provide information on habitat preference. Each habitat unit was initially designated as a pool, riffle, or flatwater based on geomorphic characteristics of the channel. However, pool and flatwater unit types were lumped for analysis due to ambiguity in classifying many of them (e.g., short, deep, sections with pool-like features in units that were otherwise characteristic of flatwater habitats or vice versa). GPS coordinates were collected at the upstream and downstream ends of each unit. Maximum depth of each habitat unit was recorded during snorkel surveys to help understand relationships between depth and pikeminnow presence and abundance. Finally, horizontal underwater visibility was visually estimated at the beginning of each sampled sub-reach.

Each habitat unit was typically surveyed by divers moving upstream or downstream in adjacent dive lanes, counting fish as they swam upstream or downstream. In habitat units (or parts of units) where it was not feasible to swim the center of the channel due to high water velocity, divers typically swam or crawled channel margins and counted all fish on their side of the channel. Some riffles or portions of riffles were not sampled since they were too shallow or fast for effective surveying and expected to support few if any pikeminnow. When possible, diveable sections of riffles were surveyed to confirm the assumption of limited pikeminnow presence and help describe the summer distribution of juvenile steelhead in the Monitoring Reach.

Data analysis methods: All raw data was entered into multiple Excel spreadsheets at the end of each day. At the end of each field season, data from that season was formatted and added to a master data sheet. Snorkel counts of pikeminnow from the 12 surveyed sub-reaches were used to obtain abundance estimates with 95% confidence intervals for each size class in the Monitoring Reach using a simple random sample approach implemented through the R package, "survey" (Lumley 2020, R Core Team 2019). Linear Density (fish/km) of each size class was calculated by dividing the total number of pikeminnow estimated for the Monitoring Reach by the length of the Monitoring Reach.

Results & Discussion

These results show annual estimates of abundance and linear density (fish/km) of pikeminnow by size class for 2021 – 2023 only (Table 3). A summary of estimated pikeminnow density that covers all five years, 2018 – 2023, is below (Figure 6). Summary tables of sub-reaches snorkeled by year and pikeminnow counts by sub-reach are included in Appendix B.

Snorkel counts of pikeminnow from the 12 (or more) surveyed sub-reaches were used to obtain abundance estimates with 95% confidence intervals for each size class in the Monitoring Reach using a simple random sample approach implemented through the R package, "survey" (Lumley 2020, R Core

Team 2019). Linear density (fish/km) of each size class was calculated by dividing the total number of pikeminnow estimated for the Monitoring Reach by the length of the sub-reach.

Table 3. Estimated abundance and linear density of pikeminnow from 2021 through 2023. Size class measured standard length in millimeters (mm).

2021						
Size Class	**Abundance**			**Linear Density (Fish/Km)**		
	Estimate	**Lower**	**Upper**	**Estimate**	**Lower**	**Upper**
100-200	43081	30920	55241	408	293	523
200-300	6773	4562	8983	64	43	85
300-450	1419	686	2152	13	6	20
450+	107	37	177	1	0	2

2022						
Size Class	**Abundance**			**Linear Density (Fish/Km)**		
	Estimate	**Lower**	**Upper**	**Estimate**	**Lower**	**Upper**
100-200	25075	16730	33421	238	158	317
200-300	8700	6585	10815	82	62	102
300-450	1349	906	1791	13	9	17
450+	155	67	242	1	1	2

2023						
Size Class	**Abundance**			**Linear Density (Fish/Km)**		
	Estimate	**Lower**	**Upper**	**Estimate**	**Lower**	**Upper**
100-200	11798	8621	14975	112	82	142
200-300	5718	4288	7148	54	41	68
300-450	2306	1649	2963	22	16	28
450+	433	246	621	4	2	6

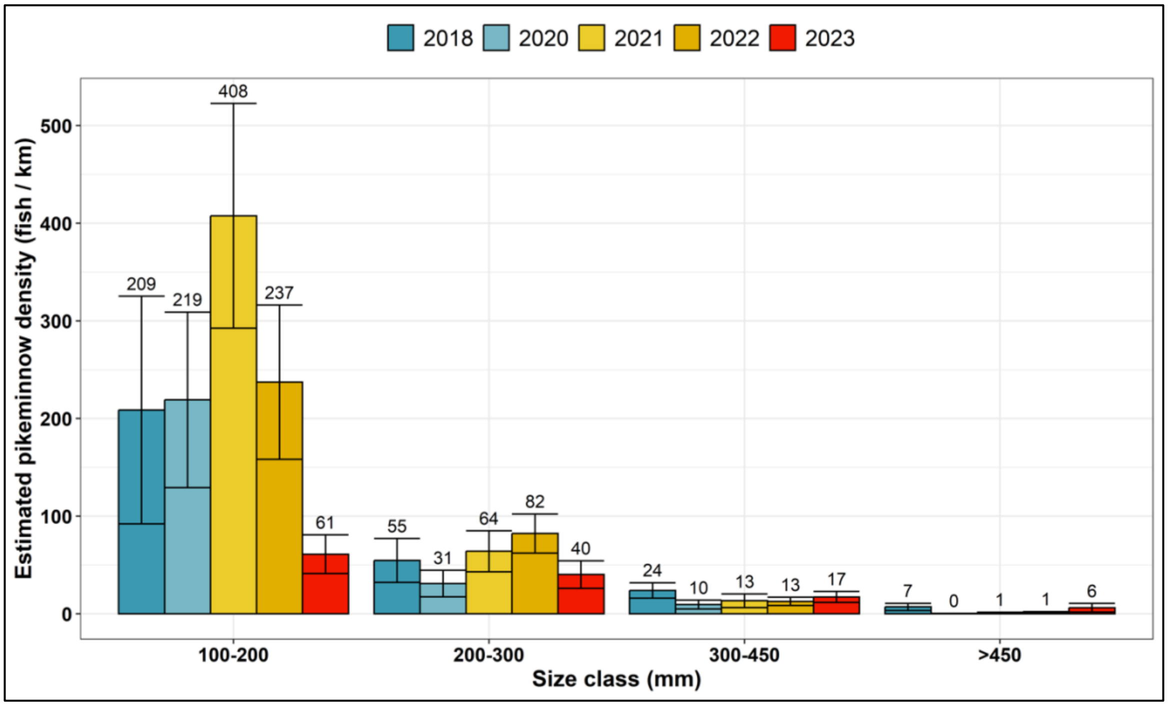

Figure 6. Estimates of linear density by size class in the South Fork Eel River from 2018 through 2023. Bars represent the 95% confidence intervals around the estimates.

Population monitoring is a critical component of understanding pikeminnow in the SF Eel River. Monitoring has indicated just how widespread pikeminnow have become in this sub-basin and it has largely influenced how, when, and where suppression occurs. There is a lot of new monitoring information coming to light from collaborative studies on pikeminnow movement using acoustic telemetry (see Appendix D). Visual observations by personnel have contributed to basic habits such as pikeminnow feeding on invertebrate drift while juvenile *O. mykiss* are simultaneously feeding on the same drift right beside them. GRTS surveyors also collected observations on many other organisms like Sacramento suckers, Pacific lamprey redds, juvenile *O. mykiss* (see Appendix B for raw data), freshwater mussels and sponges, few juvenile Coho salmon and Chinook salmon encounters amongst other observations.

Other Monitoring Efforts

The ERRP has been conducting pikeminnow monitoring efforts in the mainstem SF Eel River. Since 2016, ERRP has been implementing annual summer snorkel counts in the mainstem SF Eel River between Standish-Hickey State Recreation Area (SRA) and Rattlesnake Creek (Higgins 2020). Project partners conducted suppression efforts in this reach in 2023 and ERRP's long-term focused monitoring in this reach can be a potential way to assess the efficacy of suppression in this area.

Another ongoing and now long-term effort to monitor pikeminnow in the upper SF Eel River has been led by Philip Georgakakos of UC Berkeley. Starting with his dissertation in 2015, he has conducted consistent surveys of a 11-kilometer reach around the upper extent of pikeminnow distribution near the UC Angelo Reserve. His surveys also collect counts of salmonids and other native species as well as habitat values and water quality data. The geographical extent of these surveys expanded in 2023 to include the Elkhorn Ridge Wilderness stretch of the upper SF Eel River from Rattlesnake Creek upstream to Tenmile Creek.

CDFW conducts opportunistic observations of pikeminnow throughout the SF Eel River and the mainstem Eel River while conducting surveys primarily focused on salmonids. Observations are noted during habitat inventory, annual adult salmonid spawning ground surveys, and juvenile salmonid spatial structure snorkel surveys. CDFW has been noting pikeminnow presence in addition to all other fish species observed in stream habitat inventories conducted since 1991 and other occurrences have been documented in field notes since the species was introduced to the Eel River in the late 1970's. (Loomis/Kajtaniak pers. comm. February 2024).

PG&E has been monitoring pikeminnow populations in the upper mainstem Eel River in pools below Scott Dam, Van Arsdale Reservoir, and pools below Cape Horn Dam since 1990. PG&E and Kleinfelder, Inc. conducted snorkel surveys and backpack electrofishing to monitor populations. Additional incidental monitoring data was also collected from the video system at the Van Arsdale Fish Station.

3.1.2 Suppression

WNRD Suppression Efforts

WNRD and Stillwater Sciences (SWS) have been testing and conducting various suppression methods since 2019. This includes seining, angling, boat electrofishing, active gill netting, and spearfishing. This section describes the methods, results, and discussion on activities largely conducted in 2021 – 2023. WNRD and SWS conducted suppression trials in 2019 and 2020 that informed this current work. The full methods and results of 2019 and 2020 can be found in the WNRD and SWS Technical Memorandum (2020).

All methods are successful in their own ways but also have their cons as summarized in Table 4. WNRD and SWS have largely focused suppression efforts within the SF Eel River (Figure 7) while providing opportunistic assistance in other areas of the basin.

Methods

Timeframe: Suppression efforts took place from 2019 through 2023, but this iteration of the Plan largely covers activities that occurred in 2021 through 2023.

Locations: Suppression efforts occurred in the SF Eel River. Figure 7 shows some of the more frequented sites for suppression activities. Some of those sites were given nicknames like 'Log Slide' or 'Double Bridges' based on physical features present at the site, whereas some sites were coined simply with the geographic location. All sites featured on the map do not reflect all sites visited for suppression.

Figure 7. Frequented suppression sites along the South Fork Eel River.

<u>Field methods:</u> Suppression efforts for the late spring and summer months from 2019 to 2023 included angling, beach seining, boat electrofishing, gillnetting, and spearfishing. A separately funded project implemented in 2023 included the installation of a seasonal resistance board weir with a live trap that was intended to trap and/or prevent upstream migration of pikeminnow. Given our understanding of fish population dynamics, a predator removal approach that only targets large adult fish may result in reduced predation on younger age classes and less intraspecific competition, leading to more rapid growth, maturation, and abundance of younger size classes (Zipkin et al. 2008, 2009). A combination of methods was used to initially prioritize the removal of larger pikeminnow. Due to strong evidence of sexual dimorphism in size (see Section 2.3) we utilized multiple methods that concurrently aided in removing as many pikeminnow as possible from multiple age classes.

For more detail on the suppression trial efforts from 2019 and 2020, refer to the WNRD and SWS Technical Memorandum (2020).

Before each suppression method was utilized at sites the unit was snorkeled to determine the absence of salmonids and/or large schools of non-target species (i.e. Sacramento suckers).

Boat electrofishing was utilized with the Wiyot Tribe's jon boat equipped with electrofishing equipment and two different anode types; a traditional boom anode and a throw anode. The boom anodes (two) were determined to be not as effective overall as the throw anode, as they were only effective at capturing fish from relatively short distances – approximately 1-2 m from each anode. The boom anodes were not very effective at drawing fish upward from depths greater than ~1.5 m. The throw anode was useful at much greater distances; the spear could be thrown at fish more than 10 m from the bow of the boat. Additionally, the shock intensity was stronger than an individual boom anode. The throw anode was also useful for shocking areas the boat could not reach, such as beyond logs, underwater berms or around brush. A couple disadvantages of the throw anode are (1) the unit is static once it is thrown, whereas the booms continue moving with the boat, and (2) after a throw, several seconds are needed to gather the cord and spear before another throw is made, leaving significant time for larger fish to swim away if they were missed. The latter disadvantage was addressed by placing gill nets at the upstream and downstream ends of habitat units, which was helpful on occasion. Another disadvantage is all the moving parts that come with boat electrofishing all of which requires training and adherence to safety measures: operating a boat, operating electrical equipment in close proximity to water, towing a trailer for the boat, and having a person on-shore speaking with members of the public and their safety while this method is occurring.

Gill netting was conducted in specific habitat types (pools and runs), typically where there is little to no wood and few large boulders to avoid the nets getting snagged. A crew of four to five individuals is preferred for this method. A net would be drawn across the width of the channel on the downstream end of the habitat unit, then the crew would move to the upstream end of the unit. The crew would swim downstream in a line eventually pulling a second net across the width of the channel. While some people would be on either end of the upstream net moving it downstream, other people were spooking fish from gaps or un-snagging the net from the bottom. Eventually the upstream would be close enough where both nets would be brought together so all the larger fish were corralled in this space and snagging themselves in the net. This method was coined the "gill net shuffle." Challenges are encountered under certain conditions such as high river flows creating strong currents and pulling the net, and pools or runs that were too deep and/or too wide.

Spearfishing primarily used spear guns and secondarily pole spears. This method provided a selective approach to targeting large pikeminnow and has no location restrictions except for heavy public use or the presence of salmonids. Crew members found it to be the most desirable method due to its light weight. A disadvantage of spearfishing is it's highly skill-dependent that requires training and adherence to safety measures. Pikeminnow tended to cue in on their surroundings and become spooked once a shot had been taken. This creates a short window of time where pikeminnow are relatively easier targets.

Angling was utilized sporadically. This is a method that is also relatively low-commitment and travel friendly like spearfishing is. It is also less lethal to non-target species which if caught can easily be removed and released. Smaller size fish were captured through this method. In 2022 and 2023 specific lures and baits emerged as consistently successful: spinner effectiveness seemed to increase as lure size decreased, and the extremely small 1/12 oz mepps agila was favored. When encountering large schools of small pikeminnow Velveeta cheese could be molded around a small barbless treble hook which facilitated easy extraction of fish.

Beach seining was used in 2019 during trial suppression efforts, and once in 2023 at the 'Resting Oaks' site. A seine net was utilized to target schools of smaller size class pikeminnow. At least three personnel were needed for this 2023 event – two individuals handling the net while the third person herded fish out of deeper spots into the net. Once captured, the seine was brought on shore for fish processing. While this method proved to be the least effective in terms of overall pikeminnow removal, it did successfully capture smaller size class fish. A total of six fish with an average standard length of 81 mm were removed using this approach. Given its success in capturing smaller pikeminnow it may be worthwhile to consider testing this method in other sections of the SF Eel River to assess its effectiveness in removing smaller size pikeminnow.

One approach worth discussing was conducting suppression during nighttime. This happened on a few occasions. A crew of people went spearfishing at night. Pikeminnow were observed to almost be sleeping; they were very still in the water column and made for relatively easy targets. Unfortunately, the two events this happened the sites selected for this method did not have many pikeminnow present. In one of those same nights a crew of people laid a single gill net across the channel to stay overnight. The crew rotated and took shifts watching the net to avoid any bycatch and to remove any caught pikeminnow. From this one event, six pikeminnow had swam into the gill net and were euthanized on shore.

Once pikeminnow were captured, multiple data were collected from a majority of captured pikeminnow. Each individual was given a unique ID and measured standard and fork length (this plan only covers standard length) in millimeters. A significant sub-sample of individuals were dissected to collect stomach contents, muscle tissue for isotopic analysis, scales, and occasionally fin clips and gonad samples. If possible, individuals were sexed. Other observations were noted like if females were gravid with egg masses, worms present, etc. Almost all individuals caught were kept frozen for some amount of time. Most individuals were kept track on which method was used to euthanize pikeminnow, but sometimes that data became lost. As an example, some days crews would attempt multiple methods in a single day, collect all necessary data, but then discard all individuals into a single waste bag.

<u>Data analysis methods:</u> All raw data was entered into multiple Excel spreadsheets at the end of each day. At the end of each field season, data from that season was formatted and added to a master data sheet. All data analysis was performed using R statistical software (R Core Team 2023). Graphs and charts were made with the ggplot2 package.

Results & Discussion

These results will mainly cover the 2021 – 2023 period. Over the 2021 – 2023 period 1,924 pikeminnow were removed from the SF Eel River overall (Figure 8). If the trial suppression efforts from 2018 and 2019 are included that rounds the overall count to 2,173 individual pikeminnow over the entire five-year pikeminnow project period. As noted, 2023 also includes pikeminnow that were removed from a separately funded weir project (n=42).

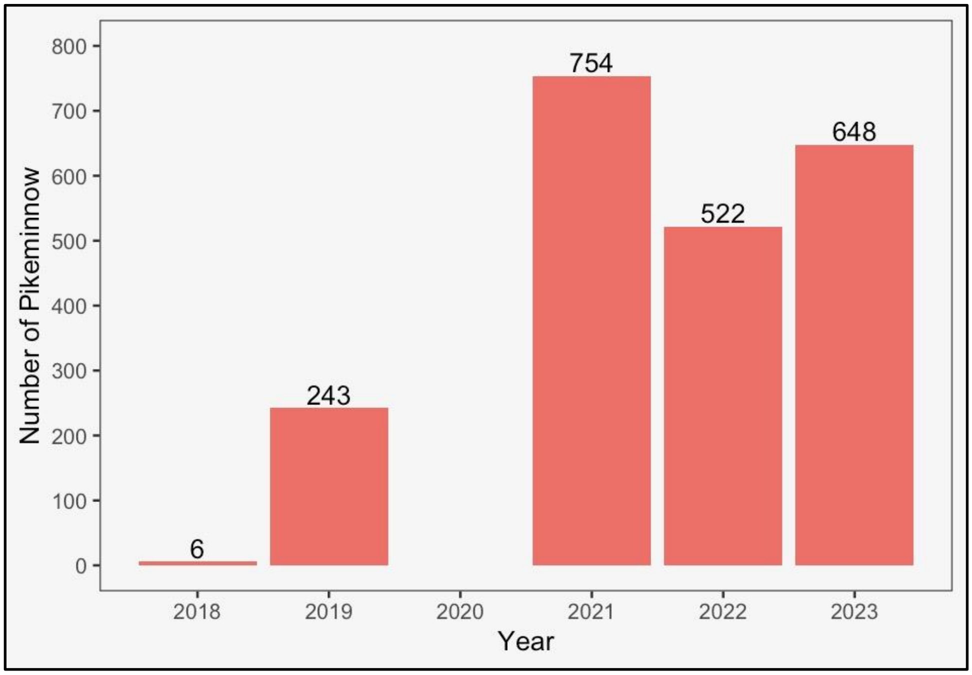

Figure 8. Number of pikeminnow euthanized over the monitoring and suppression period. Figure includes 2018 and 2019 trial years. 2023 includes counts from the separately funded South Fork Eel River weir project.

Figure 9 shows how many pikeminnow were euthanized by all methods. This figure can also show the shift in methods used over the years. Angling and seining were performed relatively less so than all other methods. Seining was nearly phased out after 2019 trial efforts but was attempted once in 2023. Boat electrofishing was the primary suppression method utilized in 2021. The use of gill nets and spearguns were approved under permits in 2022 and have been heavily relied upon since then.

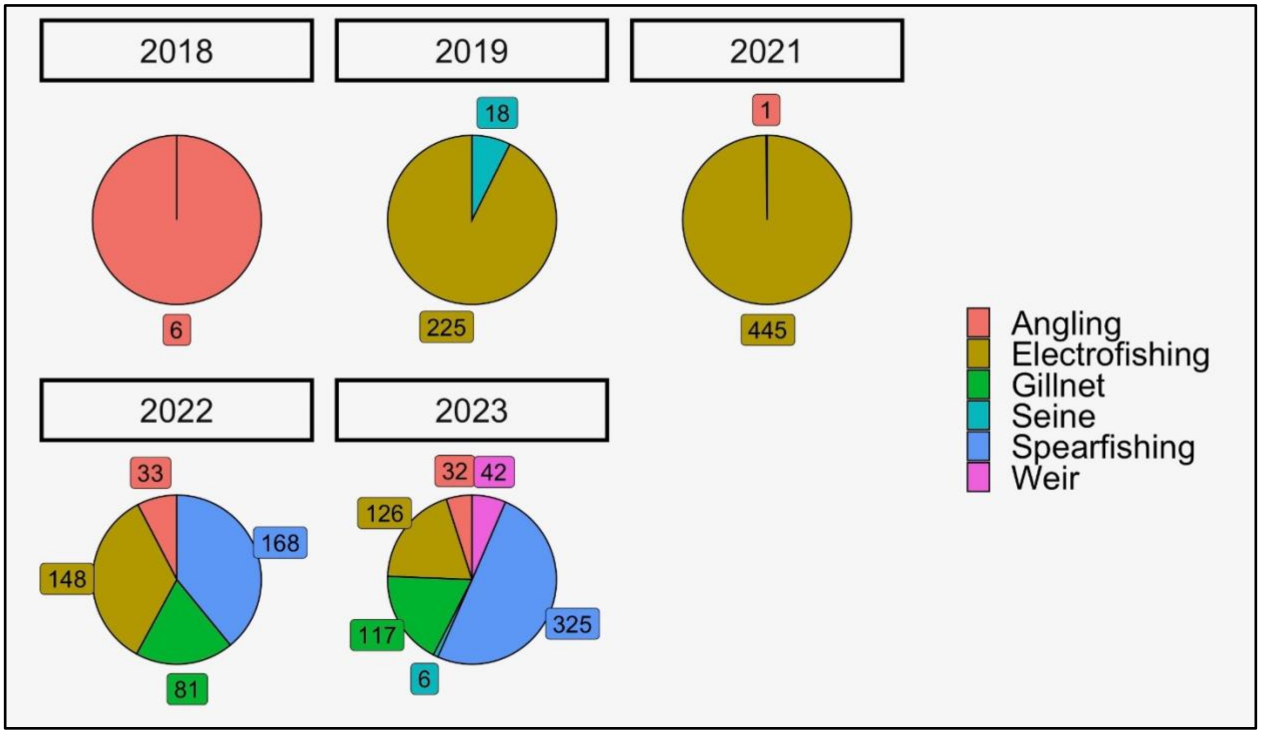

Figure 9. Pie charts showing counts of pikeminnow captured broken down by suppression method.

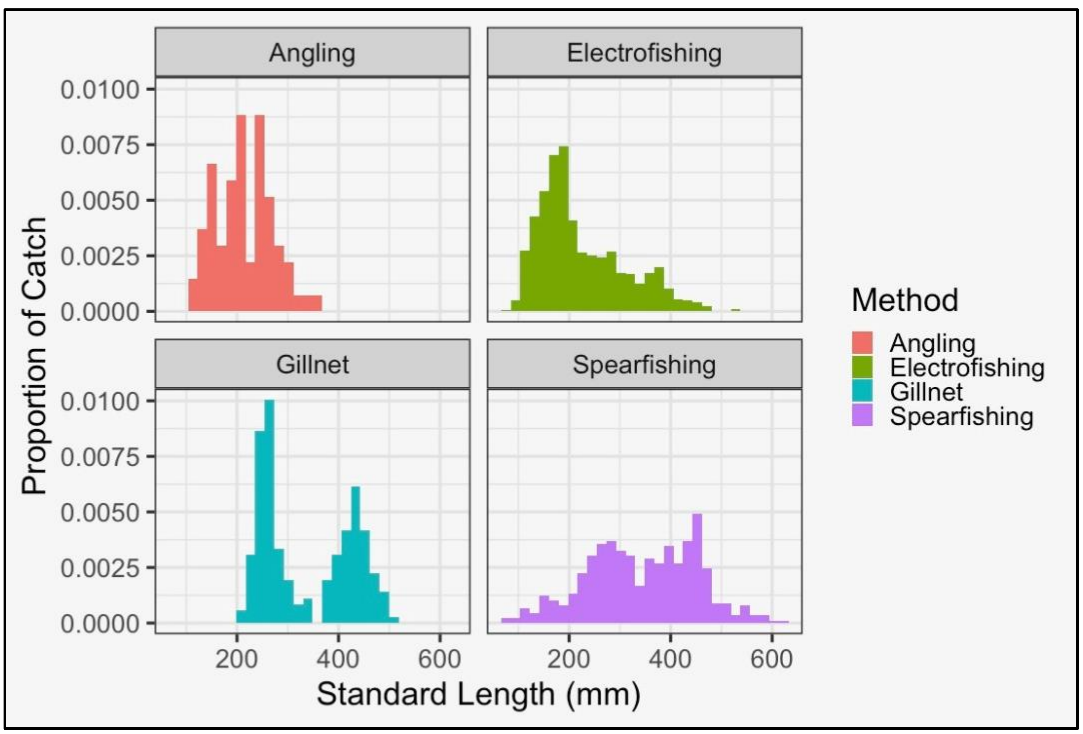

Figure 10. Proportion of catches and standard length frequency of pikeminnow separated by suppression method. Angling (pink) in top left, boat electrofishing (green) in top right, gill net (blue) in bottom left, and spearfishing (purple) in bottom right.

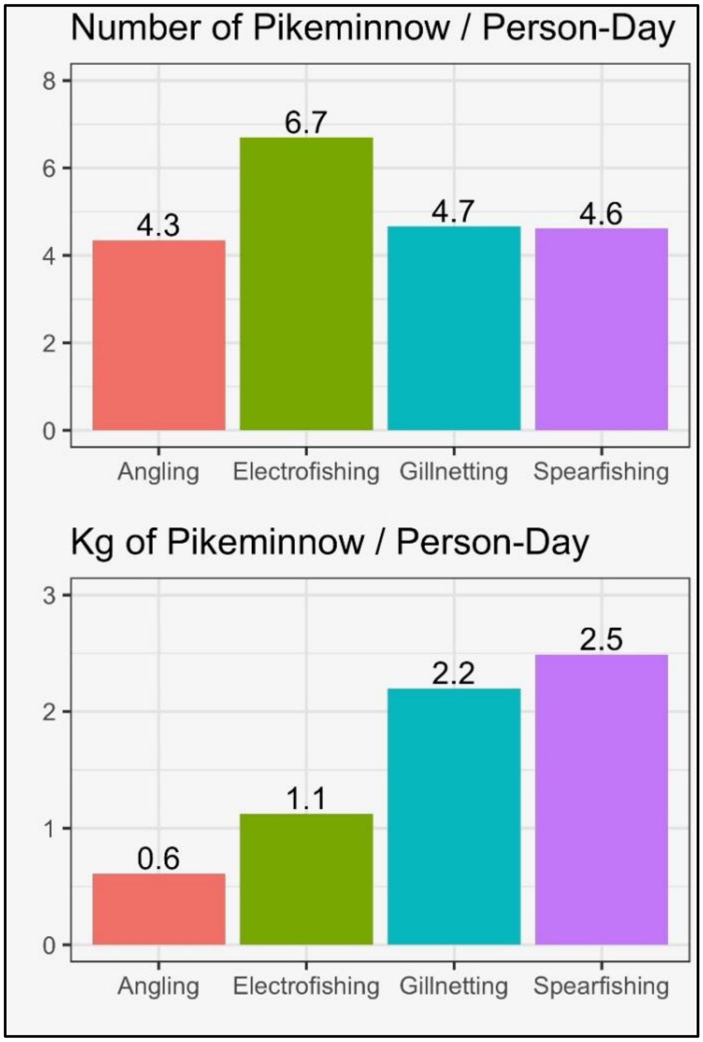

Figure 11. Calculated catch per unit effort using pikeminnow caught per person per day. Note: for days that crews caught zero fish, crew did not record anything.

Suppression methods differed day by day based on multiple variables. It depended on the number of personnel available, amount and size of pikeminnow present, presence/absence of any juvenile salmonids, data needs, and/or the state of gear amongst other variables. Personnel favored gill netting and spearfishing, because these methods seemed to favor larger individual pikeminnow, and were able to be utilized across many sites along the SF Eel River. Boat electrofishing was utilized to maximize catch amount but was limited on where it could be deployed. Boat access and the ability to drive a trailer onto river bars is limited along this river. Operating the boat and the electrofishing equipment was also a limiting factor as this required time and effort to train personnel in operating these potentially dangerous pieces of equipment. Table 4 summarizes some of the pros and cons of each suppression method along with the number of personnel needed for each method.

Table 4. Pros, cons, and number of personnel needed for each suppression method.

Method	Pros	Cons	Number of personnel needed
Seining	• Effective at capturing small fish	• Low CPUE	4
Angling	• Travel friendly • Low commitment • Low potential harm to non-target species	• Low CPUE	1
Boat electrofishing	• High CPUE	• Boat access is limited • High equipment cost • Fish spook and tend to start hiding in complex bank habitat	3 - 4
Gill net	• Effective at capturing large fish • Travel friendly	• Habitat needs to be 'simple' (i.e. lack of wood and boulders) • Clogs up with algae • Lead line bounces off bottom providing a temporary escape route	4 - 5
Spearfish	• Selective approach • Travel friendly • Low potential impact to non-target fish	• Learning curve • Fish spook and limits your time to shoot fish	1

Consistent suppression of pikeminnow will refine future suppression strategies. This will involve removing enough larger pikeminnow, thereby enhancing the chances of survival of juvenile salmonids, promoting growth by reducing pikeminnow densities, and facilitating increased smolt production and adult returns. Suppression efforts coupled with monitoring, are especially crucial for comprehending the response of both pikeminnow and salmonids to suppression measures.

Larger pikeminnow became a central focus for removal for the purpose of removing gravid and sexually mature females. However, upon deeper analysis of size at maturity by Juan (2023) it was discovered that pikeminnow captured from this study displayed sexual dimorphism as described in section 2. Learning this provided more reason to capture mid-size fish in addition to large females. Figure 10 shows the proportion of catches separated by angling, boat electrofishing, gill netting, and spearfishing, and how each method was successful at capturing different size classes. Electrofishing was generally successful at capturing fish that were considered small to mid-size in high numbers. The two peaks in the gill netting table show the use of two different mesh sizes in action. Gill nets with a mesh size of one-inch entangled fish 200 – 350 mm while gill nets with a mesh size of one and a quarter inch entangled fish >350 mm.

Other Eel River Suppression Efforts

CalTrout along with project partners installed a seasonal resistance board weir in 2023 to take advantage of the pikeminnow seasonal upstream migration (Harvey and Nakamoto 1999, Georgakakos 2020). The weir was installed in the mainstem SF Eel River just downstream from Indian Creek and spanned the entire wetted width of the channel. The weir was in place from mid-April through mid-September when pikeminnow have been observed to move more frequently, and while there are no adult salmonids migrating to spawn. The site was selected for various reasons, one being it would segregate large adult pikeminnow from critical salmonid rearing habitat in the upper SF Eel River. The weir contained an underwater motion-activated camera to monitor fish movement and a trap with the hopes of trapping migrating pikeminnow. Throughout the time it was installed it trapped 42 pikeminnow with fish measuring an average standard length of 310 mm. The weir will be reinstalled again in 2024. A formal assessment of the efficacy of the weir is forthcoming.

The BLM has been spearheading annual summer steelhead and pikeminnow surveys in the North Fork Eel River since 2017. Surveys are possible largely due to volunteers and willing private landowners. These surveys led to targeted suppression efforts aimed at controlling the small population that migrated into this sub-basin. The BLM utilized gill nets, seines, angling, and spearfishing as suppression methods. These annual surveys also collect invaluable data on steelhead and other aquatic species in a part of the basin that is made up of rugged terrain and is very difficult to access.

PG&E implemented trial suppression efforts with gill nets in 2006 in Van Arsdale Reservoir and in pools below Cape Horn Dam. The trial periods resulted in a relatively low catch of pikeminnow and take of numerous juvenile steelhead, at which point PG&E was requested to suspend further suppression efforts until less harmful methods were further investigated. Suppression picked up again in 2019 in Van Arsdale Reservoir and in pools below Scott and Cape Horn Dams using raft and boat electrofishing. The boat has proven more successful than the raft, so PG&E has continued annual boat electrofishing efforts from June to September (PG&E 2007, 2023).

3.2 Novel Pikeminnow Control Measures

A recent effort to explore pikeminnow management strategies is being conducted by graduate students and professors at Cal Poly Humboldt. One student will build a population model to evaluate the effectiveness of the Trojan Y chromosome control strategy in the Eel River. A second student is developing methods for producing YY pikeminnow. To aid the construction of the population model, students are also establishing quantitative growth, maturity, and mortality relationships for Eel River Sacramento pikeminnow which are likely to be published in 2024.

3.3 Information Sharing and Coordination

Ultimately, a large-scale, coordinated suppression program is needed to have meaningful longer-term impacts on the pikeminnow population in the Eel River basin. The SF Eel River Pikeminnow Report (Stillwater Sciences and WNRD 2020) recommended improved coordination amongst groups working in the Eel River. In the last several years, groups have in fact come together to facilitate information sharing, collaboration, funding, and development and implementation of pikeminnow management strategies. The Eel River Forum has been a space where that collaboration has taken form and been able to include the public as well.

In March 2024 an Eel River Pikeminnow Symposium was organized to inform project partners, advisory committee members, interested parties and impacted persons on pikeminnow research and management in the Eel River. Project leads from this project and other project partners throughout the basin presented on their own monitoring, suppression, and research initiatives. The symposium included a break-out session where attendees broke into smaller groups that were assigned the following questions related to pikeminnow management in the Eel River basin.

- What is the overarching goal of suppression in the Eel River (e.g. eradication, population management, etc)?
- What is a realistic short term (<10 year), phased management plan for the Eel River (South Fork, mainstem, North Fork, Potter Valley Project, tributaries, estuary)?
- What role does/should pikeminnow *monitoring* play in a larger suppression strategy?
- What are the major challenges undertaking a long-term suppression plan, and how can we overcome them?
- How does pikeminnow suppression figure in the context of Eel River dam decommissioning?
- Should the Eel River consider some sort of public incentivized suppression (e.g. sport-reward program). If so, how to deal with negative side effects (e.g. bycatch, distracting from the broader ecological focus on restoration); how to fund and manage such a program.

In summary, attendees realized that the goal of suppression was to mainly make the population small enough to the point where pikeminnow are not a significant pressure to native fish species, and that would require long-term consistent management. Regarding the removal of Scott and Cape Horn dams, attendees generally expected the decommissioning process to consider and act in removing pikeminnow during that process. Attendees were also interested in a public suppression program like a fishing derby, and attendees discussed ideas of what that would look like on the SF Eel River. Overall, this symposium was an opportunity for WNRD and other project partners to inform the local community and engage with each other on pikeminnow management.

3.3.1 Outside the Eel River

Lessons can be learned from basins outside of the Eel River. WNRD and other project partners have researched other predator control programs and created connections with individuals working in those programs to share knowledge. Those relationships are ongoing. This section provides brief backgrounds on three basins where either Sacramento pikeminnow are considered invasive or a close pikeminnow relative is the focus, and there are efforts underway in implementing monitoring and suppression efforts.

Chorro Creek is a tributary of Morro Bay on the Central Coast of California and hosts two federally listed aquatic species, steelhead and California red-legged frog (*Rana draytonii*). Sacramento pikeminnow were introduced into the Chorro Creek watershed via the aqueduct system from the Salinas River drainage sometime in the mid-1970s (Moyle 2002). Interested parties have been monitoring the distribution and relative abundance of both steelhead and pikeminnow and performing various suppression methods (gill netting, seining, angling, backpack electrofishing) in the Chorro Creek watershed (Stillwater 2017, 2020). More information can be found from two reports developed by Stillwater Sciences (2017, 2020).

The Rogue River in Oregon faces the Umpqua pikeminnow (*Ptychocheilus umpquae*) that was introduced around 1978 and has been observed to predate on Rogue River salmonids (Nico and Fuller 2024). Oregon Department of Fish and Wildlife (ODFW) has organized a Rogue Pikeminnow Roundup where anglers are encouraged to capture as many Umpqua pikeminnow as possible for chances to win prizes during an allotted amount of days. Outside of those days, anglers are still encouraged by ODFW to continue fishing for Umpqua pikeminnow to help relieve pressure on native fish species.

The Columbia River basin hosts many non-native aquatic species like walleye (*Stizostedion vitreum*) and smallmouth bass (*Micropterus dolomieu*). Northern pikeminnow are a primary focus in the lower Columbia and Snake Rivers. Although they are native to the basin it is suggested that all the dams have made significant changes to the habitat and there is more predation on Pacific salmon species than there historically has been (Storch et al 2013). Pacific State Marine Fisheries Commission (PSMFC) and ODFW produced management programs to control Northern pikeminnow and other piscivorous fish populations via boat electrofishing, while the Washington Department of Fish and Wildlife (WDFW) allows sport-reward and dam-angling fisheries. More information can be found from reports developed by PSMFC, ODFW and WDFW (Ward 1990-96 and Storch et al 2013).

The use of a fishing derby or sport-reward program in the Rogue River and Columbia River has been an idea for implementation on the SF Eel River, and more broadly, the greater Eel River basin. As mentioned earlier, WNRD and project partners have connected with entities who work in these fishing derby programs and are learning more about their programs such as cost to run it, personnel required, the use of financial incentives, etc. The implementation of a pikeminnow fishing derby on the SF Eel River was a popular and seemingly well-received type of program by the Symposium attendees.

4 Recommended Management Measures

This section lists key recommended management measures for the future for Sacramento pikeminnow monitoring, suppression, data gaps and research needs in the SF Eel River, which can further be applied to the rest of the Eel River basin. An underlying thread to support the listed recommendations is the need for consistent funding.

4.1 Monitoring

Monitoring has played an important role in suppression activities conducted over the years. Monitoring informs the distribution and abundance of pikeminnow in the basin. It can also inform if suppression is having a positive or negative impact on the ecosystem. Key recommendations for improving monitoring of pikeminnow abundance and distribution include:

- Continue conducting the SF Eel River GRTS surveys to build a long-term data set for evaluating trends in the pikeminnow population and long-term response to management measures.
- Monitor survival of native salmonids and lamprey to evaluate effects of suppression.
- Determine how pikeminnow population abundance and distribution respond to years of suppression.
- Expand understanding of tributary utilization.
- Expand understanding of spawning locations and timing to take advantage of for suppression.
- Expand monitoring frame spatially and sequence of priority to include the lower mainstem Eel River and the Van Duzen River.
- Continue coordination with other Eel River interested parties and impacted persons to conduct similar annual surveys to monitor pikeminnow population throughout the greater Eel River basin to improve overall understanding of pikeminnow population trends.

4.2 Suppression

In general, a multi-pronged suppression program that removes as many pikeminnow as possible from multiple age classes is needed. Key recommendations for improving and continuing suppression efforts include:

- Expand spatially to include the lower mainstem Eel River and the Van Duzen River.
- Expand temporally to conduct suppression both earlier and later in the season to take advantage of cold-water conditions when pikeminnow are less active.
- For all suppression methods, further describe and minimize adverse impacts to native fishes. If significant impacts are unavoidable, then the methods should be abandoned in favor of less impactful approaches.
- Expand suppression work to include nighttime.

4.3 Data Gaps and Research Needs

Filling data gaps regarding the overall ecosystem impact of Sacramento pikeminnow is crucial in influencing management strategies. Overall data management and information dissemination should be integrated with basin-wide planning efforts such as the SF Eel and Lower Eel Salmonid Habitat Restoration Priorities (SHaRP) efforts and the Eel River Conservation and Restoration Program monitoring framework.

- Expand diet sampling spatially and temporally to include additional winter, spring and early summer data and collect diet data from large (300+ mm standard length) pikeminnow individuals captured in the lower mainstem Eel River.
- Utilize bioenergetics modeling to help assess the magnitude of pikeminnow predation on native fishes.
- Determine feeding rates of pikeminnow in different environmental conditions.
- At what size classes are pikeminnow consuming different species of salmonids and lamprey seasonally?
- Utilize eDNA techniques for diet sampling.
- Determine how pikeminnow removal affects native fish survival.
- Evaluate potential compensatory population responses to removal of large (300+ mm standard length) individual pikeminnow.
- Deeper cost-effectiveness analysis for different suppression techniques, number and size classes removed of different suppression techniques per dollar spent.
- Stock-recruitment curves for pikeminnow.
- Determine how timing of suppression influences success. Suppression and pikeminnow snorkel surveys tend to happen during summer and fall, but juvenile salmon outmigration tends to be in spring.
- Determine pikeminnow spawning locations.
- Evaluate diel movements of pikeminnow to inform suppression activities.

4.4 Management Plan Refinement

This project implemented an adaptive management approach (Figure 5) that is driven by the inevitable goal of supporting native species survival and productivity with the interim goals of reducing the pikeminnow population while learning more about pikeminnow ecology. Monitoring observations have largely influenced suppression efforts throughout the project period. For example, large congregations of pikeminnow, or "hot-spots" would be revisited frequently for suppression efforts. Monitoring also informed which suppression methods would be feasible based on boat access and/or habitat complexity. Monitoring and suppression efforts have fulfilled research objectives and have informed future research needs and data gaps.

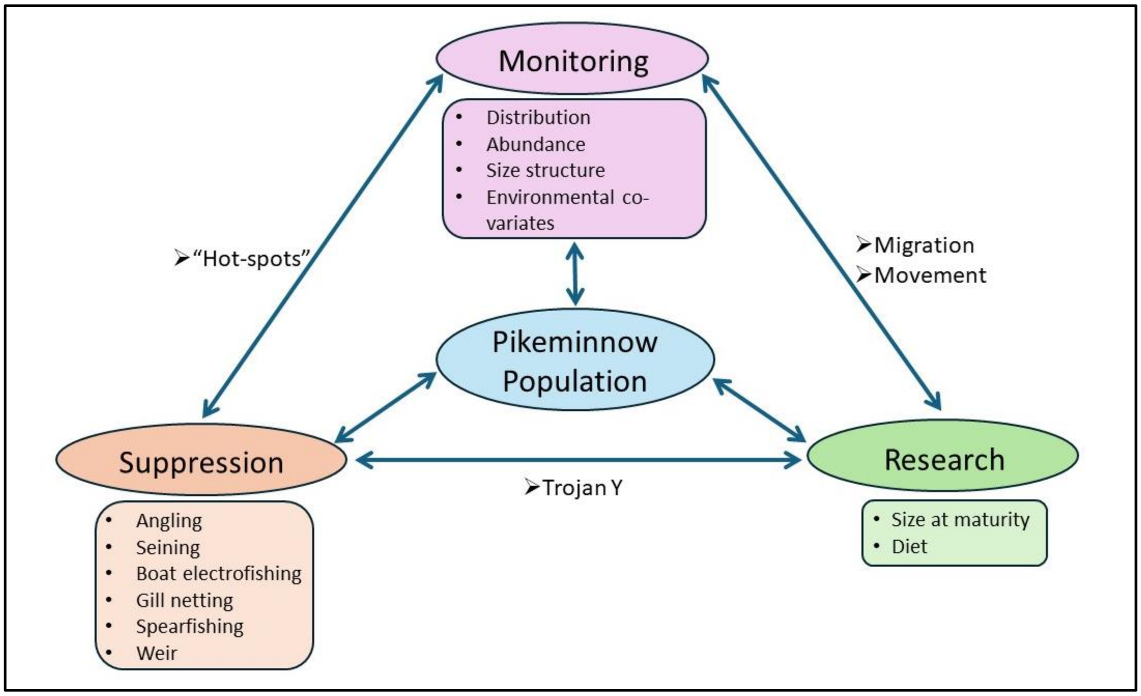

Figure 12. Adaptive management framework.

Continuation of funding and collaboration is needed for future monitoring and suppression efforts. Adequate and stable funding will support personnel expenses, address equipment needs, and build tribal capacity to persist in research, monitoring, and restoration efforts within the SF Eel River. Long-term monitoring and future research efforts, including the utilization of environmental DNA (eDNA), isotope analysis, and diet samples require ongoing financial support to fill biological gaps. Continuing to foster collaboration among SF Eel River interested parties and impacted persons is essential for recovering native fish.

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*This word has been omitted, because we refuse to perpetuate the use of harmful and outdated language.

Appendices

Appendix A

Lhou'lhaqh (South Fork Eel River) Sacramento Pikeminnow Management Plan Technical Advisory Committee, Authors, & Acknowledgements

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Appendix B

Raw data summary tables of Sacramento pikeminnow & juvenile *Oncorhynchus mykiss* counts from 2018 – 2023 GRTS snorkel surveys

Table B-1. Number of Sacramento pikeminnow counted in sampled sub-reaches of the South Fork Eel River Monitoring Reach broken up by year and size class.

[1] Considered a coarse estimate due to high numbers of small fish, potential misidentification as the co-occurring Northern Coastal Roach, and focus on surveying habitats preferred by larger size classes.
*Surveyors counted pikeminnow into two different brackets than usual: 300-400 mm and >400 mm.

	Sub-reach	Sampled date	0-100 mm[1]	101-200 mm	201-300 mm	301-450 mm	>450 mm	Total by year
2018	1	7/5/2018	336	98	126	25	34	**17117**
	7	7/17/2018	265	1	14	25	7	
	12	7/11/2018	1849	644	169	62	25	
	17	7/17/2018	1250	321	191	37	2	
	23	7/18/2018	740	82	68	37	7	
	31	7/19/2018	1325	102	89	81	14	
	35	7/19/2018	120	11	71	16	4	
	40	7/12/2018	1427	257	60	38	8	
	42	7/20/2018	350	186	38	106	8	
	48	7/24/2018	574	500	50	7	0	
	53	7/25/2018	2047	1232	291	61	42	
	57	8/1/2018	395	1130	28	30	4	
2020	6	7/15/2020	1719	51	28	7		**24539**
	9	7/15/2020	1470	46	18	6		
	18	7/17/2020	1845	332	40	12		
	20	7/16/2020	485	249	47	3		
	22	7/16/2020	650	228	81	22		
	27	7/17/2020	1420	151	10	11		
	31	7/21/2020	1710	459	52	42		
	34	7/21/2020	2350	1025	55	10		
	39	7/21/2020	1900	315	57	9		
	43	7/22/2020	1682	950	110	47	2	
	52	7/22/2020	1325	300	0	0		
	56	7/22/2020	2300	686	180	39	3	
2021	8	6/24/2021		431	8	3		**11516**
	16	6/25/2021		1134	231	93	7	
	17	6/25/2021		727	171	15		
	20	6/28/2021		485	168	10		
	25	7/1/2021		447	140	19	4	
	26	7/1/2021		348	74	26	1	
	30	6/28/2021		37	2	3		
	32	7/9/2021		457	58	30		

	40	7/7/2021		1334	131	48	2	
	46	6/30/2021		733	264	52	5	
	49	7/2/2021		767	52	6		
	53	7/8/2021		1336	124	13	5	
	57	6/29/2021		1420	95			
	5	6/30/2022		233	137	26	0	
	6	6/30/2022		336	124	22	2	
	10	6/27/2022		282	254	23	2	
	19	7/8/2022		990	211	48	8	
	30	7/5/2022		14	27	0	0	
2022	34	7/1/2022		450	127	18	2	**7299**
	37	7/7/2022		532	129	9	0	
	40	7/5/2022		542	78	8	2	
	42	7/7/2022		883	230	44	8	
	51	7/11/2022		375	177	12	0	
	53	7/12/2022		451	236	41	6	
	58	6/14/2022		100	70	28	2	
	1	7/5/2023		120	75	26	4	
	2	7/5/2023		158	104	35	14	
	7	7/19/2023		133	43	3	0	
	11	7/19/2023		380	98	41	21	
	15	6/27/2023		185	108	6	1	
	17	7/8/2023		98	101	23	1	
	19	7/20/2023		416	259	119*	10*	
	23	6/15/2023		297	97	38	1	
2023	29	6/16/2023		82	13	21	2	**5797**
	31	6/16/2023		120	113	31	2	
	37	7/7/2023		163	83	29	4	
	39	7/7/2023		384	101	41	4	
	43	7/6/2023		229	208	61	22	
	45	7/6/2023		42	130	94	11	
	47	7/7/2023		476	90	50	4	
	54	6/22/2023		31	24	60	14	
	57	6/29/2023		134	28	10	0	

Table B-2. Number of juvenile *O. mykiss* counted in sampled sub-reaches of the South Fork Eel River Monitoring Reach broken up by year and size class.

	Sub-reach	Sampled date	0-100 mm	101-200 mm	>200 mm	Total by year
2018	1	7/5/2018				**26**
	7	7/17/2018				
	12	7/11/2018		1		
	17	7/17/2018				
	23	7/18/2018				
	31	7/19/2018				
	35	7/19/2018				
	40	7/12/2018				
	42	7/20/2018			15	
	48	7/24/2018		3	2	
	53	7/25/2018			3	
	57	8/1/2018			2	
2020	6	7/15/2020				**22**
	9	7/15/2020				
	18	7/17/2020				
	20	7/16/2020				
	22	7/16/2020				
	27	7/17/2020				
	31	7/21/2020				
	34	7/21/2020				
	39	7/21/2020				
	43	7/22/2020				
	52	7/22/2020	9	1	4	
	56	7/22/2020	1	3	4	
2021	8	6/24/2021				**99**
	16	6/25/2021				
	17	6/25/2021				
	20	6/28/2021				
	25	7/1/2021				
	26	7/1/2021				
	30	6/28/2021	1			
	32	7/9/2021				
	40	7/7/2021				
	46	6/30/2021	38			
	49	7/2/2021	3		10	
	53	7/8/2021	5			

	57	6/29/2021	11	30	1	
2022	5	6/30/2022		1	2	**1523**
	6	6/30/2022			1	
	10	6/27/2022		4		
	19	7/8/2022	1	2		
	30	7/5/2022	10	16	1	
	34	7/1/2022	30	26	1	
	37	7/7/2022	64	49	23	
	40	7/5/2022	131	120	29	
	42	7/7/2022	90	92	30	
	51	7/11/2022	81	146	20	
	53	7/12/2022	179	229	38	
	58	6/14/2022	43	53	11	
2023	1	7/5/2023	2	6		**883**
	2	7/5/2023	5	31	5	
	7	7/19/2023	1	8	2	
	11	7/19/2023		10	4	
	15	6/27/2023		2	5	
	17	7/8/2023			3	
	19	7/20/2023		6		
	23	6/15/2023				
	29	6/16/2023		2		
	31	6/16/2023		4	1	
	37	7/7/2023	1	4		
	39	7/7/2023		17	13	
	43	7/6/2023		4	3	
	45	7/6/2023	3	12	6	
	47	7/7/2023	33	243	49	
	54	6/22/2023	18	159	18	
	57	6/29/2023	7	93	103	

Appendix C

Summary of sub-reaches snorkeled in 2018 – 2023 & their associated habitat data

Table C-1. Summary of sub-reaches snorkeled within the Monitoring Reach by sampled date, river kilometer of downstream end, length of sub-reach, and number of units split by habitat types.

Sub-reach	Sampled date	River kilometer of downstream end	Length (km)	Number of units by habitat type	
				Pool/flatwater	Riffle
1	7/5/2018	0	0.8	2	2
7	7/17/2018	9.4	1.2	2	1
12	7/11/2018	16.2	2.9	8	4
17	7/17/2018	26.3	1.2	2	1
23	7/18/2018	36.6	1.4	2	2
31	7/19/2018	51.4	1.6	3	3
35	7/19/2018	58.4	1.3	3	3
40	7/12/2018	66	2	5	4
42	7/20/2018	70.6	2.8	7	7
48	7/24/2018	85.6	1.5	5	3
53	7/25/2018	92.9	3.6	11	9
57	8/1/2018	101.2	1.2	4	3
6	7/15/2020	7.4	2.02	7	4
9	7/15/2020	11.8	1.25	6	3
18	7/17/2020	27.3	1.69	4	2
20	7/16/2020	32.4	1.8	4	3
22	7/16/2020	35.2	1.37	3	2
27	7/17/2020	43.9	1.87	6	5
31	7/21/2020	51.4	1.6	5	2
34	7/21/2020	56.4	2.2	3	3
39	7/21/2020	64.5	1.48	3	1
43	7/22/2020	73.4	2.18	11	9
52	7/22/2020	91.1	1.84	5	5
56	7/22/2020	100.1	1.16	10	5
8	6/24/2021	10.5	1.31	6	3
16	6/25/2021	25.4	1.02	6	2
17	6/25/2021	26.3	1.01	5	3
20	6/28/2021	32.4	1.8	4	3
25	7/1/2021	39.2	1.97	9	5
26	7/1/2021	41.1	2.78	18	5
30	6/28/2021	50.1	1.32	5	3
32	7/9/2021	53	1.74	10	6
40	7/7/2021	66	2.27	11	7
46	6/30/2021	80.1	3.43	17	6

49	7/2/2021	87	1.13	6	2
53	7/8/2021	92.9	3.63	19	8
57	6/29/2021	101.2	1.12	8	5
5	6/30/2022	5.6	1.71	6	0
6	6/30/2022	7.4	2.02	6	4
10	6/27/2022	13	1.38	4	2
19	7/8/2022	29.1	3.62	10	3
30	7/5/2022	50.1	1.32	2	3
34	7/1/2022	56.4	2.19	7	5
37	7/7/2022	61	1.65	4	4
40	7/5/2022	66	2.26	6	5
42	7/7/2022	70.6	2.84	9	7
51	7/11/2022	89.1	2	6	3
53	7/12/2022	92.9	3.62	7	8
58	6/14/2022	102.3	2.35	10	5
1	7/5/2023	0	0.81	1	1
2	7/5/2023	1.3	1.65	4	4
7	7/19/2023	9.4	1.04	3	1
11	7/19/2023	14.4	1.84	6	4
15	6/27/2023	23	1.91	4	5
17	7/8/2023	26.4	1	4	2
19	7/20/2023	29.1	3.62	9	4
23	6/15/2023	36.6	1.51	7	4
29	6/16/2023	47.7	2.5	8	6
31	6/16/2023	51.4	1.59	4	4
37	7/7/2023	61	1.65	4	3
39	7/7/2023	64.5	1.48	5	5
43	7/6/2023	73.4	2.18	8	8
45	7/6/2023	77.9	2.32	10	8
47	7/7/2023	83.4	2.17	12	9
54	6/22/2023	96.4	2.2	8	3
57	6/29/2023	101.2	1.12	7	4

Appendix D

Sacramento pikeminnow & salmonid movement

Another exciting collaboration is an acoustic telemetry study focused on the SF Eel River and expanding into the lower mainstem and the estuary of the Eel River. Collaborators from CDFW, UC Berkeley, Stillwater Sciences, WNRD with significant support from BLM and NOAA are contributing to this study. This was initiated in 2021 with the intent of studying juvenile Coho salmon movement through the mainstem SF Eel River starting in the fall of that year. In order to take advantage of this immense equipment and labor value, project partners saw this opportunity to track adult Sacramento pikeminnow movement in the SF Eel River using acoustic telemetry. Approximately 80 acoustic tags and tagging equipment were purchased, with contributions from BLM, UC Berkeley, and Stillwater Sciences. Set at a 10 second "ping rate", these tags have a battery life of over 400 days. Seventy-six tags were deployed at sites throughout the SF Eel River during summer 2021 suppression activities and during targeted tagging efforts.

Starting in fall 2021, CDFW deployed paired Lotek acoustic receivers at three locations between Piercy (rkm 81) and the mainstem Eel confluence. UC Berkeley also purchased a Lotek receiver and deployed it in a large pool near the Gomde Monastery (rkm 112) in late-September. Additionally, Stillwater Sciences purchased an ATS "shore-based" receiver to use for boat-based, mobile tracking efforts. Mobile tracking was tested at tagging sites (Miranda and Sylvandale) in the fall 2021 and several longer mobile tracking efforts in reaches of the lower mainstem Eel River were conducted by the Wiyot Tribe, Stillwater Sciences, and CDFW in January 2022 (note both the ATS receiver and ''stationary'' Lotek receivers have been used for this purpose).

This study has expanded in 2022, 2023 and the upcoming 2024 season both in number of tags deployed and the geographic range of acoustic array reach. Some of the data from both stationary acoustic receivers and mobile tracking efforts have been fully processed and summarized, but a formal report is forthcoming.