Conservation Strategy
for the
Clear Lake Hitch
(Lavinia exilicauda chi)

Photo credit: Ben Ewing
Executive Summary and Purpose

The Clear Lake hitch (Lavinia exilicauda chi) (CLH) is a subspecies of hitch endemic to the Clear Lake watershed in Lake County, California. The CLH is listed as threatened under the California Endangered Species Act and has been designated as a sensitive species by the U.S. Forest Service. Cumulative impacts to the watershed due to human activity beginning in the late 19th century and continuing through the late 20th century have resulted in greatly reduced numbers of CLH compared to historical numbers. Impacts to the watershed that have contributed to this decline include reduced water quality within the lake and its tributaries, reduced access to spawning habitat due to a lack of water retention in the tributary streams and the presence of passage barriers, the loss of gravel spawning beds in its tributaries, loss of wetland and near-shore rearing habitat, and manipulations to the Clear Lake food web due to non-native species introductions.

The purpose of this conservation strategy is to serve as a framework for the conservation and protection of the CLH, and to contribute to the species’ persistence into the future. This document identifies conservation actions that will be implemented to reduce and/or eliminate the threats that are impacting spawning, rearing, and recruitment of CLH, and preserve the viability of this unique subspecies. This strategy describes current conditions and threats, prioritizes and describes the specific conservation actions needed to establish a stable population, and identifies the roles and responsibilities of collaborating partners for each action. The essential conservation measures for establishing a self-sustaining population of CLH fall into six categories listed below in order of priority. Specific conservation actions are provided to support each category described below.

1. Increase reproduction and recruitment by improving passage into and through Clear Lake tributaries, and through the restoration of watershed function. Migrating and spawning CLH require improved passage through the primary tributary streams, including Kelsey, Cole, Hill, Adobe, Manning, Robinson, Scotts, Middle, Clover, Morrison, Schindler, and Seigler Canyon Creeks. In addition, the development and implementation of effective habitat restoration projects and management strategies to improve watershed function, including flow maintenance, restoration of gravel spawning beds in the creek channels, wetland habitat condition, and aquatic habitat condition, are essential to increase and stabilize recruitment. Adaptive management and monitoring of land use activities to support CLH conservation objectives are key to the long-term success of this goal (Goal 1, Objectives 1.2–1.4; Goal 2; Goal 3; Goal 4, Objective 4.3).
2. Continue and expand population monitoring efforts within the lake and tributary streams, and develop a standardized protocol to monitor various life history stages (Goal 1, Objective 1.1; Goal 4, Objective 4.4).
3. Continue water quality monitoring within the lake and tributary streams. Develop and support research projects to inform how water quality is affecting reproduction, recruitment, and survival of CLH (Goal 4, Objective 4.1).
4. Develop and support research projects to inform adaptive management and success criteria of conservation actions outlined herein (Goal 4).
5. Expand outreach and education programs relating to CLH and the conservation of its habitats (Goal 5).
A corresponding Conservation Strategy Agreement (Appendix A) commits participating tribes, agencies, and partners to provide, to the extent possible, necessary financial and logistical support for the proposed work. The implementation of this Conservation Strategy is intended to effectively restore spawning and rearing habitat, improve water conditions within the watershed, and provide migratory access to spawning habitat with the goal of establishing a stable population of CLH. If this strategy is effectively implemented, future generations will be able to experience a hitch spawning run, which is best described by Richard Macedo (1994):

“As spectacular as any salmon run on the Pacific coast, hitch mass by the thousands and ascend the many streams leading into Clear Lake. The tumultuous splashing in creeks and the appearance of herons, osprey, egrets and bald eagles in trees overhanging streams signify to the human observer that the hitch are in. Along stream banks, raccoons, mink, otter and even bears join the birds to feast on hitch as they make their way up swiftly flowing streams. Hitch number in the thousands and creeks teem with creatures eager to take advantage of this bounty.”
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**Acronyms and Abbreviations**

Adaptive Management:
"Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders."

– National Resource Council, adopted by the Department of the Interior

BIA: Bureau of Indian Affairs
BMPs: Best Management Practices
°C: Celsius (temperature measurement)
CALPIP: California Pesticide Information Portal
CCCLH: Chi Council for the Clear Lake Hitch
CDFA: California Department of Food and Agriculture
CDFW: California Department of Fish and Wildlife
CEPA: California Environmental Protection Agency
CESA: California Endangered Species Act
CEQA: California Environmental Quality Act
CLERC: Clear Lake Environmental Research Center
CLH/hitch: Clear Lake hitch
CLIWMP: Clear Lake Integrated Watershed Management Plan
Council: Chi Council for the Clear Lake Hitch
CRMP: Coordinated Resources Management Planning group
DDD: dichloro-diphenyl-dichloroethane
DDE: dichlorodiphenyldichloroethylene
DDT: dichlorodiphenyltrichloroethane
DO: dissolved oxygen
DU: dwelling units
DWR: Department of Water Resources
EPA: Environmental Protection Agency
°F: Fahrenheit (temperature measurement)
ft: feet (measurement)
HAMP: Hitch Adaptive Management Plan
HERC: Hintil Environmental Resources Consortium
IPCC: Intergovernmental Panel on Climate Change
KCDS: Kelsey Creek Detention Structure
km: kilometer (measurement)
Land Trust: Lake County Land Trust
LCVCD: Lake County Vector Control District
m: meter (measurement)
mi: mile (measurement)
mm: millimeter (measurement)
NGVD 29: National Geodetic Vertical Datum 1929
NPDES: National Pollutant Discharge Elimination System
OEHHA: Office of Environmental Health Hazard Assessment
PIT tag: passive integrated transponder tag
Polymictic: lake characteristic when thermal stratification does not occur
RCD: Resource Conservation District
RCP: Representative Concentration Pathway
RFID: Radio Frequency Identification
Service: US Fish and Wildlife Service
SL: standard length (fish measurement)
sq. ft.: square feet
TMDL: Total Maximum Daily Load
USACE/Corps: US Army Corps of Engineers
USGS: US Geological Survey
VOC: Volatile Organic Compound
Chapter 1. Introduction

The Clear Lake hitch (CLH) is a subspecies of fish in the freshwater minnow family Cyprinidae and is restricted to the Clear Lake watershed in Lake County, California. Clear Lake is located approximately 100 miles north of San Francisco in the Coast Ranges and experiences hot, dry summers and cool, wet winters, with most precipitation occurring from November to March. The watershed has limited snowpack in most years. The lake is fed by numerous tributaries, most of which are ephemeral and low gradient as they drain into the lake. Historically, the CLH could be found in the numerous lakes and ponds found throughout the Clear Lake watershed, and during the spring, reproductive adults would migrate into the many tributary streams to spawn. Currently, the species is still found throughout most of its historical range, although in much reduced numbers.

Adult CLH have a deep and elongated body and can grow to over 350 mm standard length (SL). They have a relatively small conical head, a terminal or slightly upturned mouth, and the morphology of their pharyngeal teeth are evidence of their limnetic lifestyle. Juvenile CLH have a black spot at the end of the tail that extends to the head region as a gradually fading black stripe; however, as individuals age, their coloring fades and they become a brownish-yellow. Female CLH are known to grow larger than males and while males are sexually mature within their first or second year, females are sexually mature in their second or third year. CLH are thought to live 4 to 6 years, but it is possible some individuals can live longer. Female CLH are highly fecund; one female that is reproductive at age 3 and lives to age 6 could produce an average 100,000+ eggs over her lifetime.

Early accounts considered the CLH to be identical to the hitch found in the Sacramento River (Lavinia exilicauda); however, in 1973 John D. Hopkirk described the CLH as a distinct “lake-adapted” subspecies and found it could be differentiated by its deeper body form, larger scales and eyes, and its greater number of gill rakers. Past nuclear DNA analysis supported the subspecies designation for the CLH; however, a mitochondrial DNA analysis did not. A more recent genomic analysis suggests the three currently recognized subspecies of hitch within California show strong population structuring, but only weak subspecies structuring. Further studies should be completed to clarify the taxonomic status of the CLH.

Anthropogenic impacts within the Clear Lake watershed in the latter half of the 19th century through the latter half of the 20th century led to the degradation and loss of natural spawning and rearing habitat, the degradation of water quality throughout the watershed, and a decline in the overall population of CLH. These impacts were due to past in-stream and lake-side mining activities, agricultural and urban development, increased fire activity, past deforestation, and historic overgrazing practices. The degradation and loss of spawning habitat due to past watershed modifications have blocked access to or altered the flow regime of tributary streams, reducing early life stage survival, reproductive success, and the likelihood of recruitment. The degradation and loss of rearing habitat also reduces early life stage survival and the likelihood of recruitment, and poor water quality reduces adult and juvenile survival. In addition to human activities that directly impacted the species’ habitat, there have also been numerous non-native fish species introduced that prey upon and compete with the hitch, further reducing survival of all life stages, reproductive success, and the likelihood of recruitment. Natural occurrences like
drought can further reduce the likelihood of reproductive success, recruitment, and survival by reducing tributary flow and wetland vegetation growth.

There are many different entities that are dedicated to the protection, restoration, and/or conservation of the Clear Lake hitch and the Clear Lake watershed. Here is a summary of some of those entities and their conservation efforts:

Since 2004, five Lake County Tribes have collaborated in targeted response to the alarming decline of the CLH. Fish populations in the tributaries surrounding the Clear Lake Basin, where past and future generations gathered, were notably less as observed in fish counts and by anecdotal evidence. The hitch are a vital part of the historical diet and cultural practices of the Pomo Indians, who have inhabited the Clear Lake region for over 11,000 years. The Habemateolet of Upper Lake Pomo, Robinson Rancheria of Pomo Indians, Big Valley Band of Pomo Indians, Elem Indian Colony, and the Scotts Valley Band of Pomo Indians, worked together collectively to increase hitch survivability by the development of the “Clear Lake Hitch Study and Recovery Program.” A detailed description of projects completed by each of the five Lake County Tribes can be found in Section 3.1 below.

The Chi Council for the Clear Lake Hitch (Council) is a coordinated resource management and planning group dedicated to the study, protection, and restoration of a viable population of CLH within a healthy watershed ecosystem. The Council was formally established in 2004 and has the following immediate objectives: coordinating and training volunteer population monitoring teams; establishing scientific protocols for the monitoring effort, and maintaining a database of the information learned; encouraging scientific research on CLH and their habitat; enhancing public awareness of CLH and their habitat; gathering and preserving information about CLH and their traditional uses by the native peoples of the Clear Lake Basin; and sponsoring habitat restoration projects.

The 15-member Blue Ribbon Committee for the Rehabilitation of Clear Lake (Committee) was created by Assembly Bill 707. The Committee includes representatives from tribes, Lake County, UC Davis, and the Central Valley Regional Water Quality Control Board, and also includes four members appointed by Lake County with expertise in agriculture, economics, environment, and public water supplies. The Committee has been given the important charge of making recommendations for rehabilitating Clear Lake, which is critical to Lake County’s economy, ecosystem, and heritage. Creation of the Committee is part of the State of California’s ongoing investments in Clear Lake, which include a $2 million multi-year scientific research contract with UC Davis, $5 million in voter-approved bonds from Proposition 68, and a $15 million bond-funded investment to aid in the Middle Creek Restoration project.

The Clear Lake Environmental Research Center (CLERC), a 501(c)3 non-profit organization, was formed in 2014 as a way to increase the amount of research being conducted on Clear Lake and use this research as a vehicle to improve the local economy. As a nonprofit, CLERC has the ability to raise funding for research independent of annual tax collections, which have failed to pass in the past. CLERC’s purpose is to locate a permanent research lab on the shores of Clear Lake that will serve as a driver of the local economy and increase the public’s understanding of Clear Lake at the same time. CLERC coordinates with the Council on their annual volunteer fish observation reporting.
The Big Valley Band of Pomo Indians and the Elem Indian Colony began a cyanobacteria and cyanotoxin monitoring program on Clear Lake in 2014. Together the two Tribes' Environmental Departments have collaborated to test the water for cyanotoxins produced by cyanobacteria (also known as “Blue Green Algae”), which can include neurotoxins, liver toxins, and skin toxins. The Tribes began this program because despite the fact that Clear Lake had thick, noxious blooms covering its surface every summer since 2009, there was no regular and active monitoring of these blooms for the cyanotoxins that the California Office of Environmental Health Hazard Assessment (OEHHA) had reviewed and suggested Action Levels for in 2012, and for which the World Health Organization provided guidance regarding exposure in the 1990s.

The Lake County Land Trust (Land Trust) has been protecting and preserving local lands since it was formed and officially incorporated as a 501(c)(3) charitable non-profit organization in 1993. The Land Trust is committed to protecting wildlife habitats and native plants, using resources wisely, and making the natural environment accessible for all, through guided hikes, field trips, special events, and designated public access areas. The Land Trust owns and/or manages five large properties as well as over 80 acres of conservation easements, including the newly acquired Wright Property.

On August 6, 2014, the California Fish and Game Commission determined the CLH warranted listing as a threatened species under the California Endangered Species Act (CESA). Fish and Game Code § 2067 states a “(t)hreatened species” means a native species or subspecies of bird, mammal, fish, amphibian, reptile, or plant that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by this chapter. As a threatened species under CESA, the take of individuals is prohibited unless the take is authorized by a permit.

The US Fish and Wildlife Service (Service) was petitioned by the Center for Biological Diversity to list the CLH under the authority of the Federal Endangered Species Act of 1973, as amended. The petition was dated September 25, 2012. The Service issued a 90-day finding on April 10, 2015 (Service 2015), stating that listing the CLH may be warranted. On December 3, 2020, the Service published a not warranted finding for the CLH (Service 2020).

Chapter 2. Clear Lake Hitch Natural History

2.1 Native Range
The CLH is confined to Clear Lake and its associated lakes and ponds within the Clear Lake watershed, found entirely within Lake County, California. Other lakes and ponds found within the watershed that are known to still support hitch include Thurston Lake, while populations previously identified in the Blue Lakes and Lampson Pond have apparently been extirpated (Macedo 1994; CDFW 2014; Figure 1). It is possible the population in Thurston Lake was introduced by a local lake resident; however, it currently supports a self-sustaining population. The Upper and Lower Blue Lakes, which drain into Clear Lake via Scotts Creek, are located about 10 miles northwest of Clear Lake (Hopkirk 1973; CDFW 2014). Thurston Lake is just to the west of the lower arm of Clear Lake and is geographically isolated from Clear Lake. During the spring, the species can be found spawning in the numerous tributaries throughout the Clear Lake basin, including, but not limited to, Kelsey, Scott, Middle, Adobe, Seigler Canyon, Manning, Cole, Morrison, and Schindler Creeks (Moyle et al. 1995; CDFW 2014).
Figure 1. Map depicting Clear Lake and tributaries.
2.2 Environmental Setting

Clear Lake is at its maximum 13 miles wide and 18 miles long, and is an average of 26 feet deep. It is fed by streams in the winter and spring, but in the summer, small cold water springs within the lake are Clear Lake’s principal source of water (Stone 1876). Some historical accounts describe the lake as “…cool, clear as crystal and pleasant to the taste… (Menefee 1873)”, whereas others claim it has always been turbid and cloudy, and you can only see a few feet below the surface (Menefee 1873; Stone 1876; Jordan and Gilbert 1895). The normal operation of Clear Lake is between 1318.26 and 1325.82 feet elevation (NGVD 1929) and it is the largest natural freshwater lake completely within California (Cook et al. 1966; Geary 1978; Bairrington 2000). Located within the northern Coast Range at an elevation of 402 m (1319 ft), Clear Lake lies about 161 km (100 miles) north of San Francisco and 129 km (80 miles) northwest of Sacramento. Clear Lake receives many visitors annually that participate in numerous recreational activities, including swimming, skiing, jet-skiing, boating, and fishing.

Climate

The climate of Clear Lake is typical of eastern-sloped mountains in northern California, with cool, wet winters and hot, dry summers with daytime air temperatures often exceeding 90°F. The rainy season extends approximately seven months (October-April), with 85% of the seasonal precipitation occurring during the five-month period from November through March (with July and August receiving precipitation only in trace amounts). The wet period is not usually a season of continuous precipitation, but is broken up by periods of clear, warm weather. The mean seasonal precipitation ranges from 24 inches at Clearlake Park, 28 inches at Lakeport, and 35 inches at Upper Lake, to as high as 45 inches in the Bartlett Mountains to the east and the Mayacmas Mountains to the west, and 65 inches on Cobb Mountain nine miles south of Clear Lake. Mornings at Clear Lake are usually calm and the afternoons breezy with prevailing westerly winds. Winds can become hazardous to small crafts during the afternoon hours.

2.2.1 Geology and Hydrology

Clear Lake’s geological history is intriguing. At one time, prior to the lake’s formation, the valley drained to the west into the Russian River watershed and into the Pacific Ocean. The area now known as Lower Lake drained into Cache Creek and then into the Sacramento River. Geologic evidence suggests the Cache Creek drainage was dammed by a lava flow and the only drainage outlet was to the west into the Russian River. After a landslide from Cow Mountain barred the Russian River drainage, the eastern drainage into Cache Creek was re-formed (Goldman and Wetzel 1963).

A water quality investigation conducted by DWR (DWR 1966) found more than 70% of the drainage basin of Clear Lake has less than 18 inches of soil mantle overlying impermeable formations. The shallowest (0–6 inches) soil mantles occur in the upper reaches of the watershed where the heaviest precipitation is measured. These mantles become saturated quickly (probably after 3–4 inches of precipitation), and runoff starts immediately thereafter. Because of the shallow soil mantle and the intense precipitation on the upper reaches of the watershed, there is little water retention by the soil (DWR 1966).

Hydrological Description

The hydrographic basin of Clear Lake consists of three distinct sub-basins. The western portion of the lake, known as the Upper Arm, is the largest and is a relatively uniform shallow
depression which is partitioned into the northwest and southwest quadrants. The northeast and southeast branches are known as the Oaks Arm and Lower Arm, respectively, and are narrower and deeper (Figure 1). Clear Lake is highly eutrophic and due to frequent winds, it is usually polymictic, except for weak stratification which occurs during the summer following periods of relative calm.

The Upper Arm, the largest of the three arms, is generally circular, having a maximal length of ten miles and a maximal width of eight miles. It comprises approximately 72% of the total surface area of the lake. The average depth of the Upper Arm is a little more than 23 ft, with a storage capacity of more than 730,450 acre-ft of water, 63% of the lake's total volume. The 35 miles of shoreline around this arm make up approximately 50% of the total shoreline of the lake and is more varied in topography than elsewhere around the lake.

The Oaks Arm is the smallest of the three arms and has the smallest drainage area surrounding it. It is approximately four miles long and 1.5 miles wide, comprising approximately 7% of the total area of the lake. Although smaller, it is deeper than the other two arms, with an average depth of 36 ft. The volume of the Oaks Arm is approximately 11,400 acre-ft, or 10% of the total volume of the lake. The arm contains approximately 17% (12 mi) of the lake's total shoreline.

The Lower Arm is the outlet for Clear Lake, which starts just south of Indian Island. The arm is irregular in shape, approximately 8.5 miles long and 2.5 miles wide at its widest point, and has a shoreline of approximately 24 miles. It comprises 21% of the total area of the lake, with an average depth of 34 ft. The total storage of the area is approximately 311,200 acre-ft, or 27% of the total volume of the lake (DWR 1966).

**Annual inflow/outflow**

The inflow of water to Clear Lake comes from three sources: runoff from precipitation, groundwater, and irrigation return flows. Of the three sources, runoff is the major contributing factor to inflow. The major tributaries include Kelsey Creek, Adobe Creek, Highlands Creek, Seigler Canyon Creek, Manning Creek, Burns Valley Creek, Clover Creek, Scotts Creek and Middle Creek, with Scotts and Middle Creek providing an estimated 57% of total inflow to the lake (County of Lake et al. 2010a). DWR has flow gauges on Middle, Scotts, and Kelsey Creeks, and USGS has one flow gauge on Kelsey Creek and one within the lake to measure lake stage. In 2018, UC Davis installed instream turbidity and temperature sensors at the same three locations with DWR flow gauges. Data collected at the three DWR/UC Davis sites can be found at: [https://terc-clearlake.wixsite.com/cldashboard/streams](https://terc-clearlake.wixsite.com/cldashboard/streams). Data collected at the two USGS gauges can be found at: [https://dashboard.waterdata.usgs.gov/app/nwd/?region=lower48&aoi=default](https://dashboard.waterdata.usgs.gov/app/nwd/?region=lower48&aoi=default).

The chemical quality of inflow is typical of most streams flowing from the north Coast Range of California. The concentration of agricultural chemicals entering Clear Lake is low, (M. Lockhart, Lake County Agricultural Commissioner, pers. comm. in Bairrington 2000). Chemical particulates are in low concentrations during heavy flows in the rainy season, and they gradually increase in concentration as the flow diminishes. In the past, almost all of the inflowing water to the lake was considered very good quality except for one stream, Seigler Creek, which can have high naturally-occurring boron concentrations (2-3 ppm) during periods of extremely low flow. This was not believed to have any noticeable effect on the waters of Clear Lake (DWR 1966). Trace element data for some of the primary tributary streams was collected in 2017 by USGS.
This data can be found at: https://nwis.waterdata.usgs.gov/. Various tributary water quality monitoring efforts have been conducted in the past or are currently being implemented. A summary of efforts can be found in Appendix B of the 2010 Clear Lake Integrated Watershed Management Plan (County of Lake et al. 2010a). Current tributary water quality parameters and their impact to the hitch, and the water quality of Clear Lake, need to be investigated further (see Objective 4.1 in Chapter 5 below).

Many water quality properties are dependent on lake temperatures. During initial inflow, the runoff water temperatures are lower than the lake temperature. The temperature variances are usually equalized within a period of one month (DWR 1966). The lake water temperatures follow the ambient air temperatures and seasons respectively. Afternoon surface water temperatures average 48°F (9°C) during the winter months and 80°F (27°C) in the summer. Thermal stratification of the lake occurs only rarely in the deepest areas and is often short-lived. Turbidity in Clear Lake is due to suspended clay, silt, and organic matter. Most of the lake's turbidity comes from currents stirring up bottom sediments, sediment from inflowing waters, and from biological growth. The strong wind currents which create wave action usually keep the lake thoroughly mixed (Bairrington 2000).

Hydraulic residence time
Water movement in the lake is rather slow during low runoff years with the hydraulic residence time probably reaching up to three years (DWR 1966). Most of the inflow enters the Upper Arm by means of runoff and then works its way in a southerly direction by flow and wind action. Water circulation is very slow, if existent at all, in various coves and keys. The problem is especially severe in the Oaks Keys. The Keys were designed in a manner which allows for little water circulation, and the water often becomes very stagnant, resulting in poor water quality (Bairrington 2000).

2.2.2 Land Ownership
Land ownership within the Clear Lake Watershed is comprised of mostly private lands, federal, tribal, county, and incorporated municipality. The federal land within the northern part of the watershed is managed by the National Forest Service (Mendocino National Forest), and the federal land within the western portion of the watershed is owned by the Bureau of Land Management (Cow Mountain Recreation Area). There are two cities, the city of Lakeport located along the western edge of the lake’s upper arm and the City of Clearlake, located along the southeastern edge of the lower arm.

Lake County’s Water Resources Department Lakebed Management is responsible for maintaining the public trust lands below the high-water mark in Clear Lake in accordance with Lake County Code, Chapter 23, the Shoreline Ordinance, and Chapter 639 in the State Statutes of 1973. Lakebed Management’s purpose is to improve and protect the public’s interest in the waters and the bed of the waters in and around Clear Lake, and to insure that the lands will be used for general statewide interests in furtherance of commerce, navigation, fishery, recreation and, wherever possible and appropriate, preservation of the land and waters in their natural state by establishing minimum standards for the construction, alteration, removal and maintenance of structures or other prescribed activities in the lake.
2.2.3 Existing Land and Water Use
Lake County General Plan land use designations are summarized in Table 1 and shown in Figure 2. These designations and accompanying land use regulations and zoning ordinances are important tools to foster economic and social growth while maintaining quality of life and sustainable natural resources. By clearly defining areas for higher intensity urban services and land uses from areas emphasizing rural or resource use, they provide for sustainable management, conservation, and utilization of natural resources.

Table 1. Land use type and designations for Clear Lake Watershed in Lake County, CA (CLIWMP; County of Lake et al. 2010a).

<table>
<thead>
<tr>
<th>Land Use Designation</th>
<th>Label</th>
<th>Minimum Lot Size</th>
<th>Residential Density (dwelling units/acre)</th>
<th>Typical Uses*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rural Residential and Agriculture</strong></td>
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<tr>
<td>Agriculture</td>
<td>A</td>
<td>40 acres</td>
<td>1 DU/40 acre</td>
<td>active or potential crop production, wineries, agricultural products processing</td>
</tr>
<tr>
<td>Rural Lands</td>
<td>RL</td>
<td>20-60 acres</td>
<td>1 DU/20-60 acres</td>
<td>agricultural production, single family homes, game preserves, fisheries</td>
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<tr>
<td>Rural Residential</td>
<td>RR</td>
<td>5-10 acres</td>
<td>1 DU/5-10 acres</td>
<td>large lot single family homes, small-scale agriculture</td>
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<tr>
<td><strong>Urban</strong></td>
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<tr>
<td>Suburban Residential Reserve</td>
<td>SR</td>
<td>40,000 sq.ft.</td>
<td>1 DU/1-3 acres</td>
<td>single family homes</td>
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<td>Low Density Residential</td>
<td>LDR</td>
<td>6,000 sq.ft.</td>
<td>1-5 DU/acre</td>
<td>single family homes</td>
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<td>Medium Density Residential</td>
<td>MDR</td>
<td>8,000 sq.ft.</td>
<td>6-9 DU/acre</td>
<td>duplexes, triplexes, mobile home parks</td>
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<td>High Density Residential</td>
<td>HDR</td>
<td>10,000 sq.ft.</td>
<td>10-19 DU/acre</td>
<td>where adequate urban services are present, allows duplexes, townhouses, apartments</td>
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<tr>
<td><strong>Commercial</strong></td>
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<tr>
<td>Local Commercial</td>
<td>CL</td>
<td>8,000 sq.ft.</td>
<td></td>
<td>small, localized retail, recreational, and service businesses</td>
</tr>
<tr>
<td>Land Use Designation</td>
<td>Label</td>
<td>Minimum Lot Size</td>
<td>Residential Density (dwelling units/acre)</td>
<td>Typical Uses*</td>
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<tr>
<td>Community Commercial</td>
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<td>10,000 sq.ft.</td>
<td>10-19 DU/acre</td>
<td>full range commercial, retail, and service establishments</td>
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<td>recreation, dining, hotels, motels</td>
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<tr>
<td>Industrial</td>
<td>I</td>
<td>20,000 sq.ft. or 1 acre*</td>
<td></td>
<td>geothermal service yards, large construction yards, mills, lumber yards, welding, and fabrication shops</td>
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<td>1 DU/20-40 acres</td>
<td>significant habitats, waterways, wetlands, parks, public lands (e.g., US Forest Service, State)</td>
</tr>
<tr>
<td>Public/Facilities</td>
<td>PF</td>
<td>None specified</td>
<td></td>
<td>parks, public marinas, schools, hospitals, water, and wastewater treatment facilities</td>
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</table>

*More information on Land Use in Lake County can be found online in the General Plan Layers in the publicly available Lake County Parcel Viewer: [http://gispublic.co.lake.ca.us/portal/apps/webappviewer/index.html?id=87dfc0c535b2478bb67df69d6](http://gispublic.co.lake.ca.us/portal/apps/webappviewer/index.html?id=87dfc0c535b2478bb67df69d6)
Figure 2. Map of Clear Lake Watershed General Plan Use Designations (CLIWMP; County of Lake et al. 2010a)
2.3 Taxonomy
Early accounts consider the hitch inhabiting Clear Lake to be identical to the hitch found in the Sacramento River (*Lavinia exilicauda*) (Jordan and Gilbert 1895). However, after investigations of the geographic variation of another fish species, the tule perch, it was hypothesized that the Clear Lake basin may be isolated and a center for speciation (Hopkirk 1973). Hopkirk (1973) described CLH as a lake-adapted subspecies based primarily on the greater number of fine gill rakers. CLH are distinguished from other subspecies of hitch by their deeper body, larger eyes, larger scales, and more gill rakers (numbering 26-32) (Hopkirk 1973).

Recent research on 10 microsatellite loci supports Hopkirk’s description of CLH as a distinct subspecies (Aguilar and Jones 2009). However, mitochondrial DNA analysis was not able to distinguish CLH as a distinct subspecies from other hitch in California. Based upon morphological and microsatellite analysis, some researchers believe there is sufficient evidence to warrant the designation of CLH as a distinct subspecies of hitch (Aguilar and Jones 2009; Hopkirk 1973). More recent genomic analysis indicate the three forms of hitch within California show strong population structuring, but do not show strong support for subspecies structure (Baumsteiger *et al.* 2019). Additional studies should be completed to clarify the taxonomic status of the CLH.

2.4 Subspecies Description
Adult CLH are known to grow over 350 mm standard length (SL; measurement from the tip of the mouth/snout to the end of the tail, excluding the tail fin). Their body is deep and elongated, and in cross section have been described as oval. The species has a relatively small conical head and their mouth is terminal or slightly upturned. Their pharyngeal teeth (teeth found in the throat area, behind the mouth and nose) are narrow, long, and slightly hooked with a broad surface adapted to grinding, which is evidence of their limnetic lifestyle (Moyle and Massingill 1981; Moyle *et al.* 1995; Moyle 2002; CDFW 2014). Juveniles have a black spot at the end of the tail that extends to the head region as a gradually fading black stripe (Hopkirk 1973 Moyle *et al.* 1995). As individuals age, their silvery coloring fades and their dorsal surface become a brownish-yellow (Moyle 1976; Moyle *et al.* 1995). The body becomes deeper in color as the length increases (Moyle 2002). During breeding season CLH show little change in pigmentation (Hopkirk 1973).

The subspecies of hitch in Clear Lake grow much faster than other subspecies of hitch found in lacustrine environments, which is likely due to the high productivity and warm water temperatures in Clear Lake (Murphy 1951; Moyle 1976; Geary 1978; Moyle *et al.* 1995; Moyle 2002). The subspecies is known to grow between 80 and 120 mm SL within their first year, and females are known to grow larger than males (Geary 1978). Males are sexually mature within their first or second year, whereas females are sexually mature in their second or third year (Murphy 1948; Moyle *et al.* 1995). Hitch are thought to live 4 to 6 years based on scale analysis, but it is possible some individuals can live longer (Moyle 2002; CDFW 2014). The larger size of female hitch within Clear Lake compared to the other subspecies of hitch within California equates to greater fecundity. For female CLH average annual fecundity is 36,000 eggs, with a range of 9,000–63,000 in a fish measuring 312 mm SL (Geary and Moyle 1980). Therefore, a female that is reproductive at age 3 and lives to age 6 could produce, on average, over 100,000 eggs over her lifetime.
The name *exilicauda* translates to slender tail, which is appropriate for the hitch as they have a narrow caudal peduncle (portion of the tail that holds the tail fin) (Hopkirk 1973; Moyle *et al.* 1995; Moyle 2002). It is unknown why *Lavinia*, a feminine Latin name, was applied to the hitch (Moyle 2002). The native Pomo referred to the CLH as *chy* or *chigh* and the eastern band used the name *hitch* or *hite* for the Clear Lake splittail (Jordan and Gilbert 1895; Barrett 1908; Hopkirk 1988).

### 2.5 Life History and Ecology

CLH begin to migrate into the spawning tributaries when there is sufficient runoff, typically between February and May, and sometimes into June if flows are sufficient (Macedo 1994; CDFW 2014). Because many of the lower reaches of the tributaries used for spawning historically did not have large obstacles to clear (i.e., waterfalls or rapids) and are fairly low gradient, the CLH have not evolved a strong jumping ability (Murphy 1948; Macedo 1994; CDFW 2014). The temperature of the water during spawning is typically 14°C–18°C and during spawning, one to five males will pursue a gravid female and proceed to fertilize her freshly extruded eggs (Murphy 1948; Kimsey 1960; Moyle 1976; Moyle *et al.* 1995; CDFW 2014; USGS 2018). While some adults are actively engaged in spawning behaviors, schools of non-spawning hitch hold in pool habitat and feed on invertebrates (USGS 2018).

Eggs are deposited on fine to medium sized gravel that is along the margin or mid-channel of the stream (Shapovalov 1940 *in* Murphy 1948; Kimsey 1960; CDFW 2014). After the eggs are fertilized, they sink to the gravel covered stream bottom and become wedged between the gravel interstices (Moyle *et al.* 1995; USGS 2018). Freshly extruded eggs that have not been fertilized are a light orange; however, once fertilized, eggs become a pale yellow (Swift 1965). Eggs develop and hatch within 7 to 10 days of fertilization, and the fry are able to swim freely after another 7 to 10 days, allowing them to migrate to the lake at about a month old before the streams dry up (Murphy 1948; Swift 1965; Moyle *et al.* 1995). Newly hatched hitch that were raised in a laboratory setting emerged with small yolks sacs. The just emerged young relied on the yolk until they were able to swim freely, which was after approximately 3 days. Once the fry were able to swim freely, they appeared to search for food (Kimsey 1960).

Juvenile hitch less than 50 mm SL are found within the nearshore habitat of the lake where they utilize stands of tules (*Schoenoplectus acutus*) and other submerged aquatic vegetation for cover, and feed on various insects including the Clear Lake gnat (*Chaoborus astictopus*), *Daphnia* and other planktonic crustaceans, and chironomid midges. Juveniles raised in tanks in a laboratory-type setting appeared to require water temperatures of 15°C or greater for survival (Lindquist *et al.* 1943; Geary and Moyle 1980; Franson 2012; CDFW 2014). Once juvenile hitch transition to adulthood and move from the nearshore portion of the lake into open water, they switch to a diet almost exclusively composed of *Daphnia* (Lindquist *et al.* 1943; Geary 1978; Geary and Moyle 1980; Moyle *et al.* 1995; Moyle 2002; Moyle *et al.* 2014). CLH feed primarily during the daylight hours (Geary 1978; Moyle *et al.* 1995).

Murphy (1948) stated CLH required gravel stream bottoms in order to spawn; however, Kimsey (1960) detailed his personal observation of approximately 50 individuals exhibiting typical spawning behavior (chasing, swimming rapidly, and splashing) along the shore at the Lakeport City park beach. The shoreline at this location did contain a band of clean gravel with some wave action, but was not as turbulent as the tributaries where spawning is typically observed (Kimsey
He also describes reports of young-of-year hitch caught in lakes without any known tributary access and of observations of annual spawning along the shoreline of Clear Lake (Kimsey 1960). A subsequent attempt to seine the shore resulted in the catch of approximately 15 hitch, all expressing milt or eggs, and a survey of eggs after resulted in the catch of three eggs. All three eggs were allowed to develop and hatch in a lab setting in order to confirm they were hitch (Kimsey 1960).

Kimsey (1960) also documented a self-sustaining CLH population within a farm pond near Schindler Creek. This large population was a plant from 1948 and in 1956 approximately 60,000 individuals between 1.5 and 5 inches were collected from the pond. What was unusual about this population was that there was no connection to Schindler Creek and the pond itself did not contain gravelly areas. Instead, the bottom was covered in mud and the margins contained heavy plant growth (Kimsey 1960). Therefore, it is possible the subspecies does not require streams with gravel to successfully spawn. Kimsey believes that a portion of the population is obligatory stream spawners and the other portion is able to spawn along the lake shore. Early researchers believed shore spawning in Clear Lake is likely somewhat successful and results in some recruitment to the overall population. However, they did not believe it was a major contributor to overall population recruitment due to the number of introduced predators found within the lake that prey on eggs and larvae compared to the lack of major predators within their stream habitat (Kimsey 1960; Geary 1978). More recent studies suggest the subspecies may be using Clear Lake for spawning more frequently than first thought, especially during drought conditions. The areas of the lake that the species is likely using for reproduction are along the shore, the mouths of tributaries, and Rodman Slough, which is a backwater-like area of the lake (Feyrer et al. 2019). Hitch have been observed spawning in lower Clover Creek, using a vegetated stream with limited to no coarse substrate, as well as displaying spawning behavior in a vegetated-bottom flooded field near Lakeshore Boulevard and the Nice-Lucerne Cutoff Road (pers. obs. McGinnis and Ringelberg 2010).

Adults of both sexes are presumably able to participate in at least one or two migration cycles. In recent years and as long as two or more decades ago, creeks began running dry earlier in the year. The time frame for hitch to migrate and spawn successfully has grown increasingly brief. What used to last from February to late June or even early July now appears to last from around February to April, then often only when a heavy rainstorm has occurred and runoff swells creek water for a short time. It appears that adults are very quick to migrate, spawn and return downstream, and that hatchlings and fry are equally efficient at making their way to the nearshore environment of Clear Lake, as both adults and young hitch are not easily found returning downstream (pers. obs. in Scotts Valley Band of Pomo Indians 2013; Geary and Moyle 1980).

After fertilized eggs have swelled and have become lodged in the substrate, they reportedly hatch in three to seven days at preferred water temperature ranges from 15°C to 17°C (Moyle 2002) and swim freely within several days. Older hatchlings were observed (pers. obs. in Scotts Valley Band of Pomo Indians 2013) remaining near edges of sandy creek shoreline, while fingerlings were observed in shoals, deeper in the water column in shady areas. Lighter colored hatchlings were not easily seen against the sandy substrate nor were fingerlings in shady areas, with the counter shading they had begun to develop. Participants in fish tagging and water monitoring during the 2009 migration observed that hatchlings and fry were difficult to find and when
spotted were quick to move away into deeper pools where their counter shading rendered them more difficult to find.

Hitch require sufficient water depth to navigate creeks and avoid avian predators, and observations have indicated that they are not especially strong swimmers or jumpers. They appear to avoid swift currents and enjoy resting pools and quiet areas before attempting a passage that is difficult for them. A low gradient creek is ideal, as a current that is too swift for them to navigate is a barrier (pers. comm. and pers. obs. in Scotts Valley Band of Pomo Indians 2013). They have been observed gathered behind instream boulders and clumps of plant material before venturing into a main part of a channel where water is deeper and water velocity fairly swift, making many unsuccessful attempts to continue upstream and darting back behind cover (pers. obs. in Scotts Valley Band of Pomo Indians 2013). Fish ladders designed for them would ideally have lengthy swimming areas between small rises and would have well-placed boulders and/or woody debris that creates eddies and breaks where they can rest and from which they can launch themselves upstream. If faced with a vertical challenge in a creek, they have been observed to burrow rather than to attempt a vertical jump (unpublished manuscript, Ringelberg 2009 in Scotts Valley Band of Pomo Indians 2013). When heading downstream they have been observed seeking passage over a low (approximately 15 cm) waterfall, turning back upstream and eventually being swept downstream tail first.

2.6 Population Trends

Historical Population Estimates/Observations

There are not any robust, statistically valid population estimates for the historical population of CLH. However, there are various recorded observations and incidental catch data from past commercial fishing operations, local tribal knowledge and observations, and other monitoring efforts which allows a comparison of the size of the population in the past to the size of the population now. Historical accounts of the species were primarily recorded observations of the vast spawning runs that would migrate up the tributary streams in the spring and early summer and not estimates of the species’ overall population size. Early accounts made claims that the CLH was once so abundant that during their spawning migrations they would crowd each other out to the point they would strand individuals on the shore where they would die (Rideout 1899; Thompson et al. 2013). A 1925 account of the species described hitch as the most abundant fish species in Clear and the Blue Lakes, and that hitch were “…so abundant that one can hardly step without stepping on several (Coleman 1930).” Cook et al. (1966) described the hitch as very common in Clear Lake during the early 1960s, although the authors also describe a general decline in the abundance of other stream spawning fish species.

Incidental catch records for commercial fishing operators operating between 1961 and 2001 included information about catch of CLH. Because commercial fishing operators were harvesting blackfish, carp, and goldfish, species that would be targeted within the open water of the lake, any hitch incidentally caught were likely adults (Bairrington 2000; CDFW 2014). The incidental catch data should not be directly compared to each other since the amount of effort was not recorded, sampling was not random since the commercial fishing operators fished in specific areas for their target fish species, and there is no way of knowing whether the operators were correctly identifying the species. However, these data show the number of hitch within the lake can vary widely, with some reported hauls catching no hitch at all and others recording over 10,000 individuals. The high variability of the population was likely in response to
environmental conditions within the basin, with prolonged dry periods reducing overall abundance (CDFG Commercial Catch Records 1961-2001; Cook et al. 1966; CDFW 2014).

Electrofishing surveys conducted from the 1980’s to the early 2000’s to monitor the fish population in Clear Lake showed the population of hitch can fluctuate considerably from year to year. Good years for the hitch were 1996, 1999, and 2006, and years that were considered bad for the hitch were 2000 and 2001. One thing to note is that electrofishing efforts often concentrate on the near-shore areas of the lake and not in open waters where adult hitch are more typically found (Cox 2007). The Lake County Vector Control District also kept records on hitch incidentally caught during shoreline surveys since 1987. The number of hitch incidentally caught varied from none caught at all to a high of almost 1,700 in 1991. Years with a large number of hitch captured include 1990, 1991, 2005, 2006, 2008, and 2010 (CDFW 2014).

Past incidental catch records, observational data, and the seining that Vector Control conducted cannot be compared because survey methodologies differed drastically, the purpose of these efforts, besides the spawning observations, were not to estimate the population of hitch within the lake, and because estimating the total population size in a particular year can be challenging due to the different habitats the subspecies can occupy during their different life stages.

Current Population Estimates and Distribution
CDFW began a mark and recapture effort in 2019 to estimate the size of the hitch population inhabiting Clear Lake. During the 2019 effort, electrofishing surveys were conducted at four locations within the lake: Holiday Harbor, Konocti Casino Harbor, Clear Lake State Park, and Soda Bay. A total of 184 hitch were collected over the nine sampling efforts; however, because no marked individuals were recaptured, a population estimate could not be made (Ewing 2019c). During the 2020 effort, 431 hitch were collected with five recaptures over the four sampling efforts. Additional sampling efforts were initially planned but due to the COVID-19 pandemic they were canceled. The relative population estimate for the four locations sampled in 2020 was approximately 12,770 and 15,195, using the Schnabel and Schumacher-Eschmeyer methods, respectively (Ewing 2020b). The 2021 effort resulted in a total of 384 hitch captured, with only two recaptures, over the ten sampling efforts. The population estimates for 2021 at the four locations sampled was 24,784 and 16,126, using the Schnabel and Schumacher-Eschmeyer methods, respectively (Ewing 2021b). It should be noted that many of the locations sampled during the previous efforts in 2019 and 2020 were too shallow in 2021 for the electrofishing boat to access (Ewing 2021b). Mark and recaptured surveys at these four locations are planned through at least 2023 (Ewing 2020b). Data collected during the 2020 effort and calculations to estimate population size can be found in Chapter 5, Objective 1.1.

Other recent survey efforts conducted by CDFW, local tribes, and USGS are accruing more data help inform the population estimate. Recent efforts include CDFW conducting mark and recapture surveys on a few primary tributaries to Clear Lake and visual spawning surveys on seven different tributaries to the lake. In addition to CDFW’s efforts in the tributary streams, the local tribes have been conducting visual surveys during the spawning season. The purpose of the mark and recapture and the visual spawning surveys are to determine the number of hitch spawning in each creek, determine whether individuals are returning to the same tributary to spawn every year, and collect population data to compare to existing and future efforts. Lake surveys conducted by CDFW include electrofishing efforts to identify hitch spawning in the lake,
assess the population residing in the Soda Bay, Konocti Casino Harbor, Clear Lake State Park, and Holiday Harbor areas of Clear Lake, and to determine whether hitch occupied two different waterbodies. Lake monitoring by USGS has been on-going to determine the status and distribution of the subspecies throughout the lake, and to evaluate habitat associations.

In 2013, CDFW began their mark recapture study on Kelsey and Cole Creeks, where a total of 82 fish were collected and tagged. A majority of fish were caught in Kelsey Creek (69) and only one individual was recaptured on Kelsey Creek on the last day (Ewing 2013). The 2014 effort focused on Kelsey and Adobe Creeks, and a total of 475 hitch were captured. Adobe Creek accounted for a majority of the fish collected at 357, with 118 collected from Kelsey Creek (Ewing 2014b). There were two recaptures on Adobe Creek, one that contained a passive integrated transponder (PIT) tag from a previous Upper Lake Pomo Tribe survey and the other was marked with a fin clip, which was how CDFW was marking individuals that were too small for a PIT tag (PIT tag: individuals larger than 275 mm or greater; fin clip: individuals between 200 mm and 275 mm). During the survey effort, 13 fish that were tagged in Adobe Creek were re-located into Kelsey Creek because they were at risk of stranding (Ewing 2014b).

CDFW continued the mark and recapture studies in Kelsey and Adobe Creeks in 2015, with 27 hitch captured on Kelsey Creek and 160 hitch captured on Adobe Creek (Ewing 2015a). A total of 181 hitch were tagged between the two tributaries, with 127 PIT tagged and 29 fin clipped on Adobe Creek, and 24 PIT tagged and 1 fin clipped on Kelsey Creek (Ewing 2015a). The 2016 effort also concentrated on Kelsey and Adobe Creeks, with only 30 fish caught in total. The eight hitch captured in Adobe Creek were all PIT tagged, while 17 hitch captured from Kelsey Creek were PIT tagged and the other five received a fin clip (Ewing 2016c). All of the hitch captured during the 2016 spawning survey were in the 225 mm or greater size class (Ewing 2016c). The 2017 mark recapture survey resulted in many more fish than the previous year with a total of 688 hitch, 680 of which were captured in Adobe Creek. One difference in 2017 from the past mark and recapture surveys was that high flows prevented CDFW staff from setting up the fyke nets on certain days (Ewing 2017b). Of the 688 individuals captured, 528 were PIT tagged and 24 were fin clipped. There were no recaptures on either creek and most fish captured were in the 2 to 3 year age class (Ewing 2017b). Out of all the years of sampling, only one individual that CDFW tagged had truly been recaptured (Ewing 2017b).

Beginning in 2005 and continuing until today, members of the Council conduct observational surveys on the tributary streams to Clear Lake during the spawning season. Over that time period, the number of tributaries containing spawning hitch varied. This was likely due to annual variation in environmental conditions and accessibility to spawning habitat. Observations of hitch were documented in the main tributary streams throughout the watershed in most years, except for 2013 when hitch were only observed in a few select portions of the watershed. Adobe and Kelsey Creeks had observations documented every year, although the number of fish recorded varied (CCCLH 2005-2019, observational records accessed at: https://lakelive.info/chicouncil/; CDFW 2014). Table 2 is a summary of tributaries with documented hitch from the Council observational surveys, by year.
Table 2. Summary of visual spawning surveys conducted by the Chi Council for the Clear Lake Hitch

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In addition to the mark recapture studies, CDFW initiated visual spawning surveys during the spring of 2014 on seven different tributaries to Clear Lake. The seven tributaries surveyed were McGaugh Slough, Adobe Creek, Hill Creek, Kelsey Creek, Cole Creek, Manning Creek, and Thompson Creek (Ewing 2014c). Surveys were repeated again in 2016 and have continued through 2021, and like the observational surveys conducted by the Council, the results of CDFW’s visual spawning surveys varied from year to year. The number of tributaries being utilized by spawning hitch and the number of hitch seen in each tributary or at each observation location varied each year, likely due to environmental conditions and in-stream visibility. Exactly like the Council surveys, Adobe Creek had spawning observations every year except for 2020 and 2021 when hitch were only seen by CDFW on Kelsey Creek; however, CDFW surveys were cut short in 2020 due to the COVID-19 pandemic and most survey sites were dry or had very low flow in 2021 (Ewing 2014c; Ewing 2016b; Ewing 2017a; Ewing 2018b; Ewing 2019b; Ewing 2020a; Ewing 2021a). A summary of the visual spawning surveys conducted by CDFW are shown in Table 3.
From 2017-2019, USGS surveyed Clear Lake to determine the status, distribution, and habitat preferences of the CLH throughout the lake (USGS 2018; Feyrer 2019). Survey sites were randomly spread out among the three regions of Clear Lake (Upper Lake, Lower Lake, Middle Lake/Oaks Arm) and multi-mesh monofilament gill nets were used to sample individuals one year or older (USGS 2018). A total of 653 hitch were captured over all three survey years. Minus the individuals kept for otolith analysis (see below), all hitch captured were measured for weight and length, tagged with a PIT tag, and then released back into the lake (USGS 2018; Feyrer 2019). In 2017 and 2018, 280 and 297 hitch were captured, respectively. Unexpectedly, the CLH was the 5th most abundant species collected over the course of the 2017 survey and the most abundant species captured during the 2018 effort (USGS 2018). However, the number of hitch captured during the 2019 survey drastically declined to only 76 individuals. It is unknown why the number captured in 2019 was so low, but it could be due to the atypical clarity of Clear Lake during that survey season (Feyrer 2019), which may have resulted in hitch avoiding being captured because the gill nets were visible.

One alarming observation over the course of the lake monitoring was the difference in size distribution of hitch captured over the three survey years. During the survey effort in 2017, most of the hitch captured were less than 175mm SL. That same cohort dominated the catch in 2018 and there were few individuals caught in the younger year classes. This suggests there was either a strong cohort produced in 2015 with a poor cohort in 2016 or that the 2016 cohort had poor survival going into 2018. The same cohort continued to dominate the 2019 catch, although at much reduced numbers, possibly suggesting low survival or senescence of the cohort between 2018 and 2019 (USGS 2018; Feyrer 2019). During the 2017 and 2018 efforts, the younger
cohorts were most often encountered in shore habitats while adults were more distributed among the shore, surface, and lake bottom. Hypoxia was noted in both years; however, dissolved oxygen levels were better in 2018 and more adults were captured in bottom samples that survey year (USGS 2018). Lake surveys were cancelled in 2020.

In conjunction with the lake monitoring, USGS kept a subset of adult hitch captured to analyze strontium signatures in their otoliths (ear bones) to determine natal habitat source and to estimate the age at which those individuals left their natal habitat and entered the lake (Feyrer et al. 2019). Strontium signatures from water samples taken throughout the watershed indicated the watershed could be assigned to one of five unique strontium isotope groups (SIG). Otoliths were collected and analyzed from 45 hitch approximately 2-5 years old, and individuals were assigned to one of the SIG’s based on the strontium signature on the portion of their otolith associated with early development, and therefore, natal habitat source. The waterbodies associated with the five SIG’s include: Cole Creek, Schindler Creek (SIG1); Kelsey Creek, Burns Valley Creek (SIG2); Clear Lake, Adobe Creek, Scotts Creek (SIG3); Rodman Slough (SIG4); Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5). The use of adult otoliths for the natal habitat strontium groupings indicates those areas associated with the SIG is contributing to reproduction and recruitment (Feyrer et al. 2019).

Each of the five SIG’s were represented in the otolith signatures, with most (58%) of the adults being assigned to SIG3. It is likely the natal habitat associated with a majority of individuals representing SIG3 is Adobe Creek or Clear Lake and not Scotts Creek because migration from Scotts Creek would require passage through Rodman Slough, which would be revealed during the otolith strontium analysis. A large proportion of individuals were also assigned to Rodman Slough (SIG4), which is an unexpected natal habitat type in that it is a backwater-like area of Clear Lake. Because they are well known, somewhat stable spawning tributaries, Cole Creek is the most likely natal habitat source for individuals from SIG1 and Kelsey Creek is the most likely source for individuals from SIG2. Middle, Clover, and Seigler Canyon Creeks all likely contribute to SIG5 since they all are well known sources. Additional markers need to be developed to differentiate the individual habitats within each SIG. Furthermore, additional water samples should be collected throughout the watershed since there was evidence some habitats may not have been sampled. The otolith study suggests the subspecies is able to spawn in a number of different habitat types and not just tributary streams with continual flow. The CLH is able to utilize the mouths of streams with little to no flow movement and areas within Clear Lake itself (Feyrer et al. 2019).

Chapter 3. Clear Lake Tribes

3.1 Cultural Significance, Traditional Use, and Current Use
The Clear Lake hitch is a culturally significant fish to the Native American communities, Pomo, Wappo, and Lake Miwok within the Clear Lake watershed and surrounding coastal mountains and valleys. The Tribes of the Clear Lake region continue to be concerned about the dwindling populations of native fishes within the Clear Lake watershed and the local Tribal governments have become involved in the management of Clear Lake fisheries.

The Clear Lake hitch still remains to present day a primary traditional food source to the Native Americans of the region and was a food staple of local Tribes in the past. According to stories of
Native American traditional gathering, historical populations were far greater than they have been for well over the last century. People relied on spring migrations for harvests of hitch, also called chi, which were dried and then stored for use year-round. Hitch were never difficult to find during their annual migration because tributaries, marshes and wetlands around Clear Lake were intact, and hitch reportedly spawned prolifically in all of them (anecdotal information from Tribal elders). Figures 3 and 4 below show traditional fishing equipment.

Figure 3. Fish dam, Upper Lake Area (1906)
3.2 Tribal Project Descriptions
Since 2004, five Lake County Tribes have collaborated in targeted response to the alarming decline of the Clear Lake hitch (*Lavinia exilicauda chi*). Fish populations in the tributaries surrounding the Clear Lake Basin, where past and future generations gathered, were notably less as observed in fish counts and by anecdotal evidence.

The hitch are a vital part of the historical diet and cultural practices of the Pomo Indians, who have inhabited the Clear Lake region for over 11,000 years. The Habematolel of Upper Lake Pomo, Robinson Rancheria of Pomo Indians, Big Valley Band of Pomo Indians, Elem Indian Colony, and the Scotts Valley Band of Pomo Indians, worked together collectively to increase hitch survivability by the development of “Clear Lake Hitch Study and Recovery Program”.

This “Multi-Tribal effort” (*hereafter referred to in each of the Tribal project descriptions*), whereby each Tribe worked on projects to improve the hitch lifecycle through water monitoring, scientific research, habitat restoration, study of impacts of existent management efforts, and education and outreach. It was the Tribes’ shared intent to use this information to have the hitch listed on both the State and Federal Endangered Species Act lists. In 2014, the hitch was listed on the California Endangered Species list as a “threatened” species; however, in 2020 the CLH was denied listing under the Federal Endangered Species Act. Hence, the “Multi-Tribal effort” continues the undertaking to assign hitch as “threatened or endangered” under the Federal Endangered Species Act. The Clear Lake Hitch Conservation Strategy will include previous studies and research data on the hitch compiled by the Tribes, and will expand programs and projects the hitch require to regain sustainability and to thrive once again in beautiful Clear Lake.
A detailed description of Tribal projects, by Tribe, their funding source, and Tribal contact information, are provided below.

3.2.1 Big Valley Rancheria of Pomo Indians

Clear Lake Hitch Study Project
This project was based on a Multi-Tribal effort to access local streams for viability of hitch survival, by estimating hitch population numbers, establishing a fish tagging program and participating in the gathering of baseline data and habitat information to better understand the hitch populations and what qualifies as functioning hitch habitat. The consequences of reduced water flows in the creeks where the hitch spawn, predators such as bass in the lake where they spend most of the year, and potentially polluted waters have not only reduced the hitch population, but has also reduced the number of creeks where hitch congregate to mainly two creeks, both of which are in the Big Valley sub-basin. As with other Tribes, the use of professional consultant teams assisted in this Multi-Tribal effort, which increased the efficiency of the project with shared information.

The following project objectives were accomplished:

1) The Tribe conducted water quality parameters monitoring at the creeks in the Big Valley sub-basin, several of which have hitch runs, to determine how water quality impacts hitch presence. For example, 15 years ago the hitch runs were larger than current runs, and each year the water quality prior to and during these runs provided critical information. The water quality assessment of major tributaries of Clear Lake (2010-2011) found differences in creek water quality, and it is possible these differences could determine whether hitch would be present within that creek or not. The “establishment of a Multi-Tribal water quality program and Clear Lake Specific database model” was achieved through joint water quality monitoring events, discussions and presentations of data, planning of future water quality monitoring activities and in general, a heightened sense of the need for Multi-Tribal water monitoring. The water quality data from these database models was submitted in a STORET type format shared with consultants. In 2012, the Tribe standardized its monitoring data to submit into the WQX federal water quality exchange;

2) The Tribe provided input into the development of Robinson Rancheria’s hitch hatchery operations, as part of the Clear Lake Hitch Study and Recovery Program. As noted in the Hitch Adaptive Management Plan (HAMP), this served as an excellent reference and a living document to plan future hitch recovery projects;

3) In continuance of the Multi-Tribal effort, the Tribe coordinated their fishery consultants with Habematolel of Upper Lake Pomo’s consultants in development of the hitch fish tagging and fyke net systems used in 2009, 2010, and 2011. There was a lot of trial and error in establishing the locations of the net and “corralling” the hitch into the net, as well as creating a good fence to hold the tag reader because the creek flow had been eating away at the creek bed, which undermined the efforts to have the hitch pass through the tag reader. This objective established a “Multi-Tribal fish management program”, through collaboration on equipment purchases, staff sharing, shared tasks, discussion of data, meetings on hitch issues throughout the years of the program, and
holding joint Tribal activities;

4) As a result of the Big Valley Rancheria Clear Lake Hitch Study Project, Tribal members and staff were reinvigorated to work toward the goal of identifying key factors causing the demise of the hitch. Conducting outreach and education was important to this project. A large portion of the outreach and education effort was the collection of anecdotal information through interviews of Tribal members (youth and elders) on their hitch experiences and their perspectives on how to improve hitch habitat in order to increase their numbers; and

5) Thompson Creek was chosen as a location to increase the extent of hitch habitat. The results show that creeks in the Big Valley sub-basin rarely hold water long enough during the spawning season to ensure that just-hatched hitch can swim to the lake. Tribal members and longtime locals attested that these creeks usually ran throughout the spring, up until the last few decades. It is suspected that residential and agricultural wells, along with water diversions, are causing this extreme loss of water. Thompson Creek was dry in most reaches in 2009 and 2010, but did have water during the hitch migration in 2011.

This project benefits the hitch by supplementing the natural population with hitch propagated and reared in the fish hatchery; through the evaluation of water quality and hitch movement data to help determine limiting factors and habitat usage; through the identification and evaluation of migration barriers with the goal of increased water quality and quantity of available hitch habitat; and the promotion of public education, which led to increased public awareness and support for Clear Lake Hitch Recovery. All of these benefits are essential for the successful achievement of the Multi-Tribal efforts toward protection and restoration of the hitch lifecycle.

Project Funding: US Fish and Wildlife Service Tribal Wildlife Program (2008-2011)
Project Staff: Sarah Ryan – Environmental Director

Assessment of Levels of Volatile Organic Compounds (VOC’s) and Pesticide Residues in the Creeks of the Big Valley Sub-Basin of Clear Lake

This study was conducted within the auspices of the Clear Lake Region Pesticide Environmental Risk Project which brought together 6 tribes that formed the Hinthil Environmental Resources Consortium (HERC) that sought to accomplish an intertribal pesticide environmental goal with the Clear Lake Region Pesticide Environmental Risk Project. The main aim was to increase Tribal knowledge of pesticide routes of exposure for each Lake County Tribe and to promote effective management through education and communication inside and outside of Tribal boundaries. The specific objective of this study was to quantify the residual levels of pesticides (and their metabolites) in water and sediments in the creeks within the Big Valley sub-basin.

Sampling for VOCs and pesticide residues was carried out on April 20th, 21st, and 28th of 2011, and covered the following creeks: Forbes, Manning, Thompson, Adobe, McGaugh/Hill, Kelsey, and Cole, located in the Big Valley sub-basin. Standard methods were employed in the analysis of VOCs and pesticide residues. A total of 47 VOCs and 51 pesticide residues were screened in water and soil/sediments. Results revealed that the concentrations of VOCs and pesticide residues in water and sediment are below detection levels at or above the reporting limit, though a previous study indicated widespread use of VOCs and pesticides in the Big Valley sub-basin. The detection of DDT (dichlorodiphenyltrichloroethane) and its metabolite, DDE
(dichlorodiphenyldichloroethylene), is not surprising in this area, as it was used extensively to eradicate agricultural pests from 1949 until 1964 (see section 4.4.1 below), and is known to persist and bioaccumulate in the environment. Even though the majority of the general population may not come into direct contact with large quantities of pesticides, many of the pesticide residues that are ingested tend to be lipophilic and can bioaccumulate in the body. This increases the risk of contamination along the food chain; specifically, on the culturally significant plants and fish that form the bulk of the diet of the native Indians living on the reservations adjacent to large scale agricultural farms. In the recent past, basket weavers and other consumers of culturally significant plants expressed a great concern for pesticide exposure to wild plants. A more serious concern is application of antibiotics on apples, peaches, pears, and nectarines. Application of antibiotics in the agro-ecosystem present unique circumstances that could impact the buildup and persistence of resistance genes in the environment. This study recommends further study, focusing on levels of VOCs and pesticide residues in culturally significant plants (e.g., native vegetation such as dogbane, tules, willow) and of course, the hitch.

Project Staff: Sarah Ryan – Environmental Director

Water Resource Climate Adaptation Plan on Adobe Creek for the Recovery of hitch Lavinia exilicauda chi in Clear Lake, Lake County, California

Adobe Creek is a tributary to Clear Lake and provides spawning habitat for the CLH. Adobe Creek flows from upstream in the Coastal Range, approximately seven miles to the southwestern boundary of Clear Lake and provides recharge to the aquifers within the Big Valley sub-basin. In the early 1960s, the Adobe Creek Dam was built on Adobe Creek. The Highland Springs Dam was built on Highland Creek, approximately one-half mile upstream of the confluence with Adobe Creek. Sections of Adobe Creek downstream of the Highland Springs Dam were also channelized for flood control purposes. Channelization and gravel mining led to downcutting of the creek bed, lowering the creek elevation by as much as six feet in some areas (County of Lake 2010). Flood control measures, transportation infrastructure, mining, and agricultural use of Adobe Creek have led to passage barriers and consistently reduced instream flow, and the ability to access the creek is critical for hitch survival. Climate change impacts including increased drought, higher temperatures, and more variability in precipitation patterns threaten further reduction to instream habitat for hitch. The Big Valley Rancheria used professional consultant services to address the technical aspects of this project.

The main purpose and scope of work of this study is to develop water resources management recommendations for Adobe Creek to improve habitat and enhance on-going recovery efforts for the hitch. To accomplish this, the following was completed: (1) Compiled groundwater monitoring data, hydrology data, and water use data; (2) Conducted infill survey of Adobe Creek; (3) Developed rating curve for pressure transducers; (4) Built hydraulic model of Adobe Creek; (5) Built fish habitat modeling; (6) Conducted agricultural water demand modeling; and (7) Developed recommendations for a groundwater/surface water management plan for Adobe Creek. The December 2020 Technical Memorandum performed by Flow West, “Water Resource Climate Adaptation Plan on Adobe Creek for the Recovery of Hitch in Clear Lake, Lake County” details the technical information derived from this project.

The recommendations for groundwater/surface water management to benefit hitch lifecycle requirements will require continued data collection and monitoring of water resources and land
use data in order to ensure strategies to support Clear Lake hitch survival in Adobe Creek are effective and sustainable. The following are recommendations from FlowWest: (1) Surface water monitoring: High quality, reliable streamflow monitoring is essential for ensuring hitch survival; (2) Monitor hitch passage and spawning to improve criteria for depth, velocity, and step height; (3) Groundwater monitoring: Expand monitoring locations and frequency of groundwater elevation data collected would enable tracking impacts of streamflow fluctuations on shallow groundwater table; (4) Adobe Creek channel terrain/bathymetric data: Improved in-channel terrain data will help identify and monitor hitch stranding locations; (5) Hitch counts: Coordinate with Chi Council on Adobe Creek hitch monitoring plan; (6) Land use/crop data in the Big Valley sub-basin: Improved spatial data of crops along Adobe Creek is needed to better estimate the agricultural water demand and improved water resources planning; (7) Replace culverts at Bell Hill Road, which are passage barriers; and (8) Coordinate with the County of Lake to advance the reoperation of Highland Springs Reservoir to enhance streamflow for hitch habitat through the Adobe Creek Conjunctive Use Project, if possible, for future spawning seasons.

The Multi-Tribal effort on projects completed under the Clear Lake Hitch Study and Recovery Program can assist with many of these future recommendations, as the Tribes have shown their abilities over the decades on water quality monitoring, hitch habitat restoration, and hitch observations.

Project Funding: Bureau of Indian Affairs (2018-2020)
Project Staff: Sarah Ryan – Environmental Director

Comprehensive Groundwater and Surface Water Monitoring Program for the Big Valley Groundwater Basin
The Tribe was just awarded this grant and is in the beginning stages of implementing the project. In Clear Lake, information regarding water availability for hitch during the different stages of its life cycle is lacking. A comprehensive and science-based approach for a vulnerability analysis is therefore warranted for the Big Valley Groundwater Basin Groundwater Sustainability Plan to determine the impacts on hitch from agricultural withdrawal and climate change. The objective is to both protect the aquatic ecosystems and meet resource quality objectives.

The project proposes to conduct landowner outreach to ensure successful implementation and monitoring of the project, and in addition, complete the environmental review on the 2015 “Kelseyville Creek Fish Passage Improvement Project-Basis of Conceptual Design Report.” The Elem Tribe completed 90% of the Conceptual Design Report, however, the remaining 10% for environmental review was not completed. This project aims to complete the following environmental documentation in order to move forward to the implementation phase:

- Complete a geotechnical assessment of the Kelsey 5 Creek Bridge;
- Environmental compliance - including: cultural resource survey, special status species surveys, CEQA documentation (mitigated negative declaration), USACE 404, CDFW 1600, and Lake County permits;
- Design modification to satisfy permits and specifications for a bid package;
- CDFW design review;
- Apply for California Prop 1 funding for implementation.
Results from this monitoring program and analysis will provide the capacity to directly inform the development of the Big Valley Groundwater Basin Groundwater Sustainability Plan on how they can improve habitat conditions for hitch to enable and enhance recovery efforts.

Project Funding: Bureau of Indian Affairs Climate Resilience (2020-2022)
Project Staff: Sarah Ryan – Environmental Director

3.2.2 Elem Indian Colony

Clear Lake Hitch Recovery Migration Barrier Removal
In continuance of the Multi-Tribal effort for the Clear Lake Hitch Study and Recovery Program, the Tribe applied for Service funding (for the first time) to further their role in the Multi-Tribal efforts and projects identified in the Clear Lake Hitch Study and Recovery Program. After gaining more understanding of the biology of the hitch, ecosystem restoration, and potential avenues for the stabilization and mitigation of the historic degradation of Clear Lake tributaries and losses in the hitch population, the Tribe initiated new projects recommended in the HAMP.

In the HAMP recommendations, the Tribe implemented two of three highest priority projects mentioned, one of which was in two parts. These are the three priority projects:

1a. The removal of barriers in creeks supporting hitch migration (below the barrier) and creeks with barriers that do not currently support hitch migration, but could eventually support, with a high probability, hitch migration. This project removed a migration barrier on Seigler Creek, a small creek that supports hitch spawning migration located near the Elem Indian Colony. The “2015 Seigler Creek Pipeline Replacement and Streambed Restoration Project” report provided project technical details and the scope of work. The project area consisted of approximately 0.16 acre on the bank and within the streambed of Seigler Creek. This project involved the replacement of a damaged and exposed sewer pipe and the construction of a roughened channel fish ladder. The old fish ladder was attached to the exposed sewer pipe and encasement, which was acting as a barrier to fish migration, preventing passage to good quality habitat just upstream of the barrier. Completion of the project has also opened up the potential of Seigler Creek to provide spawning habitat for the Clear Lake hitch outside of the Big Valley area, which addresses HAMP Service Goal 2.3: Habitat Conservation Off Service Lands, to provide the restoration of important habitats for the hitch and improve their life cycle quality. Other secured funding came from the U.S. Bureau of Reclamation for the fish ladder portion of the project and the Lake County Special Districts funded the replacement of the old sewer pipe. Approved permits and reports for the project include: Biological Assessment, Archeological Report, Wetland Delineation, 1600 Notification of Streambed Alteration, and NEPA. The County of Lake secured the Right of Entry and CEQA. The project was deemed successful and on March 12, 2017, Clear Lake hitch were spotted spawning above the new fish passageway confirming that it was designed properly.

1b. The development of the “2015 Kelsey Creek Fish Passage Improvement Project-Basis of Conceptual Design Report” was completed and provided technical details and scope of work for future project implementation. The purpose of the conceptual design was to
advance the design of a fish passage structure to the level suitable to obtain additional funding for final design and construction. The report summarizes the basis of a preferred conceptual design for the Kelsey Creek Fish Passage Improvement Project downstream of the Main Street Bridge, Kelseyville, California. Kelsey Creek is the third largest tributary to Clear Lake; the creek drains part of Cobb Mountain, and flows through Big Valley to its confluence with Clear Lake. The objective of this project is to improve passage for the Clear Lake hitch and other native fish species. Currently, the existing fish passage structure and grade control structure immediately downstream of the Main Street Bridge are barriers to migration for hitch and are located about four miles upstream of the confluence of Kelsey Creek with Clear Lake. These barriers prevent the use of over 8 miles of habitat upstream of the Main Street Bridge, which provides critical pools for hitch. Kelsey Creek supports an annual hitch migration that is limited from Clear Lake to reaches below the bridge. A lot of this information and data was compiled through Multi-Tribal efforts through the Clear Lake Hitch Study and Recovery Program over the last decade; and

2. Continued water quality monitoring and support as a Multi-Tribal effort for the Clear Lake Hitch Study and Recovery Program at sites located near creeks, near Tribal lands, and surrounding sites around Clear Lake. Using the Tribes Quality Assurance Plan Program (QAPP), the field data is used to support the less frequent collection of laboratory data and to provide insight regarding the more frequent changes in water quality. A principle use of the data is to scope the need for additional hitch collection and habitat restoration. The overall water quality for Clear Lake is a concern; previous studies have shown an increasing trend for conductivity which is often associated with degradation of aquatic habitat. Recent values from lake sampling generally show higher values compared to samples taken in the past, and are comparable to the range of values in samples collected by the California Department of Water Resources. Future recommendations to follow include: combining the two sampling points into one at Seigler Creek since both have similar sampling periods, ease of access should determine which is to be limited; install continuous monitoring devices at the remaining tributary sampling points that support or can potentially support hitch migration (the exception would be Schindler Creek since the flow period is short, presence of significant barriers to migration near the lake and likelihood of restoration is limited); monitoring should continue at sites that have been restored (Seigler and Middle Creeks, planned for Scotts and Kelsey Creeks) and to scope additional efforts; and data from the lake and other tributaries should be added to future analysis.

3. Burns Valley Creek Clean-ups, which historically supported a hitch migration near the Tribes land. A creek clean-up is not expected to restore the hitch habitat, but rather improve the restoration efforts and improve water quality. The creek clean-ups were public outreach events designed to improve water and habitat quality, by removing trash, green waste, and recyclables in and around the streambed, and taken to nearby disposal dumps. Burns Valley Creek is an urban creek, which makes it easily accessible for involvement of the local community and to conduct the project’s environmental outreach and education efforts provided by the Tribes. An event took place during the 10th Annual Clear Lake Clean-up Day on May 10, 2014. Several Tribes, and a few Clearlake residents
participated. A total of 25 trash bags were filled with creek debris. The Tribe provided funds for a citizen’s group of “anti-litter advocates” to organize multiple clean-ups in October, November, and December of 2015. These clean-up events took place at various locations in Clearlake and Lower Lake. At least 16 participants helped with each of the clean-up sites.

The Multi-Tribal effort in the Clear Lake Hitch and Recovery Program was instrumental in getting these projects to enact the HAMP recommendations.

Project Staff: Karola Kennedy – Environmental Director, Lamont Brown – Environmental Specialist

3.2.3 Robinson Rancheria of Pomo Indians

Robinson Rancheria Clear Lake Hitch Study and Recovery I
The goals and objectives of this three-part proposal study and recovery program is to benefit and protect the hitch. The following four project components have been accomplished: (1) The study of migration barriers in major tributary creeks of Clear Lake and the prioritization of those barriers by threat level, which enabled the Tribe and the County to develop a barrier removal plan (segment of a conservation plan for the hitch); 2) Increased tribal capacity by creation of a Habitat Conservationist position within the Robinson Rancheria Water Resources Department to represent the tribe on the Chi Stewardship Council; (3) The conservationist collected count data during the hitch spring spawning run, developed and supervised a tribal native plan greenhouse/nursery that grew culturally significant riparian plants, and sold plants to local groups and other Lake County Tribes for creek and/or lake restoration projects; and (4) Partnered with the Lake County Flood Control District on the modification of the Clover Creek Diversion Structure, to allow for improved passage during the hitch spawning migration. Robinson Rancheria completed the Fish Passage Reconnaissance: A discussion of fish barrier issues on Middle Creek, Lake County California, including engineering notes and observations from a site review of the Kelseyville fish ladder report in July 2006. The reconnaissance was intended to identify fish passage barriers, identify potential fish passage improvements, and identify restoration opportunities for reaches of Middle Creek in Upper Lake, California. Other locations including the Clover Creek bypass and two areas on Kelsey Creek, including the fish ladder near Main Street. Significant migration barriers were found in the study area on Middle Creek. These included the Rancheria Road bridge apron as well as the constructed rock weirs below the bridge. Fortunately, Middle Creek remains an ideal candidate for fish passage remediation as the lower reaches have every indication of providing safe passage for all life stages, sufficient riparian cover, and appropriate spawning gravels.

Robinson Rancheria Clear Lake Hitch Study and Recovery II
The goals and objectives of this project is to expand tribal capacity by allowing the Tribe to be the lead agency in developing a comprehensive watershed restoration plan. A Watershed Coordinator position was created and funded to interact with volunteer groups, agencies, and community members. The Project’s tasks involved working with county agencies and the Middle Creek Coordinated Resources Management Planning group (CRMP) to collect and organize existing habitat data; development of a request for proposal in the construction of a
comprehensive restoration plan for Middle Creek to re-establish a defined channel in those areas suffering from severe meandering and "braided-channel"; implement erosion control measures in areas where the channel cut into private property and infrastructure (roads, culverts, etc.); re-vegetate areas where previous work was done; promote landowner buy-in and support of the project; and continued collaboration with Middle Creek CRMP for support in implementing the ground work.

This project required collaboration with the Middle Creek CRMP and Westland Resource Conservation District (RCD) in the development of the watershed restoration and adaptive plan. In addition, the Watershed Coordinator sought funding for future projects in the Middle Creek Watershed, and conducted public education and outreach on the relationship between ecosystem vegetation, water quality, and fish health that focused on the Clear Lake hitch. The project also provided resources for Tribal members and local property owners who wanted to engage in habitat restoration. This was done in coordination with Natural Resources Conservation Service (NRCS) efforts to offer services to property owners. The Tribal Nursery provided native plants for the project and promoted the use of culturally significant vegetation for habitat restoration.

In its 2nd year, an extension was granted with Lake County Public Works on the Modification of the Clover Creek Diversion Structure project. This phase of the project required permit certification prior to construction. This included filing for: 1) CEQA Notice of Determination, Lake County Community Development, 2) 1600 Permit, California Department of Fish & Game (now referred to as California Department of Fish & Wildlife), 3) Encroachment Permit, State Reclamation Board, 4) 401 Water Quality Certification, Regional Water Quality Control Board, and 5) Memorandum of Understanding between the County of Lake and Robinson Rancheria. This took another year to get all the permit certification approved, which then required another project extension, which was granted. Actual construction of the Modification of the Clover Creek Diversion would take another year to complete.

Project Staff: Rhonda Mottlow – Environmental Director, Robert Geary – Watershed Coordinator, Anthony Duncan – GIS Technician

Robinson Rancheria Clear Lake Hitch Study and Recovery II (Continued)
The goals of this project were to continue expanding tribal capacity for the benefit of the hitch, their habitat, and to reduce CLH losses by conducting on-going research on its behavioral ecology and requirements.

At this stage of project development, the Lake County Tribes decided to join forces in formation of a Multi-Tribal effort in hitch recovery work, because the hitch is a native fish source, are a main part of the Tribes native diet, and are considered culturally significant during ceremonial practices. This Multi-Tribal effort led to each Tribe applying for hitch study and recovery projects. Examples of this work involved Multi-Tribal efforts performing water monitoring, hitch observation data, fish tagging, removing stream barriers, and re-vegetating streambeds. All data was compiled and used to move forward in promoting other hitch projects, as well as providing support and technical assistance for future grant proposals that would benefit hitch recovery.

The Watershed Coordinator continued to work and interact with volunteer groups, agencies, and
concerned community members. This included working closely with local, state, and federal agencies and the Middle Creek CRMP to collect and organize existing habitat data, overseeing the fish tagging pilot program, coordinating collection of water quality data with other agencies, and overseeing activities related to research, education, and outreach. Other important accomplishments were landowner buy-in and support of the project by conducting informational meeting summaries of fish behavioral ecology and its relationship to water quality, and implementing on-the-ground work with support from the Middle Creek CRMP. The Tribe continued working closely with the Middle Creek CRMP and RCD to secure rights of entry from willing private property owners to allow access to areas for habitat restoration. A huge part of public outreach was to provide education on the importance of the relationship between the ecosystem, native vegetation, water quality, and fish health on a broad scale. Armed with this knowledge, tribal members and local property owners engaged in habitat restoration through services offered by NRCS. This project allowed the Robinson Rancheria Nursery to continue to propagate native plants and culturally significant vegetation for restoration projects. In addition, the project continued interaction with the Clear Lake Chi Council to implement data collection, and a recovery plan for the Clear Lake hitch.

As previously mentioned, a main goal of this project was to reduce the losses of the Clear Lake hitch by conducting ongoing research on their behavioral ecology and requirements. This included the idea of raising hitch in an aquaponics tank and tag and releasing them into Middle Creek and/or Clear Lake as appropriate. To gain a greater understanding and knowledge about fish hatcheries, the Tribal Environmental Protection Agency (EPA) staff took an educational field trip to the Pyramid Lake Tribes fish hatchery in Reno, Nevada. This provided perspective on how they were raising and releasing their native fish, the Cui-ui, which has similar behavior and habitat as the hitch. This led to looking at how the hitch spawn and what type of hatchery operation would be most appropriate to construct locally, for this undertaking.

In its 3rd year after numerous project extensions, the County of Public Works completed the Modification of the Clover Creek Diversion Structure. With this done, the hitch will be able to slowly return during their spawning migration up the Clover Creek tributary.

Project Staff: Rhonda Mottlow – Interim Environmental Director, Robert Geary – Watershed Coordinator, Anthony Duncan – GIS Technician, Irenia Quitiquit – Environmental Director

The Clear Lake Hitch Study Project
This project was comprised of three parts to provide for hitch conservation and management by increasing the population through habitat restoration. In conducting this work, the Multi-Tribal effort to support the Clear Lake Hitch Study and Recovery Project continues to make progress. The Tribes accomplished a combination of water quality monitoring and fish tracking, collection of baseline water quality values, and collection of much needed ecological information using grant funds to continue hitch research and study.

The three parts implemented in this project were; (1) Establishment of a water quality sampling program (field analysis); (2) Establishment of a captive breeding program (Aquaculture) to accelerate recovery and provide stock to recovering streams and other areas of the watershed, and; (3) Establishment of a pilot tagging program to identify and track adult spawning hitch
which, along with the captive breeding program, would improve our understanding of focused and effective hitch recovery efforts.

Each of these three components included public outreach to form and build community interest and involvement. In addition, this project assessed the existing tagging systems, attempted to distinguish spawning stream fidelity, and estimated sub-population numbers. The water quality data was used as a baseline and compared with tagging results. The data was used to increase the general understanding of the hitch populations and to direct other currently proposed Middle Creek restoration efforts.

The main objective of this project was to conduct water quality assessments associated with spring migration and spawning to improve understanding of the timing and conditions for reproduction. This important target was to create efficiencies in multiple programs to improve captive breeding success and fingerling survivability. The Tribes water monitoring continued locally and eventually extended to other areas on Clear Lake. The Multi-Tribal programs led to Big Valley Rancheria conducting water monitoring in nearby Adobe Creek on Soda Bay Road, the only tributary that still supports significant hitch migrations. Later, the Habematolel Pomo of Upper Lake conducted water monitoring in Middle Creek and Clover Creek, tributaries that currently support fewer hitch migrations, but are undergoing habitat improvements including removal of barriers to migration. Findings from the project would be utilized in other surrounding areas in order to analyze habitat in and around tributaries and feeder streams of Clear Lake. The primary focus at that time was on the Northshore creeks. Hitch habitat included current and historical migration and spawning habitat in Rodman Slough, the only entrance to Northshore tributaries.

Next, a small-scale facility was established for aquaculture and propagation studies (fish hatchery) on Robinson Rancheria’s tribal land. This provided a foundation for capacity building, self-determination, and to assist in the recovery of a species of cultural concern and provide support to be listed on the State and Federal Endangered Threatened Species Lists. The Tribe recruited fishery consultant experts who were very familiar with the Clear Lake Region and the Clear Lake hitch to set-up the facility, and assisted in development of standard operating procedures and provided training to select tribal staff. The fishery consultants provided the necessary skills and expertise on the fundamentals of aquaculture, the mechanics of species propagation, and the capability of examining the life history of the hitch. The hatchery facility was comprised of a water delivery and management system, breeding troughs, egg jars, fry tanks, and all the standard fish hatchery elements. To date, juvenile hitch of a certain age, approximately 2 months, have been reared successfully at the Tribe’s fish hatchery, but egg incubation and larval hitch development and growth were not successful. However, two larval hitch thrived and grew in a small, un-aerated and warmer aquarium with the purpose of raising daphnia, a food supplement for fish in the brood tank.

The project also established a “Hitch Tagging Program” to identify and track adult spawning hitch in the streams to improve understanding of the hitch and to focus on effective recovery efforts. Robinson Rancheria completed the Clear Lake Hitch Study and Recovery Project Water Quality Report a Tagging and Habitat Study Report, December 2008-2009 as a component of the HAMP. Fishery consultants participated in and oversaw the Multi-Tribal efforts during the hitch tagging events. Nearly 500 fish were tagged with Radio Frequency Identification (RFID)
units on Adobe Creek. Due to the nature of tagging and the concern for the hitch, the fishery consultants found it necessary to develop a standardized protocol. These protocols were used to reduce injury or mortality to the hitch, to reduce measurement error from individual field practices, and to facilitate procedures by using standardized methods, measuring equipment, tag type, and tag frequencies. In addition, the Tribes used the project to train Tribal staff in fish tagging and other management methods essential to the long-term success of the program and they, in turn, supported the development of effective capture, tagging and measurement methods. A 2010 Draft Hitch RFID Tagging Protocol was developed to follow when fishery consultants were not available. The Habematoel Pomo of Upper Lake took the lead on following up on collecting the RFID’s readings during the following year’s hitch migration upstream as a Multi-Tribal effort. To capture the hitch for this tagging event, Fyke nets (temporary system) were installed in the streambed using various design methods to capture as many hitch as possible and was very successful. The same time the hitch tagging was occurring, the fishery consultant also organized water quality monitoring around the lake, and each participating Tribe was responsible for their own monitoring equipment and organizing monitoring in their areas. In general, water quality equipment, tagging equipment, and tagging events were shared as a Multi-Tribal effort.

Hopefully, in the future, the following hitch management recommendations resulting from tagging, habitat restoration, and fish hatching and rearing can be further implemented through study, research, and on-the-ground habitat restoration:

- Readers that record tagged hitch will help us learn more about hitch behavior including whether they return to tributaries where they spawned. On-going work should focus on habitat restoration in areas where hitch occur, where they prefer to be, and where they are or could potentially be most successful reproductively and where safe passage is available for adults and juveniles. It would also provide insight into where adults reside in the lake, whether in the main body of Clear Lake or if they spend most of their time near Tule beds or other protected areas. Tagged hitch will help us to learn where they are, where they go, and hopefully what stimuli they use for migration.

- The Clear Lake Basin and its watersheds were once habitat for hitch, where they evolved and until the last century or so, where they maintained their populations. Present day observations of hitch appear to show a decline in migrating and spawning. They seem to have very few places to go given obstacles, water extraction, levees, and more. Currently, Adobe Creek supports hitch migration and spawning with numbers fluctuating every year. The large Scotts Creek watershed supported spawning runs in 2010, Robinson Creek in 2011, and a marshy, flooded field off of Cole Creek was targeted by hitch, also in 2011. Some promising management tools to increase juvenile hitch populations would be the placement of conservation easements, implementation of habitat restoration, and stream barrier removal. The proposed Middle Creek Restoration Project will offer marshland and wetland habitats, both of which would benefit hitch reproduction.

- The Tribal fish hatchery has ended its project and is seeking to find future funding to continue its operation. The primary focus will be to gather more information for successful hitch propagation and for raising hitch to help replenish their populations. Because it appears that restoration of marshland and wetland habitat is a vitally important component of the Clear Lake hitch life cycle, and therefore important to its recovery, the proposed Middle Creek Restoration Project will be an enormous benefit to hitch
recovery. Historically, this project location will bring back a gathering place for the Pomos in areas where ceremonies once occurred, allowing for, and reinforcing old cultural traditions like harvesting and drying hitch as a sustainable food source. It will be important to pursue conservation easements in critical hitch spawning habitats, in Northshore areas like Tule Lake, areas in Scotts Valley, areas along Middle and Clover Creeks, and in southern and southwestern areas of the Clear Lake watershed, especially those areas that were former floodplains of Clear Lake.

Ultimately, increasing the hitch population is not only an important outcome for these projects, but the hitch is also a key species indicating how successful these projects are in restoring targeted, key habitats. Subsequently, actions to promote hitch populations are important to the success of this and other habitat restoration projects. This project has provided valuable data about the hitch lifecycle, their waterways, their habitats, and their critical spring migration patterns.

Project Staff: Meyo Marrufo – Environmental Director, Sunny Franson – Habitat Conservationist Biologist, Dean Rogers – Water Resource Manager, Anthony Duncan – GIS Technician, Irenia Quitiquit (former Environmental Director)

The Clear Lake Hitch Study Project Phase II
The overall goal of this project is to protect and assist in the recovery of the Clear Lake hitch. A number of habitat restoration projects have been implemented in the Clear Lake Watershed, including the ongoing Middle Creek and Robinson Lake wetland restoration by the Army Corps of Engineers, the removal of barriers to hitch migration by Lake County, and the water quality monitoring and improvement projects by the Multi-Tribal effort and County of Lake.

To further advance in accomplishing the hitch study, the Lake County Hitch Adaptive Management Plan (HAMP) was completed in September 2010, spearheaded by Robinson Rancheria Environmental Staff and the Multi-Tribal effort. The HAMP included the following topics: Introduction to adaptive management; Hitch characteristics and life cycle; Conditions of current habitat; Problems assessment for habitat recovery; Hitch data summary and interpretation; and after implementation, plan modifications to minimize problems and to address needs within each category. The HAMP was initiated from a previous grant as an important undertaking. The Tribe invited the general public, local tribes, county, state, and federal entities to participate in the HAMP workshop, held on Robinson Rancheria’s land. These participants also provided comments on the Final Draft HAMP. The HAMP contributors included Big Valley Rancheria, Elem Indian Colony, Habematolel Pomo of Upper Lake, Middletown Rancheria, and Scotts Valley Band of Pomo Indians. Under the Multi-Tribal efforts, other goals included interpretation and database management of water quality data generated for the hitch program collected by Robinson Rancheria, Elem Indian Colony, Big Valley Rancheria, and the Habematolel Pomo of Upper Lake Tribes, including historical and anecdotal information from Tribal elders and Tribal members. This data required its collection be presented in a uniform and useable source, in a database for technical interpretation. The Robinson Rancheria developed and maintained the database to insure the collected data was used to support the development of the HAMP. The final goal of this project was conducting public outreach highlighting the cultural and ecological role of hitch in Clear Lake and encouraged community interest and involvement.
in hitch recovery as part of overall resource stewardship. In particular, a Multi-Tribal effort was made to co-sponsor seminars and meetings to the public, as well as provide outreach to the tribal community and its tribal youth at various tribal events in support of hitch recovery efforts. Resources were distributed (hitch maps) and interviews were conducted at the Lake County Fair’s HERC booth, showcasing current hitch projects and sharing the Tribes’ multi-tribal outreach materials. The intent is that the HAMP will record and integrate what was found or observed, and will be updated on a regular basis.

In spring 2011, Robinson Rancheria completed their own tagging events to continue contributing data to the HAMP. This effort was done because the six tagging events planned for all participating Tribes during spring 2010 were cancelled due to drought conditions. Robinson Rancheria focused their tagging event within the Northshore tributaries and designed an easily portable tagging table with needed equipment and readers used on Robinson Creek. That year, Robinson Creek was the only Northshore creek where hitch were observed migrating. During the Robinson Creek spring 2011 migration, a total of 20 hitch were tagged. During various periods of the hitch migration run, many of the juvenile fish were observed stranded in a pool in a drying creek where adults had migrated a few months earlier. Smaller individuals were near banks and larger individuals were in deeper water. This information increased our understanding about the future survivability of the hitch, especially where spawning areas occur, as only decayed eggs were seen on creek substrate. In 2010, juvenile hitch were found stranded in rice paddies that had been flooded some weeks previously and near banks in three locations. In 2011, larval hitch were found in a culvert fully exposed to the sun, near a grassy, marsh-like field that had been flooded near Robinson Creek. While adult hitch appeared to migrate in the cooler waters of spring runoff, they also appeared to seek a warmer environment with vegetation for spawning and successful incubation that included egg and larval hitch development. A Final Report on the Clear Lake Hitch Study and Recovery Project was prepared for the U.S. Fish and Wildlife Service by the Robinson Rancheria Tribal staff summarizing all the grant goals completed from October 2009-2011.

Furthering our hitch goals and objectives of the Multi-Tribal effort, Big Valley Rancheria and Habematolel Pomo of Upper Lake were also funded by the Service the same year as Robinson Rancheria for projects addressing the Clear Lake hitch, in an attempt to accelerate the recovery of the fish for the Clear Lake Hitch Study.

Project Funding: US Fish and Wildlife Service Tribal Wildlife Program (2009–2011)
Project Staff: Meyo Marrufo – Environmental Director, Sunny Franson – Habitat Conservationist Biologist, Dean Rogers – Water Resource Manager, Anthony Duncan – GIS Technician, Mike Schaver – Incoming Environmental Director

Upgrade Hatchery Operations
As part of the Multi-Tribal effort, Robinson Rancheria was awarded a Bureau of Indian Affairs (BIA) grant to upgrade the fish hatchery operations to set up a second system that included a new brood tank complete with chiller and bio filter to manage hitch juveniles. A bigger facility was needed to allow for more room to successfully hatch and rear hitch. The second rearing system also reduced the chances for a hatchery-wide infection and reduced competition for food between adults and juveniles. Originally operating with just one well, a second well was identified near the southeast corner of the hatchery where a new well pump, well covering, and
concrete barriers were installed. Having two operating wells provided a well-equipped operation for the hatchery. Once the BIA Fish Hatchery Upgrade was completed it provided important information about the about the fragility of hitch larvae, which no scientist had yet discovered. Furthermore, Tribal Environmental Protection Agency (EPA) staff identified how to tell the difference between hitch and other non-native fish at the larval stage. Hitch rearing was also accomplished; however, incubation proved to be a challenge. Due to the high costs of maintaining the fish hatchery and a lack of funds to sustain it, the operation was closed until further notice.

Project Funding: Bureau of Indian Affairs (2012–2013)
Project Staff: Mike Schaver – Environmental Director, Dean Rogers – Water Resource Manager, Debbie McCubbin – Environmental Coordinator/Water Resource Technician

The Robinson Creek Restoration and Clear Lake Hitch Conservation Strategy Committee
This project is currently being implemented until September 2021. The project has two main goals to implement; (1) Stream restoration on Robinson Creek and. (2) Update the 2013 HAMP.

Goal 1 - The Robinson Creek stream restoration is located at the Old Robinson Rancheria, which is held in trust by Tribal Allottees. Robinson Creek runs through the Old Rancheria and borders State Highway 29, and runs in the north and west vicinity of the Rancheria. The creek is highly seasonal in its flow regime and is degraded through the long-term impacts of agriculture, roads, dumping, etc. Regardless, Robinson Creek hitch spawning habitat is essential, as it is currently one of the most important streams for successful hitch spawning. The habitat along Robinson Creek needs restoration due to degradation impacts over time, which are negatively affecting the quality and quantity of fish-spawning gravel beds. As part of the initial restoration effort, this project involved a general clean-up of approximately 1,000 feet of the creek bed. The clean-up involved removal of tires, appliances, residential, and adjacent highway garbage and litter. The clean-up effort is designed to alert local citizens and tribal members to the creek’s health and to engage more community involvement for long-term healthy stream protection. Currently in progress, another segment to the Robinson Creek effort is to consult with an experienced streambank engineer to provide streambank demonstrations to tribal members and other interested parties, in which bioengineering methods would be employed as much as possible in streambank stabilization. This effort would continue until most stream banks have been stabilized or at least prepared for further efforts at permanent stabilization. As part of this effort, an assortment of native vegetation will be planted along the streambed in order to help maintain integrity and to prevent further soil loss, and to return the stream to a less disturbed condition. The plants will be cared for and watered for a period of at least a year, and would be followed up with monitoring to ensure long-term efficacy of the project. The monitoring of the hitch spawning migration will continue to help determine the population status and the species’ response to the clean-up efforts.

Goal 2 - The task changed from updating the 2013 HAMP to participating on the development of the Conservation Strategy. The Service invited the Lake County Tribes to participate with other partnerships in developing the Conservation Strategy, which the Tribes supportively joined and continue to provide their input and perspectives. Developing the Conservation Strategy could lead to improved status for the hitch and determine if threatened or endangered listing is warranted under the Federal Endangered Species Act.
Project Funding: USFWS Tribal Wildlife Program (2017–present)
Project Staff: Irenia Quitiquit – Interim Environmental Director, Karola Kennedy – Water Resource Manager, Dean Rogers – Water Resource Manager

3.2.4 Scotts Valley Band of Pomo Indians

Scotts Creek Eight Mile Valley/Hitch Habitat Restoration Enhancement
In keeping with the Multi-Tribal effort for the Clear Lake Hitch Study and Recovery Plan, the Tribe received a planning grant to initiate the Scotts Creek Eight Mile Valley/Hitch Habitat Restoration Enhancement Project (hereafter, Project). The goals of the Project are to restore the natural channel-floodplain relationship within Eight Mile Valley to reduce the sediment load into Scotts Creek to improve spawning conditions for the CLH. The Eight Mile Valley are the headwaters of Scotts Creek flowing into Clear Lake. The Project has the added benefit of reducing nutrient (phosphorus) loads into Clear Lake, a Clean Water Act Section 303(d) “impaired water body”. The Tribe worked in partnership with the Bureau of Land Management (BLM)-Ukiah Field Office, and the Lake County Resource Conservation District. The majority of the Project is located on BLM land on Cow Mountain Recreation Area. The Tribe and the BLM built a working relationship through this Project, which enabled the two partners to develop a source of native plants for use in cultural, medicinal, and educational activities and the re-establishment of seasonal wetland plants in the Project area. Upon successfully establishing the native plant communities, a native seed source and culturally significant materials were provided for the tribes to gather and plant where needed.

The goals and objectives accomplished in this project were:

1. Developed a BLM Engineering “Design Plan” for Eight Mile Valley, completed by SHN Consultants.
2. Studied Lower Scotts Creek to Improve Hitch Spawning Habitat.
3. Conducted Multi-Tribal efforts on outreach and education at tribal events and to Lake County citizens groups, local, state, and federal agencies.
4. Hire of Habitat Conservationist for project oversight and coordination.

Ultimately, the Project design expectation was to restore the natural streambed geomorphology relationship within Eight Mile Valley to reduce the sediment load into Willow/Scotts Creek entering Clear Lake and to improve spawning conditions for the Clear Lake hitch.

With additional U.S. Bureau of Reclamation funding, the overall goals and objectives of this Project remained the same, which was to restore the natural channel – floodplain relationships within Eight Mile Valley to reduce the sediment load into Scotts Creek to improve spawning conditions for the Clear Lake hitch. However, other specific tasks were completed which allowed the tribe to study the Clear Lake hitch through other water resource studies. These specific tasks involved:

1. A study on lower Scotts Creek to improve hitch spawning habitat, which involved monitoring hitch spawning conditions, populations, and water quality monitoring, resulting in the creation of a database. The resultant benefits are threefold: 1) The
headwaters of Scotts Creek can be stabilized to dramatically reduce erosion into lower Scotts Creek; 2) Scotts Creek can be studied and monitored for the first time, to improve CLH spawning habitat; and 3) The amount of sediment to phosphorus laden Clear Lake can be reduced.

The following two studies were completed in June 2018, the “Scotts Creek Water Quality Monitoring Project” and the “Hitch Study Assessment”. The goal of the Scotts Creek Water Monitoring Project was to characterize short-term water quality conditions and long-term trends in the monitored watershed, and to meet the requirements specified in the Monitoring and Reporting Program for the CWA 319(h). The Hitch Study Assessment showed historical records and current monitoring which illustrated the presence of hitch within the Scotts Creek Watershed. Suitable habitat for hitch appears to be present as defined in the literature reviewed and from assessment of the monitoring sites. There is one limiting barrier to hitch upstream movement and access to spawning habitat located at the Decker Road Bridge on a private access road as it passes over the main stem of Scotts Creek. A second barrier to Blue Lakes may also exist but is not clear to what extent it may impede passage to the lakes. Recommendations made were that monitoring continue and be expanded to include more locations, and consideration given to more in-depth studies and pursuit of grant funding for a design for the Decker Road Bridge barrier site.

Additional studies identified that should be pursued include: a water flow study; stream substrate mapping; expanded SWAMP benthic macro invertebrate studies to more sites; continued water quality monitoring and; climate change study. These recommended studies would enable greater understanding of the current and potential future condition of the Scotts Creek watershed and provide a clear blueprint of restoration and mitigation efforts needed to ensure hitch populations will endure into the future;

2. Completion of the QAPP required for the Eight Mile Valley Sediment Reduction and Habitat Enhancement Project. The QAPP included water quality and hydrology monitoring and flow characteristics (i.e., timing, quantity, velocity) and collection and analysis of benthic macro invertebrates (BMI) samples. The QAPP created a regional water quality-monitoring program for all waterways within the Upper Cache Creek Watershed, which Scotts Creek is an integral part.

In 2018, the “Scotts Creek Benthic Macro Invertebrate Communities Study” was completed. This study corresponded with the Hitch Habitat Assessment Project. In order to ascertain the biological condition of the stream and to further understand the conditions hitch must endure during their annual spawning migration in the Scotts Creek watershed. The results from this study allowed a greater understanding of the biological health of the watershed. This study was conducted in phases as grant monies became available. Two sites were surveyed in 2013 and the remaining three were surveyed in 2017. Samples were adequately stored at the Scotts Valley Band of Pomo Indians until they were sent to John Lee in Eureka, CA, for sorting and identifying in 2017. In addition, this study was conducted prior to the implementation of the Eight Mile Valley Meadow Restoration Project. Final results of the BMI samples were sorted and identified using SAFIT (Southwest Association of Freshwater Invertebrate Taxonomists) Level 2
(genus/species identifications with chironomid midges identified to genus/species group). This level of identification allows for sufficient detail to calculate the IBI (Indices of Biological Integrity) which describes the biological health (condition) of the watershed. Final values score the sites sampled against reference sites determined to be representative high value sites with high species diversity and abundance. High scores also indicate higher value habitat with fewer stressors degrading the overall health of the site. Sites scored from 35 to 68 on a scale of 1 to 100;

3. The Tribe updated the HAMP, completed in July 2013. The latest development of the Clear Lake hitch research, data, maps, studies, and projects were submitted. Public workshops were conducted to all interested parties for HAMP comments and review. This update is the most recent HAMP version available.

Project Staff: Irenia Quitiquit – Environmental Director, Larry Ray – Habitat Conservationist

3.2.5 Habematolel of Upper Lake Pomo

Clear Lake Hitch Study and Recovery Project Fish-Tagging and Surface Water Quality Support
To support the Multi-Tribal effort, this project provided on-going hitch conservation and management to increase the hitch population and implement habitat restoration. As noted throughout all the tribal hitch projects, the hitch is dependent on an annual migration into Clear Lake tributaries for spawning, and habitat loss in these tributaries along with barriers to migration, water quality issues, and competition from invasive fish species has resulted in reduced populations. With an improved understanding of the hitch, along with ecosystem restoration from other tribal hitch projects, this has helped stabilize and mitigate historic impacts to Clear Lake tributaries and populations. This project proved baseline water quality values and the use of ecological information was needed for habitat and population recovery.

The main goals of this project were comprised of three parts: (1) a water quality sampling program (field analysis), (2) a captive breeding program to accelerate recovery and provide stock to recovering streams and other areas of the watershed, and (3) a pilot tagging program to identify and track adult spawning hitch. This, along with the captive breeding program, would provide an improved understanding of the hitch to focus effective recovery efforts. These components included public outreach to build community interest and involvement.

In the Tribes’ 2009 Hitch Study Report & Tagging and Habitat Study, a total of 332 hitch were observed, captured, implanted with individually coded Biomark-brand Radio Frequency Identification (RFID) tags, and released at two locations in Lake County on Adobe and Kelsey Creeks. Additional other creeks were visually monitored to assess potential use by this and other native species. Hitch were quantitatively observed only at Adobe, Kelsey, and Cole Creeks, all on the southwestern side of Clear Lake. Numerous anecdotal observations were also made for Clover and Middle Creeks, on the northwestern side of Clear Lake. However, at the time of field observations, no hitch of any age class could be directly documented in Clover or Middle Creeks, and only non-native inland silverside (Menidia beryllina) were documented. Additional sampling using trap nets at selected locations on these two creeks during the 2010 hitch
spawning run provided more evidence on this issue. Although the loss of potential spawning habitat is an obvious issue, recovery of the CLH requires a working knowledge of specific habitat needs, spawning triggers, and water quality facts. In determining the effectiveness of recovery and habitat remediation efforts, the Tribe found it necessary to track fish numbers, and their health or condition.

Water quality is always an important component to fish populations and Clear Lake has documentation of water quality declines. In this project, water quality was assessed by monitoring before, during, and after the spawn in order to assess general water quality ranges, identify key factors associated with triggering the spawning run, increase the predictability of the start and end of the spawning run for ease of management, and to aid the prioritization of restoration. This study identified areas that did not support a spawning run, but showed relatively high water quality. It was determined these areas should be prime candidates for removal of barriers to migration and other physical habitat improvements, since the CLH failed to reach adequate spawning areas when they encountered features that block the channel and are too large to jump over or move around. These barriers included weirs, low head dams, and some irrigation features. Other impacts included changes in the channel, including many flood control improvements that have resulted in channels being too steep and fast flowing, too shallow, or have no canopy which leave fish more susceptible to predators. In a 2007 survey, Middle Creek, the largest tributary into Clear Lake historically and once supported a hitch spawn, was found to have multiple barriers to migration, nearly all man-made.

The Tribe has participated in Robinson Rancheria’s fish hatchery operation during construction. This undertaking involved raising hitch to be released into existing and restored habitat. This opportunity to observe many of the factors important to the survivability of fry was a step closer to increasing hitch populations.

In the next phase, the Tribes future efforts to continue hitch research and recovery, depending on additional funding, includes: (1) continue hitch tagging and RFID reader locations that corresponded with migration barrier improvements and potential spawning events within Middle and Clover Creeks; (2) additional water quality monitoring to define sources of water quality degradation in Cold Creek and McGaugh Slough, and expand the water quality parameters list including targeting known pesticide and mercury issues, and improve resolution on non-point and point sources; (3) additional water quality monitoring in Clover and Middle Creeks, including convergences in the Robinson Lake area that correspond with the proposed Middle Creek Restoration Project; (4) migration barrier removal; and (5) development of habitat restoration methods specific to the Clear Lake Basin.

In this Multi-Tribal effort, the Tribes have made tremendous efforts to study this rare and isolated species, and have created the initial base of ecological understanding. There is significant work that remains to better understand the hitch, the degree and extent of the risks associated with its survival, and potential suite of solutions available to stabilize and ultimately de-list this species.

Funded by the U.S. Fish and Wildlife Service Tribal Wildlife Program (2008–2010)
Project Staff: Paula Britton – Environmental Director, Christina Harrison – Water Technician, Joy Thomas – Water Quality Monitor
Clear Lake Hitch Study and Recovery Project Phase II
This project is a culmination of previous work with additional stream bed restoration in conjunction with the County of Lake. This project also leveraged funds with the BIA Water Resource Program and the Bureau of Reclamation Native Affairs Program. This project supports the Clear Lake Hitch Study and Recovery Project and was extended from 1 year to 3 years with additional leverage funds.

The four main principle components completed include: (1) continuation of water quality sampling (field analysis), leveraging Multi-Tribal efforts with concurrent water quality data (laboratory analysis); (2) continued the captive breeding program (fish hatchery) with Robinson Rancheria to accelerate recovery and provided stock to recovering streams and other areas of the watershed; and (3) continued the tagging program which identified and tracked adult spawning hitch, along with the captive breeding program, which improved better understanding of the hitch to implement effective recovery efforts.

As noted earlier, the Multi-Tribal effort included the following previous work: Fish hatchery construction; The tagging of over 500 hitch with RFID devices; Creation of permanent monitoring locations and water quality monitoring from the 2009 migration collected for 22 locations, and; The compiling of sufficient data collected that identified important habitat and evaluation efforts for habitat improvements. All these components are ongoing and are complimentary to the Multi-Tribal effort.

Project work performed during Year 1 included hitch tagging and water quality monitoring on selected sites, completed by the Multi-Tribal effort. A total of 427 fish were tagged. Some hitch were found in smaller tributaries off Adobe Creek for the first time in years, however, none were sighted in Kelsey Creek. The water quality monitoring for hitch migration had transitioned from the migration schedule to a post migration schedule as spring turns to summer. Sample frequency dropped from twice a week to once a week with a number of sampling locations dry. Water quality measurements continued to show decreasing water quality, as indicted by low dissolved oxygen concentrations and elevated conductivity associated with late spring flows in smaller tributaries such as Lyon and Manning Creeks. Clover Creek also showed a low dissolved oxygen period late in the spring, but elevated conductivity was only observed in the downstream sampling locations. Year 1 also found that the hitch was using smaller streams, including Manning Creek. Water quality data accumulated from these locations has become more important in meeting goals of identifying important habitat and priority restoration areas. This new data will continue to provide important insight of the hitch and the Clear Lake watershed. In partnership with the County of Lake, the Middle Creek fish passage restoration project permit and design was approved. The County of Lake constructed the two additional weirs on Middle Creek to help support the fish passage. The project construction was completed in Fall 2011.

During two wet rainy years fish were observed coming up the other tributaries in very turbid waters and in interviewing tribal people they said the fish used to run at night. The tagging methods and timing were adapted to coincide with fish spawning runs which are usually in the early morning and evening when predation is low. Due to difficulty with reading RFID tags with supported antenna design, software, and other peripheral equipment, antennas were developed and modified for suitability to the environment.
During project work in Years 2 and 3, the hitch spawning run was horribly low, with virtually no migration at all. Few hitch were sighted in only two streams, Adobe and Middle Creeks. Due to the candidacy listing by the State at that time, electrofishing occurred at the mouths of certain critical streams where hitch have been seen. After the electrofishing, no hitch was observed and no tagged fish came through the reader on these streams. To get a more detailed hitch count, staff walked the streams every other day or so for about two weeks between midnight to 3:00 am and only saw a few hitch migrating, where tagging previously took place. It was decided that fish that could be netted would be tagged and about 30 live hitch were tagged during the migration. Due to lack of water and the alteration of the streambed caused by riparian destruction in the most prolific sighting spot and spawning area, the hitch migration was further hampered. A massive amount of predation and hunting by a number of wildlife species, including turkey vultures, was observed. The hitch had nowhere to hide, due to lack of vegetation bank cover. Predation and pools drying up caused a lot of the hitch spawning to die.

During Year 4 the hitch had another poor spawning migration run, with an estimated 300-400 fish sighted. There was no fish tagging that took place due to the State of California implementing their own tagging program on Clear Lake. Due to drought conditions, many attempts were made to rescue adult hitch trapped in pool areas. They were ultimately released into Clear Lake. CDFW biologists assisted the Tribes in the hitch rescue work. Despite the Tribes work utilizing new antennas and readers to track any tagged fish in Adobe and Kelsey Creek, results show few hitch returning. More analysis will require additional funding to compile more data on this project.

The Clear Lake Hitch Study and Recovery projects continue their Multi-Tribal efforts until the hitch populations recover and are healthy, so the species can complete their life cycle and exist with barrier free migration, have restored habitat that is appropriately re-vegetated, have clean water quality, and can provide a sustainable source of food for the Pomo Indians.

Funded by the U.S. Fish and Wildlife Service Tribal Wildlife Program (2011–2014)
Project Staff: Paula Britton – Environmental Director, Christina Harrison – Water Technician, Joy Thomas – Water Quality Monitor

Chapter 4. Threats and On-Going Conservation Actions

4.1 Habitat Loss, Degradation, and/or Modification
Beginning in the mid-1800’s when European’s first started to settle in the basin, the Clear Lake watershed began to undergo numerous changes. Various forms of past mining activities, agricultural and urban development, increased fire activity, past deforestation, and historical overgrazing practices have all contributed to the degradation of the Clear Lake watershed, causing toxic cyanobacteria blooms and periodic fish kills in the lake. The degradation of tributary streams has changed their hydrology, reducing the amount of water retained in the streams over the CLH’s spawning season. This loss of flow earlier in the season and the presence of numerous passage barriers in the tributary streams have greatly reduced reproduction and early life stage survival (egg, larvae). The conversion of wetland habitats surrounding the lake not only negatively impacted Clear Lake’s water quality, but it also reduced the amount of rearing habitat for any juvenile hitch that are able to migrate to the lake from their natal stream. This loss of rearing habitat also reduces early life stage survival (juvenile), further reducing the
likelihood of recruitment. The impacts to Clear Lake’s water quality likely impact adult hitch survival, especially when poor lake conditions result in large fish kills. Due to these past changes in the watershed, current hitch populations are vulnerable to ongoing changes in the remnant habitat that is still available. See Suchanek et al. 2003 for a detailed account of issues in the Clear Lake watershed.

4.1.1 Riparian Vegetation
Native riparian vegetation offers natural filtration, shade, bank support, and varied instream habitat. Parameters important to fish communities are stream depth, flow velocity, substrate composition, cover, and temperature. Riparian vegetation is an integral part of watershed ecosystems due to energy exchange and interaction with flow and temperature regimes (Baltz and Moyle 1984).

Natural cycles of deposition and erosion effect change by distributing soils carried in floods resulting in accretion and by eroding and lowering floodplains. Catastrophic flood events affect every living organism in an ecosystem but changes over time are natural, and plants and animals adapt. Native riparian vegetation might time seed release to coincide with high water and germinate and grow quickly to occupy available space, and to securely root themselves in preparation for northern California winter rains.

Currently, most remnant riparian corridors found within the watershed are not high quality and in areas where they are, access for hitch migration is generally limited or denied due to physical barriers of various kinds. It is important to reestablish stretches of riparian corridor that contribute to a more natural and healthier environment for a naturally sustainable hitch population. Adequate riparian vegetation along streams and sloughs provides shade and recruitment materials such as woody debris and boulders, presumed to be necessary components of good instream habitat for hitch. The riparian vegetation provides cover and structure and helps with erosion control and protects banks. It is a vital component of any freshwater ecosystem providing niches for biodiversity and micro ecosystems that extend into streams, allowing for abundance and diversity of wildlife. This also includes insects and their larvae, pupae, phytoplankton, small planktonic crustaceans and more that hatchlings require (Moyle 2002; Wang 1986). Diversity encourages establishment of complex food webs that offer prey items for hatchlings, fry, fingerlings, and spawning adults.

Riparian restoration efforts can include re-vegetation with native plants in areas where they will grow and provide optimal benefits. A few of many species observed in the Clear Lake Basin and along stream banks in the northshore watersheds are box elder (Acer negundo), buckeye (Aesculus californica), occasional wild columbine (Aquilegia formosa var. truncata), mugwort (Artemesia douglasiana), wild mustard family (Brassicaceae), common horsetail (Equisetum arvense), creeping wild rye (Elymus triticoides), Oregon ash (Fraxinus latifolia), lupines (Lupinus latifolius), cottonwoods, (Populus sp.), California wild rose (Rosa californica), several willows (Salix sp.), California bay (Umbellularia californica), poison oak (Toxicodendron diversilobum), white alder (Alnus rhombifolia), sedges, grasses, wild grape, and more. These native plants help to stabilize soil and banks, provide shade and varied instream habitats, provide energy exchange, and aid in temperature control, all of which are important to fish (Baltz and Moyle 1984).
4.1.2 Spawning Habitat
The reduction in stream spawning fish, including the CLH, seen in Clear Lake during the late 1940’s was attributed to the modifications seen within the lake’s tributaries, which the species relies on for spawning and early rearing (Murphy 1951). It is estimated that historically, the tributaries to Clear Lake ran until at least September; however, streams are now drying in early summer or late spring (Murphy 1951). A combination of activities have contributed, and are continuing to contribute, to the reduction in tributary flow during the subspecies’ spawning season. Increased fire activity and legacy effects from instream gravel removal and deforestation have likely increased the rate of runoff within the tributary streams during the winter. Those same factors, in conjunction with both in-creek and groundwater pumping for urban and agricultural uses, have greatly reduced the amount of flow that actually makes it to the lake during the summer (Murphy 1951).

The impacts of spawning habitat alterations to CLH may be inferred by the fate of another native Clear Lake fish that required tributaries for spawning: The Clear Lake splittail was last recorded in 1972 (Puckett 1972). The Clear Lake splittail formerly spawned later in the season than did CLH and the drying up of tributaries contributed to their demise (Moyle 2002). All stream spawners had “declined precipitously” by 1944 (Murphy 1951). Earlier drying of tributaries by both natural and man-made processes likely impacts the CLH population.

Loss of Consistent Tributary Flow
Gravel mining activities in the Clear Lake basin first began in the latter half of the 19th century and occurred in most of the spawning tributaries to Clear Lake (Suchanek et al. 2003; Thompson et al. 2013). Gravel mining originally occurred as scattered operations throughout the basin until the early- to mid-20th century when operations became centralized within the creeks (County of Lake 1992; Richerson et al. 1994). This time period coincides with improved automobile technology and increased pressure to build more reliable roads (County of Lake 1992). Then as the human population within the county grew in the 1960’s and 70’s, new houses and associated roads needed to be constructed to accommodate the new residents. Since the instream gravel was available as a convenient source of material, gravel was extracted from the tributaries and was used as building material for both homes and roads (County of Lake 1992; Richerson et al. 1994). Until the 1981 partial moratorium on instream gravel extraction, approximately 1 million metric tons of instream gravel was extracted from the watershed (Richerson et al. 1994; CDFW 2014). Although large scale gravel mining no longer occurs within the Clear Lake tributaries, approximately 5,000 cubic yards of gravel is still removed from Scotts Creek annually (Murphy 1948; CDFW 2014).

Past gravel mining in tributary streams not only removed spawning substrate that the species needs for reproduction and egg development, it also lowered streambeds and destabilized channels, causing increased erosion, incision, and channelization. In Kelsey Creek, mining downstream from the Main Street bridge in Kelseyville, precipitated the erosion and loss of gravel spawning beds extending over three (3) miles upstream from the bridge (Windrem 2021). In addition, large swaths of riparian vegetation were removed from along the streams to allow access for gravel extraction, further exacerbating the issues with erosion. The flushing of eroded material not only negatively impacted tributary streams by increasing the amount of suspended sediments and silt within the creek, ultimately increasing turbidity in some streams to zero visibility, but it also negatively impacted the lake ecosystem when those sediments eventually
were transported into the lake (CDFG 1955; Richerson et al. 1994; Suchanek et al. 2003; CDFW 2014). Flood control projects in the watershed have also contributed to increased nutrient and sediment transport in the watershed by channelizing and armoring tributary streams with rip-rap and by reclaiming large portions of wetland habitat that once surround the lake (CDFW 2014). There are almost 14 miles of levee structures that were built by the U.S. Army Corps of Engineers (Corps) on Scotts, Middle, Clover, and Alley Creeks (County of Lake 2012). These structures are currently maintained by the California Department of Water Resources and the Lake County Watershed Protection District.

Fire has always occurred naturally in the Clear Lake watershed; however, with European settlement in the middle of the 19th century, widespread intentional burning occurred throughout the watershed to clear brush or promote grass growth for livestock grazing (Suchanek et al. 2003). Numerous fires have occurred in the basin in the recent past, with several large 10,000+ acre fires occurring directly in the watershed (Suchanek et al. 2003). The 2017 and 2018 fire seasons in California were some of the worst on record and it is likely fire activity will continue to increase within the Clear Lake watershed (CalFire 2019a). The 2018 Mendocino Fire Complex, a portion of which occurred in Lake County, was the largest fire on record in California (CalFire 2019b). Past fire suppression practices within the state of California have reduced the occurrence of fire, but due to the accompanying fuel accumulation, these practices have made fires more devastating when they do occur (Suchanek et al. 2003). Fire activity within the watershed results in increased erosion and bank incision, which can decrease the amount of time water is retained within the tributary channel (Murphy 1948; County of Lake 1992).

Deforestation within the watershed began in the mid-19th century and was primarily conducted for agricultural uses. Forests were cleared to plant orchards and vineyards, and trees were removed for timber harvest, which was then sold as fuel to nearby mining operations or as lumber. Commercial timber harvest operations continued in the watershed into the middle of the 20th century. Large-scale forest removal within the Clear Lake watershed increased the amount of erosion occurring in the tributary streams, contributing to bank incision within the tributaries and increased sediment and nutrient transport into the lake (Suchanek et al. 2003). Increased erosion and bank cutting further decrease the amount of time water is retained within the tributaries.

Livestock grazing, primarily cattle and sheep, began in the Clear Lake basin in the mid-1800’s and still continues today. Although overgrazing no longer appears to be a current stressor acting on the Clear Lake watershed, overgrazing was an issue until the mid-20th century. The number of sheep grazing in the watershed peaked in the 1870’s and again in the 1930’s, but has declined to a fairly low number since that time (Suchanek et al. 2003). Past overgrazing in the watershed has resulted in the loss of stream-side vegetation, which decreased soil stability and increased the rate of runoff within the creek, effectively reducing the amount of time water is retained within the channel (Murphy 1948; Suchanek et al. 2003). Although the amount of grazing pressure has decreased in the watershed, the impacts of past practices are still contributing to the issues in the watershed seen today.

Although a majority of instream gravel removal and all large-scale deforestation no longer occur in the basin, the rate of runoff within the tributary streams is not likely to decrease into the
future. In addition, fire activity will likely continue to increase within the Clear Lake basin as the incidence of drought increases and intensifies. Furthermore, some believe that the early season draw down of the tributaries is due to water extraction in the upstream reaches of the spawning streams (Suchanek et al. 2003). In 2013 and 2014, water rights users in Kelsey Creek used 85 and 134.5 million gallons of water, respectively, and 31.4 million gallons in each of those years from Adobe Creek. In addition, from 2008 to 2014 18 private water wells were permitted for installation along the two creeks. Although this amount of water withdrawal is legally permissible, it is unknown what effects this amount of water extraction is having on the hydrology of these tributary streams and the CLH (Big Valley 2015).

While the vast majority of Lake County agriculture is irrigated with groundwater, some farmers do use and have used surface water from Clear Lake tributaries for crop irrigation. Wine grapes are generally irrigated for frost protection during the early spring and farms with riparian rights have utilized surface water within the creeks in addition to groundwater. Water pumped away from streams can encourage creeks to run dry early in the year, especially with increasing drought conditions. Furthermore, groundwater pumping and increased extraction during certain times of the year (i.e., during the spawning season) can further exacerbate reduced flow conditions in the watershed. There are current efforts underway to quantify and better understand the connection between surface water and groundwater along the creeks. The Draft Groundwater Sustainability Plan (GSP), under development by Lake County Watershed Protection District, identifies hydraulic connectivity between surface water and groundwater in sections of both Kelsey and Adobe Creeks (LCWPD 2021). The Big Valley Band of Pomo Indians is currently undertaking a study to investigate groundwater and surface water trends along Kelsey and Adobe Creeks through the installation of pressure transducers and groundwater level sensors in coordination with local landowners. Both surface water and groundwater data are very limited in the Big Valley Subbasin, notably, the USGS stream gage on Adobe Creek was discontinued after 1977 and the creek does not have any other streamflow gaging maintained by a public agency (Big Valley 2020). New data sources on groundwater-surface water interactions made available through the GSP process, as well as Big Valley Tribe’s studies, can be used to improve the quantification of instream flow needs for the hitch. Other water uses, such as adjacent creek pumping, can also reduce flow conditions in the watershed. Pumping during certain times of the year, like over the spawning migration (upstream and downstream migration), can have impacts to the hitch by limiting migration or through direct mortality from stranding. Furthermore, climate change is likely to exacerbate drought conditions, resulting in an increase in low flow condition in the future. The current effect ground and surface water pumping have on the hitch is unknown and needs to be further investigated (see Action 4.3.1 below).

Agricultural production in the basin was first initiated during early European settlement in the mid-1800’s. Early crops included apples, almonds, grapes, nectarines, peaches, pears, plums, and prunes, many of which are still grown today (Suchanek et al. 2003; USDA 2019). The conversion of land for vineyard establishment has recently increased. From 1989 to 1999 the acreage of grapes grown in the watershed almost tripled from around 2,500 acres to over 7,000 acres. During the initial establishment period the potential for sediment and nutrients entering the aquatic ecosystem increases, which can result in negative impacts to both the tributary streams and the lake. However, measures can be implemented to reduce this risk (Suchanek et al. 2003).
In 2008 over 8,370 acres of grapes, 2,226 acres of pears, and 2,800 acres of walnuts were grown in Lake County (Lake County undated). In comparison, in 2017 over 9,500 acres in Lake County were dedicated to grape production, over 2,000 acres were in pear production, and 3,750 acres were in walnut production (Lake County 2018). The acreage of fruit, nut, field, seed, and vegetable crops in Lake County slightly increased from 2008 to 2017, with just over 107,100 acres in 2008 compared to 108,226 acres in 2017 (Lake County undated; Lake County 2018). However, range land accounts for around 90,000 acres in those figures. A more accurate total for all farmed land in 2017 is 14,392 acres of fruit and nut acreage, 700 acres of irrigated pasture, 43 acres of nursery, 2,150 acres of dry-farmed hay, and 962 non-bearing acres (Lake County 2018). Agricultural development is found throughout the watershed; however, it is most concentrated in the southwestern portion of the watershed, primarily near Kelsey and Adobe Creeks (USDA 2019). The presence of agricultural production in the watershed not only has an impact on the amount of water flowing in the tributaries to Clear Lake, but also has the potential to increase the amount of contaminants, in the form of pesticides and fertilizers, and sediment entering the lake.

There have been numerous recent efforts to save hitch that become stranded in pools within the tributaries when the tributary streams began to rapidly dry up. In March 2014, 197 individuals were rescued from two pools within Adobe Creek and the surviving fish were released into Kelsey Creek (Ewing 2014a). A few months later in June 2014, over 1,400 hitch were released from Cooper Creek and 389 hitch were rescued from Adobe Creek when the flow within those creeks began to rapidly drop. The surviving individuals from both rescues were released into Rodman Slough and the Konocti Vista Casino boat ramp, respectively (Ewing 2014e). Unfortunately, during visual spawning surveys that same year, approximately 300 hitch were found dead in a portion of Adobe Creek that had dried (Ewing 2014c).

In May 2017, approximately 10 hitch were stranded in a pool along a portion of Kelsey Creek, and during the spring of 2018 numerous young of year were stranded in a pool within Cole Creek when the water flow began to rapidly drop (D. Rogers in litt 2017; Ewing 2018a). The creek no longer had continuous flow into the lake and the small pool the fish were stranded in would have eventually dried, killing all of the 3,100+ young fish. Fortunately, members of Robinson Rancheria and CDFW were able to rescue the fish and transport them for release at Clear Lake State Park, the outlet of Cole Creek into the lake (Ewing 2018a). In May 2019 members from Robinson Rancheria and CDFW rescued 13 hitch from a rapidly drying, isolated pool and relocated them to the confluence of Rodman Slough with Clear Lake (Ewing 2019a).

**Passage Barriers**

The lack of adequate tributary flow can act as a barrier to migrating fish, reducing the amount of available spawning habitat, and leaving young stranded before they can migrate to the lake. However, even when flow conditions allow for migration, most of the tributaries in the watershed contain physical barriers that prevent hitch passage, reducing the amount of spawning and rearing habitat available. The installation of dams, diversions, roadways, and crossings have had a negative impact on migrating hitch by eliminating access to portions of stream with suitable spawning habitat or impeding passage during certain years until specific flow conditions (i.e., high flow) are met (Suchanek et al. 2003; CDFW 2014). In addition, since the presence of a barrier on a spawning stream reduces the amount of available spawning habitat, reproducing adults have to compete for available spawning substrate and fertilized eggs are known to accumulate just below a barrier to the point that they will die due to oxygen deprivation.
(Robinson Rancheria undated). Using a variety of data sources, CDFW estimated that over 92% of the historical 180 stream miles of spawning habitat is currently blocked or has reduced access due to the presence of barriers (CDFW 2014; Figure 5). Appendix B contains a list of tributaries and some of their suspected barriers.
Figure 5. Clear Lake hitch spawning barriers located on tributaries throughout the watershed.

Numerous dam structures can be found throughout the Clear Lake watershed, including dams on Kelsey, Adobe, Highland Springs, and Manning Creeks. These dams were installed in the mid-
to late 20th century and were installed primarily for irrigation and recreation (Suchanek et al. 2003). During the spring of 2016 CDFW identified potential barriers on Lyon’s, Scotts, Seigler Canyon, Clover, and Kelsey Creeks (Ewing 2016a). An unusual barrier in the watershed is the diversion of flow from Alley Creek into Clover Creek. This diversion has reduced the probability of hitch accessing that tributary for spawning, although in some circumstances they are still able to use the Clover Creek channel bypass to access Alley Creek. However, sometimes the diversion becomes filled in with sand and silt, in which case it can be a barrier (CDFW 2014).

CDFW has begun to address some of the barriers in the spawning tributaries. On Kelsey Creek there are two fish ladders that were constructed to allow fish passage over the Kelsey Creek Detention Structure (KCDS). Although local county water resources staff had seen the species use the west ladder, the species did not seem to be using the east ladder. So, in late September 2017, CDFW staff reconstructed the fish ladder to allow for hitch passage. The reconstruction included installing holding pools for the fish to rest as they move upstream and breaks in the ladder to help slow the rate of water flow (Ewing 2017c). In addition to the Kelsey Creek fish ladder enhancement, CDFW, in conjunction with the California Department of Transportation (CalTrans) also installed a fish ladder on Cole Creek at the Highway 29 culvert in 2017 to allow for hitch passage. At this location the culvert’s foundation was acting as a barrier and the installation of the fish ladder will allow the hitch to move upstream of the culvert in future years (Ewing 2017d). CDFW and CalTrans also removed multiple boulders from Seigler Canyon Creek that had fallen into the creek channel. Local reports stated hitch were spawning below the boulders but not above, so the removal of these boulders will open up additional spawning habitat on that tributary (Ewing 2017e). Additional efforts to address barriers throughout the watershed are currently being implemented or being developed.

4.1.3 Nursery Areas

Juvenile hitch require nearshore habitat containing tules or other emergent vegetation for cover from predators and for their prey base. Starting in the mid-19th century and continuing through the mid-20th century, large tracts of wetland, nearshore habitat was converted for agricultural production and urban development (Suchanek et al. 2003; CDFW 2014). With the loss of surrounding wetland habitats Clear Lake lost its natural filter. Over time, increasing amounts of sediment and nutrients from the degraded tributary streams were transported directly into the lake, and nutrient inputs from surrounding urban and agricultural development ended up in the lake. This increase in nutrients and sediments entering Clear Lake degraded its water quality, resulting in increased cyanobacteria blooms and potentially to periodic fish kills. Moreover, contaminants from historic mercury mining and processing along the lake’s shore and the use of various pesticides in and around the lake have also contributed to the degradation of water quality within the lake (see subsections 4.1.7 and 4.4.1 for a discussion of these threats). Additionally, shoreline conversion from naturalized “soft shorelines” full of native aquatic and riparian vegetation such as tules, smartweed, water lilies, characeae, sedges, and eleocharis into “hardscapes” of seawalls, rip rap, docks, lawn, and gravel beaches can have negative impacts to fish habitat and spawning areas. In addition to the reduced benefit from removing shoreline vegetation, hardscapes add increased sediments and nutrient resuspension into the water column, increase wave energy from boating and wind activities, and cause erosion and destabilization to shorelines (Scyphers et al. 2015). To date, a shoreline survey has not been completed and would be a useful task to identify priority areas for restoration that would maximize hitch population improvement efforts.
Wetland/Tule Habitat Loss

Prior to early European settlement in the basin, large wetland/marsh complexes surrounded Clear Lake (CDFW 2014). The conversion of these large wetland complexes was largely driven by the desire for agricultural production and urban development (Suchanek et al. 2003; CDFW 2014). Large wetland complexes in the Tule and Robinson Lake areas were reclaimed for agriculture by the late 19th century and within 60 years two other wetland reclamation projects, primarily for agriculture conversion, were completed in the Middle Creek and Rodman Slough areas (Suchanek et al. 2003). The area that is now the town of Clear Lake Oaks was once a large marsh that was described as a “tule bog” (DWR 1975). It has been estimated that there were at least 9,000 acres of marsh habitat that surrounded the lake prior to early European settlement (mid-19th century) and by 1977 the amount of marsh had declined to just under 1,500 acres; a loss of almost 72% of Clear Lake’s nearshore, wetland/tule habitat (Week 1982; Suchanek et al. 2003).

The largest concentration of agricultural production and urban development surrounds the lake and the lower reaches of the tributary streams. The population within Lake County has increased from just over 2,200 people in 1850 to approximately 55,000 by 2000 and in just a 20 year timeframe (1966-1986) Lake County’s population more than tripled (Suchanek et al. 2003; Thompson et al. 2013) (Figure 6). However, more current census information has seen a -0.4% decrease in the Lake County population in the last 10 years or so, from over 64,660 people in 2010 to almost 64,400 people in 2018 (U.S. Census Bureau website: https://www.census.gov/quickfacts/fact/table/lakecountycalifornia/PST045219.

As a secondary consequence of urban development directly abutting the lake, emergent vegetation was removed to install not only lakeside homes, but also various lake structures such as the estimated 600+ docks and boat ramps that line the shore (Week 1982; CDFW 2014). The installation of these structures removed the nearshore habitat that juvenile hitch require for rearing and they also provide structure for predatory fish (CDFW 2014). Guidance for future development within Lake County can be found in the Lake County General Plan. The county plans to implement “smart growth” by aiming to direct growth within existing developed areas and by discouraging urban sprawl (Lake County 2008). Limiting future urban growth to already developed areas will reduce or eliminate future habitat loss due to urban development; however, an increased population in the county will likely increase the need for water and other resources, which will have different negative effects to the watershed (i.e., decreased tributary flow, decreased lake water quality).

Fish Kills

Historical accounts of fish kills were recorded as early as 1873, when large numbers of dead blackfish, perch, and roach were observed in the lake and along the lake’s shoreline during the summer (Stone 1876). Large fish kills were documented in the Clear Lake Oaks area and within Cache Creek during the late summer of 1932, and again within the lake during the summer of 1933 (Murphy 1951). The most recent large fish kill was documented in 2017 (USGS 2018). There have been many different theories regarding the source of these fish kills, including over-exertion from spawning, high temperatures, pollutants, algae blooms, disease, low dissolved oxygen, increased alkalinity from volcanic activity in the Clear Lake area, or a combination of heavy algae blooms causing an oxygen depletion (Ingram and Prescott 1954; Murphy 1951; Cook et al. 1966). Whatever the ultimate cause, a hypoxic zone develops in the summer at the
bottom of the lake (Cook et al. 1966; Hopkirk 1973). Fish kills have been observed in the absence of algae blooms and these have been attributed to surface water temperature changes (Macedo 1991).

Figure 6. Urban development throughout the CLH range.
4.1.4 Hydrologic Changes
Aquifers in the basin require study and monitoring to evaluate trends in the reduction of ground and surface water resources as both surface and ground water is being diverted from Clear Lake tributaries for agricultural purposes and domestic use (CDFW 2014). Approximately 60% of the water supply comes from groundwater sources in an average year (County of Lake 2014). These diversions are legal extractions conducted under riparian and water rights associated with land ownership. Surface water is diverted via intake pumps and groundwater is extracted via the installation of shallow wells near the tributary channel where they capture underflow (CDFW 2014). In 2013 and 2014, water rights users in Kelsey Creek used 85 and 134.5 million gallons of water, respectively, and 31.4 million gallons in each of those years was from Adobe Creek. In addition, from 2008 to 2014, 18 private water wells were permitted for installation along the two creeks. Although this amount of water withdrawal is legally permissible, it is unknown what effects this amount of water extraction is having on the hydrology of these tributary streams and the Clear Lake hitch (Big Valley 2015). A 2016 memorandum from Lake County’s Water Resources Department summarized groundwater conditions throughout the Clear Lake watershed for that year. Although the previous three years were considered drought years, the county determined groundwater levels during the spring of 2016 were close to normal. Groundwater levels and their deviation from normal during the spring of 2016 varied throughout the watershed (County of Lake 2016).

Although stream gauges are installed in some of the tributary streams, no studies have been conducted on the effects water extraction is having on Clear Lake tributaries or the Clear Lake hitch. The CDFW compared stream flow conditions at the USGS gauge on Kelsey Creek (USGS Station 11449500) and catch data from the early 1990s. Both 1990 and 1991 were considered dry water years with below average tributary flow during the spring; however, the highest number of hitch were captured during seining efforts during those years. Flow conditions improved to average or above average the following three years, but the number of fish captured declined (CDFW 2014). The impact of diversion on the CLH and its spawning tributaries is poorly understood. However, significant flow reductions can lead to increased water temperatures, reduced available aquatic habitat, altered or decreased biodiversity, increases in non-native species, and alterations to fish assemblages (Bellucci et al. 2011; Bunn and Arthington 2002; Marchetti and Moyle 2001).

Water extractions are often cited as one of the primary reasons for the reduction in the Clear Lake hitch’s population, but another hydrological change that has also been mentioned in the literature is the maintenance of the storage level of Clear Lake. By court decree maximum storage for Clear Lake is 1325.82 feet elevation (NGVD 1929), which came into existence when a dam for storing water was built in 1914 on Cache Creek, the lake's only outlet, and that is controlled by neighboring Yolo County. The lake's storage capacity at 1325.82 feet elevation (NGVD 1929) is 319,000 acre-feet, but during dry years this capacity is not realized and during wet years, the lake level can reach much higher than 1325.82 feet elevation. It is possible that maintenance of the lake at this reduced capacity could be impacting water retention within the tributary streams; however, this is speculative and additional study needs to be completed.

4.1.5 Dams
Cache Creek Dam was constructed at the outlet of Clear Lake in 1914, and the Yolo County Flood Control and Water Conservation District manipulates the lake water level several feet
seasonally to allow for diversions for irrigation (DWR 1975). Clear Lake is allowed to fluctuate on a yearly basis a maximum of 1325.82 feet elevation (NGVD 1929) (DWR 1975). The effects of lake water manipulations on CLH populations have not been quantified. Manipulation of water levels in the Clear Lake watershed likely results in decreased water quality, a reduction in spawning and rearing habitat, and increased risk for predation (Converse et al. 1998; Cott et al. 2008; Gafny et al. 2006; Hudon et al. 2010; Wetzel 2001). All these impacts can lead to the extinction of native species that evolved in lakes free of habitat modifications as a result of impoundment structures (Wetzel 2001). Impounded systems also tend to be dominated by non-native species (Moyle and Light 1996).

The KCDS, maintained by the Lake County Watershed Protection District, is used for groundwater storage flood control. The KCDS Operating Criteria, revised in 2016, outlines protocols for communications between the District and CDFW to ensure safe passage through the structure for CLH during the spawning season. These protocols include but are not limited to: the documentation of ponding upstream and downstream of the structure, upstream flow, and CLH in Kelsey Creek. During the 2019 CLH spawning season, Lake County Water Resources staff identified CLH, and other fish species such as the Sacramento sucker, utilizing both the eastside and westside fish ladders located at the KCDS.

4.1.6 Levees and Other Flood Control Structures
Flood control projects in the watershed have also contributed to increased nutrient and sediment transport by channelizing and armoring tributary streams with rip-rap and by reclaiming large portions of wetland habitat that once surrounded the lake (CDFW 2014). There are almost 14 miles of levee structures that were built by the U.S. Army Corps of Engineers (Corps) on Scotts, Middle, Clover, and Alley Creeks (County of Lake 2012). These structures are currently maintained by the California Department of Water Resources and the Lake County Watershed Protection District.

The Northshore watershed of the Clear Lake basin was altered in the late 19th and part of the 20th century as floodplains were claimed for crops and water was channeled for irrigation and reduced seasonal flooding. Large expanses of floodplain were exposed by privately built levees, and the U.S. Army Corps of Engineers constructed more levees further to the north within the Scotts and Middle Creeks systems. Most tributaries have been altered in some way. Miles of Middle Creek above Rodman Slough are leveed, Scotts Creek from Tulelake to Rodman Slough is leveed, and what used to be Robinson Lake is now the greatly reduced Rodman Slough.

Much of original natural channels with healthy, native riparian vegetation reinforcing banks and filtering out silt have disappeared. Dynamic channels that by nature change over time do not exist throughout most of this watershed. Water that would ordinarily flow in winding channels with woody debris and boulders, and be affected by natural events over time especially because these are low gradient streams, has more force now because it is channeled into long, straight, clear stretches. Hitch are not strong swimmers and do not handle strong currents well.

4.1.7 Mercury Mining
In addition to gravel mining operations throughout the watershed (see 4.1.2 Spawning Habitat), there were some small-scale commercial mining operations in 1864 and 1865 in the Clear Lake area that mined both borax and sulfur (Suchanek et al. 2003). Large-scale commercial sulfur
extraction along the eastern shore of Clear Lake began in 1865 when the Sulphur Bank Mercury Mine was established. The sulfur mining operation switched over to mercury mining in 1873 after mercury sulfide deposits were found beneath their sulfur source. Early extraction methods were not as destructive; however, in 1927 the mine began to implement open-pit mining at a large-scale level and would bulldoze any waste products into the lake itself (Richerson et al. 2008). The company continued to mine sporadically throughout the 1950s until the Sulphur Bank Mercury Mine was officially closed in 1957, although waste continued to contaminate the lake well into the 1990s (Suchanek et al. 2008).

Sediment cores taken throughout Clear Lake provided some insight into when and why mercury concentration began to increase within the lake. Sedimentation rates began to increase from about 1 mm/year to an average of 8.6 mm/year beginning in 1927 (Richerson et al. 2008). Calculated sedimentation rates were 13.3–20.4 mm/year from 1927 to 1954, and then decreased to 2.2–4.3 mm/year from 1954 to 2000 (Richerson et al. 2008). In addition to increased levels of sedimentation post-1927, there was also a significant increase in the concentration of mercury, methylmercury, dry matter, phosphorus, and an isotope of nitrogen (15N) found within the sediment horizon after 1927, and the concentrations of nitrogen, sulfur, carbon, and water content decrease within the post-1927 horizon. The dramatic changes in the sediment cores seen post-1927 were likely from the implementation of open-pit mining using heavy equipment to extract ore deposits (Richerson et al. 2008). The highest concentrations of mercury were found in the Oaks Arm of the lake, which is where the Sulphur Bank Mercury Mine is located; however, elevated mercury levels were also found lake-wide (Richerson et al. 2008). The use of heavy ground moving equipment associated with the open-pit mining also likely contributed to the algal blooms seen in the lake by excavating and disturbing large swaths of sediments, which increased nutrient runoff (Richerson et al. 2008).

Mercury and other mining-associated contaminants have entered the lake via erosion of waste piles, purposeful dumping/bulldozing of mine waste, atmospheric deposition, and subsurface drainage (Richerson et al. 2008). Since 1992 the EPA has implemented numerous remediation projects to address the continued mercury contamination originating from the Sulphur Bank Mercury Mine. The remediation projects include the removal of waste rock piles that continued to erode and discharge mercury, removal of contaminated soil from residential areas, installation of diversions to prevent contaminated water and sediments from entering Clear Lake, closure of three abandoned geo-thermal wells, the capping of mine waste used to build an old road, and the installation of two test sediment covers to contain mercury contaminated sediment within Clear Lake (Richerson et al. 2008).

The Sulphur Bank Mercury Mine became an EPA Superfund Site in 1990 due to the elevated mercury levels found in Clear Lake’s larger piscivorous fish (Curtis 1977; Suchanek et al. 2003; Thompson et al. 2013). Elevated levels of mercury in fish can significantly impair reproductive success; however, effects can vary based on a multitude of factors, including species and life stage, and there are no specific studies for CLH (Crump and Trudeau 2009; CDFW 2014). Mercury concentrations found in hitch caught in Clear Lake from the 1980s and 1990s averaged 0.19 mg/kg, while the larger piscivorous fish such as adult largemouth bass averaged .54 mg/kg (CEPA 2002; CDFW 2014). The Regional Water Quality Control Board, Central Valley Region, proposed a target of 0.13 mg/kg for fish in trophic level 3, which includes the CLH (CEPA 2002). Consumption advisories for fish removed from Clear Lake were first issued in the 1980s.
and the California Office of Environmental Health Hazard Assessment continues to provide advisories for Clear Lake fish and invertebrates (Thompson et al. 2013; OEHHA 2018).

4.2 Disease
Outbreaks of koi herpes virus and fish fungi (Saprolegnia spp.) have been documented in various fish species found in Clear Lake, but these diseases do not appear to negatively impact the CLH. Parasites, such as anchor worms (Lernaea spp.), do infect the CLH and there have been numerous documented observations of individuals with attached anchor worm parasites or of individuals containing lesions, which are evidence of previous anchor worm attachment (Big Valley 2015). Anchor worms are a parasitic crustacean (copepod) that infect freshwater fish (Steckler and Yanong 2012). Although a low-level anchor worm infection may not necessarily cause adverse symptoms to the fish other than being irritating, a heavy infection of anchor worms can cause inflammation at the attachment site that can later become infected by a bacteria or fungus, which can eventually result in death. Fish can also die if a large number of anchor worms attach to the gills. Fish that are chronically infected with anchor worms will have lower fitness (Steckler and Yanong 2012). Heavy anchor worm infections had not been reported for CLH until 2021, when USGS lake monitoring revealed all CLH captured had a heavy infestation (CDFW 2014).

In addition to anchor worm infections, there have been three instances of CLH having facial deformities often referred to as “pug nose.” Two were captured by the United States Geological Survey (USGS) while conducting monitoring surveys in the lake and one was captured by a local tribal member during a fish rescue on one of the tributary creeks. The two individuals caught during the lake monitoring studies were both under-weight compared to other hitch their length and one of them in particular looked unhealthy (Feyrer 2018; Clear Lake Hitch Conservation Strategy Meeting Notes 2019). This deformity has been seen in other fish species, but it is unknown what causes it and what effect, if any, it has on the individual (Franks 1995; Schmitt and Orth 2015). However, because it is a deformity of the mouth area, it likely reduces feeding efficiency and results in an overall lower fitness for those individual fish.

4.3 Introduced Fish
Non-native fish introductions into Clear Lake date back as far as the late 1800s (Dill and Cordone 1997). Prior to the introduction of non-native fish species, between 12 and 14 native fish species occupied Clear Lake (Bairrington 2000; Moyle 2002; Thompson et al. 2013). Currently, approximately ten native species and 15 non-native species inhabit the lake (Ewing pers. comm.; Bairrington 2000; Thompson et al. 2013). Over the past 100 years two native species, thicktail chub (Gila crassicauda) and Clear Lake splittail, have gone extinct from the lake and another, Sacramento perch (Archoplites interruptus), has not been captured in sampling efforts since 1996 (Bairrington 2000; CDFW Commercial Fisheries Data; Thompson et al. 2013).

The majority of non-native species introductions have been conducted by CDFW and various local agencies and angling groups in an effort to increase sport fish opportunities. Introductions of fish at Clear Lake have been warmwater sport fish (largemouth bass (Florida strain) (Micropterus spp.), sunfish (Lepomis spp.), catfish, etc.) or forage species for piscivorous sport fish. The CDFW has not stocked fish in Clear Lake in the past decade. Four fish species have been introduced without authorization from CDFW (Dill and Cordone 1997; Rowan J. pers.}
comm. in CDFW 2014). Mississippi silverside, threadfin shad, smallmouth bass (*Micropterus dolomieu*), and pumpkinseed (*Lepomis gibbosus*) were introduced to provide forage for other game fishes, provide Clear Lake gnat control, or as part of a new sport fishery (Anderson *et al.* 1986; Dill and Cordone 1997; Bairrington 2000). Smallmouth bass and pumpkinseed never established sustainable populations in the lake. Non-native game fishes comprise nearly 100% of the sport catch from the lake.

Non-native fish introductions can have significant impacts on native fish species. Mississippi silverside and threadfin shad are thought to compete directly with CLH for food resources and potentially prey on their larvae (Geary and Moyle 1980; Anderson *et al.* 1986; Bennett and Moyle 1996; Bairrington 2000). A comparison of Mississippi silverside and threadfin shad abundance from graphs in Eagles-Smith *et al.* (2008) and population trends for CLH indicate a possible connection between abundances of these species. From 1990 to 2002 a similar pattern exists in increased CLH captures and observations during years of decreased Mississippi silverside and threadfin shad abundance. All three species are limnetic foragers that rely on macroinvertebrates for food. During years with decreased populations of Mississippi silverside and threadfin shad limnetic zooplankton numbers increase in stomach analysis of fishes indicating an increase in their availability to limnetic foragers (Eagles-Smith *et al.* 2008). Years with declines in threadfin shad and Mississippi silverside are thought to coincide with increases in CLH numbers, and years with decreased threadfin shad and Mississippi silverside result in increased young of year recruitment for other native and non-native species (Eagles-Smith *et al.* 2008; LCVCD 2013; Rowan J. pers. comm. in CDFW 2014).

Eagles-Smith *et al.* (2008) found that zooplankton populations declined precipitously as threadfin shad populations increased, causing other common plankton-feeding fishes (juvenile largemouth bass and bluegill, Mississippi silverside) to switch to benthic feeding. CLH, being more specialized for zooplankton feeding and not being able to switch to benthic feeding, may have been strongly affected by the threadfin shad boom-and-bust population cycles in the lake (Eagles-Smith *et al.* 2008). Competition for juvenile rearing habitat and food has likely increased with the reduction in wetland habitat and increase in non-native fish species. Rearing habitat is essential for CLH recruitment to any year class. A reduction in recruitment leads to a decrease in spawning adults the following years. A species with highly fluctuating population trends, such as CLH, is particularly vulnerable to population level impacts in years with reduced recruitment.

Piscivorous fish species such as largemouth bass (*Micropterus salmoides*) prey directly on both juvenile and adult CLH. Omnivorous species such as bullhead catfish (*Ameiurus* spp.) are known to prey on various life stages of native fishes. The introduction of white catfish (*Ameiurus catus*) was described, by Captain J.D. Dondero of the Division of Fish and Game, as having solved the problem of large spawning runs of fish dying in tributaries to Clear Lake and that the population of nongame fish diminished following their introduction (Dill and Cordone 1997). Jordan and Gilbert (1895) also describe catfish as being destructive to the spawn of other species. The rates at which CLH are consumed in relation to other prey species and the amount of CLH consumed are unknown.

Anecdotal reports suggest CLH are a main prey-item for largemouth bass, particularly the Florida-strain of largemouth bass that has been described as a voracious predator. Observations of bass chasing hitch have been published in a well-known online fishing website (Bassmaster),
bass anglers are known to use lures that look like the CLH, and when reeling-in their fishing line, anglers are known to mimic hitch movements to specifically target largemouth bass in the lake (Macedo 1994; Knight 2009; Shangle 2010; P. Windrem in litt. 2020; T. Smythe in litt. 2020). Macedo (1994) found a large hitch in the digestive tract of a record sized bass caught in Clear Lake (17.52 lbs.). In addition, bass anglers are known to position themselves at the mouths of streams during the spawning season to take advantage of congregating bass that feed on the schooling hitch prior to their upstream migration (T. Smythe in litt. 2020).

4.4 Pesticides and Pollutants

4.4.1 Pesticides
Previously, Clear Lake gnat outbreaks occurred regularly in Clear Lake and were considered a nuisance to residents near the lake. In order to control these outbreaks, the county applied various pesticides to the lake to control the gnat at different life stages. Over 120,000 lbs. of the larvicide DDD (dichloro-diphenyl-dichloroethane) was applied to the lake on three different occasions in 1949, 1954, and 1957, and its biological accumulation up the food chain resulted in elevated concentrations of DDD in fish tissues and the mortality of numerous western grebes (Aechmophorus occidentalis) within the lake (Goldman and Wetzel 1963; Cairns and Parfitt 1980; Suchanek et al. 2003). Although the highest levels of DDD concentrations were seen in piscivorous fish species, fish species at lower trophic levels like the CLH also had concentrations of the larvicide in their tissues (Cook 1965). Conversely, later analysis of the lake bottom revealed concentrations of 0.05 to 1.0 ppm (parts per million) within the first 5 inches of sediment, which some researchers indicated that bottom feeding fish species would be most impacted by their greater exposure to high levels of DDD. This was further supported by the high levels of DDD or its metabolic products found in carp tissues decades after the larvicide applications (Cairns and Parfitt 1980). Even after almost 20 years post-application, concentrations of DDD or its metabolic breakdown products continued to be seen in various fish species tissues, including the hitch (Cairns and Parfitt 1980). It is possible that agricultural pesticide application, specifically the use of DDT which can break down to produce DDD, has contributed to the elevated levels seen in fish tissue years after the final application of the larvicide to the lake (Cook 1965; Cairns and Parfitt 1980).

The application of DDD not only had a direct impact on the hitch through contamination, but it also likely impacted the hitch by targeting, and greatly reducing, one of their main prey items. An estimation of the gnat population in Clear Lake and other nearby lakes after DDD application revealed the gnat population was 99-100% eliminated, although the effectiveness of subsequent DDD applications to Clear Lake declined (Lindquist and Roth 1949; Hunt and Bischoff 1960). The application of DDD not only eliminated or greatly reduced gnat populations, it was also known to reduce another prey item of juvenile CLH, chironomid larvae. However, chironomid larvae populations were able to recover faster than gnat populations post-DDD treatment (Lindquist and Roth 1949).

Due to the rebounding gnat population in Clear Lake after treatment with DDD and because subsequent DDD applications were losing effectiveness, other pesticides were used to target the gnat population (Cook 1965; Suchanek et al. 2003). In 1959, a petroleum based larvicide was sprayed on gnat eggs found along the shores of the lake and malathion was sprayed on terrestrial vegetation to target adult gnats. Methyl parathion was applied annually to Clear Lake during the
summer from 1962 to 1975 after multiple applications in 1962 appeared to be effective. However, similar to the DDD application, the gnats began to develop a resistance to the methyl parathion treatments and it proved to no longer be effective (Suchanek et al. 2003). The gnat population is thought to fluctuate in response to the silverside and threadfin shad populations in the lake, with the former specifically introduced to help control gnat outbreaks (Cook and Moore 1970; Prine et al. 1975; Geary 1978; CDFW 2014; B. Ewing in litt. 2020).

Other pesticides are also used throughout the watershed on private homeowner and agricultural lands. Pesticide use on private, non-agricultural land does not legally have to be reported, so it is unknown what chemicals are being applied and in what amounts (Suchanek et al. 2003). The reported application of pesticides on agricultural lands has increased from 2008 to 2017. In 2008, over 589,500 lbs. of different forms of chemicals used as pesticides were applied in Lake County (CALPIP 2019). In 2017, the use increased to almost 759,000 lbs. (CALPIP 2019). However, it is important to contextualize those numbers, as nearly 80% of total pesticides applied in pounds is from elemental Sulphur; a pesticide used by both organic and conventional winegrape growers (CDPR 2017). In the period between 2012 and 2018, the Lake County winegrape acreage increased from 8,392 acres to 9,680 acres, an increase of 1,288 acres, with 1,098 bearing acres and 190 non-bearing acres. Non-bearing acres include both new plantings and existing vineyards that are no longer managed or farmed (Lake County Department of Agriculture 2013; Lake County Department of Agriculture 2019).

The past use of DDD had direct and indirect impacts on the CLH; however, it is unknown what effect the current pesticide use is having on the aquatic environment or if they are being transported through tributary streams into the lake (Suchanek et al. 2003). Furthermore, it is unknown what effect, if any, they could be having on the CLH.

4.4.2 Effect of Excessive Nutrient/Sediment Load from Streams

Soil in the Clear Lake area is naturally erosive, and creeks continue to dump heavy loads of sediment into the lake (Lake County Grading Ordinance). The Central Valley Regional Water Quality Control Board’s Clear Lake TMDL document identifies point-source and non-point source contributors of sediment discharge into Clear Lake by way of streams and tributaries. Point source discharges in the watershed, such as urban storm water and CalTrans road building and maintenance activities, have been given load specific allocation reductions. A general load limit was set for the nonpoint sources, including irrigated agriculture, County of Lake, U.S. Bureau of Land Management, and the U.S. Forest Service. Source contributors were given a deadline of 2016 to meet a 40% phosphorus load reduction. (CEPA 2012). The Regional Water Board is currently following-up with contributors to confirm this reduction has been met.

The County of Lake updated their grading ordinance in 2007 to minimize the impacts of agricultural conversions, native brush clearing, and general grading projects. This ordinance defines agricultural grading projects, provides a narrow list of exemptions for non-orchard agricultural conversions in non-erosive soil and flat grades, sets a clear grading season between April and October, and identifies BMPs (Best Management Practices) for grading projects (Lake County Code, Grading Ordinance, Chapter 30: https://library.municode.com/ca/lake_county/codes/code_of_ordinances).
All agencies should be involved in maintaining and encouraging riparian growth along the streams and lakeshore to prevent excessive sediment loads from entering the lake. It is also important that CDFW continue to work with the public to ameliorate or minimize streambed and riparian habitat alterations which decrease a stream's ability to filter out silt. In addition, a nutrient budget is currently in progress under a grant (Clean Lakes Program) from the Environmental Protection Agency (EPA). The University of California, Davis, has undertaken the research in coordination with the Department of Water Resources. Test programs such as those in Scotts Creek, are examining methods for reducing erosion and sedimentation. The nutrient budget should go a long way toward a better understanding of the Clear Lake ecosystem.

4.4.3 Aquatic Plants (Macrophytes)
Aquatic plants serve many aquatic ecosystem services including improved water clarity, provide primary production, stabilize shorelines and sediments, provide habitat for zooplankton, macro invertebrates, and numerous fish and amphibian species (Carpenter & Lodge 1986; Sass et al. 2017; Valley et al. 2004). In Clear Lake, increased clarity and warming conditions have resulted in increased aquatic plant growth over the last 30 years, which can be beneficial for overall water quality and maintaining reduced concentrations and blooms of cyanobacteria. Some aquatic plant species compete with or inhibit cyanobacteria growth through allelopathy (Amorim et al. 2019).

Aquatic plants provide natural infrastructure that is beneficial to hitch and other native fish species, providing refuge for juvenile fish. Aquatic plant beds reduce wave and boat action impacts and provide a diverse, food rich habitat suitable for young fish (Sass et al. 2017; Valley et al. 2004). Additionally, even in shorelines areas with hardscapes such as riprap or sea walls, the presence of aquatic and emergent vegetation can reduce impact from wave action, preventing sediment scour and reduced structural integrity of the infrastructure (Michigan Natural Shoreline Partnership website: https://www.mishorelinepartnership.org/).

While the majority of native or naturalized aquatic plant species found in Clear Lake are beneficial there are several aggressive invasive aquatic plant species that are of concern and are currently being managed for eradication in the lake, including Hydrilla. Hydrilla (Hydrilla verticillata) is a highly invasive aquatic plant that has the capacity, by forming dense mats that reduce dissolved oxygen (DO) levels, to disrupt many of the water-based activities that are synonymous with Lake County. Statewide efforts, driven and managed by California Department of Food and Agriculture (CDFA), to eradicate Hydrilla have been generally successful, with the invasive plant fully eradicated in 15 California counties. Lake is one of three counties currently affected by Hydrilla infestation, but the path towards eradication is getting closer. Since being introduced into Clear Lake in 1994, Hydrilla populations have been reduced significantly since CDFA treatments began. For example, there were no reports of sightings of Hydrilla in 2017 or 2018, and only a small 5-in fragment was found in the Clear Lake Keys during summer 2019. It is possible recent lake conditions might have prompted dormant reproductive plant tissues, called tubers, to sprout. Tubers can survive in sediments for up to 4 years making long-term monitoring and management a vital component of the CDFA’s eradication program.

If Hydrilla is left unmanaged, there could be severe and damaging consequences to both the ecology and economy of Clear Lake. For example, Hydrilla can grow very quickly and aggressively and outcompete native plant species for space and light. Hydrilla has also been known to grow so densely that it changes the chemical and physical properties of lakes where it dominates. Sportfish surveyed from lakes where Hydrilla is the prominent species have been
shown to be smaller in weight and size as Hydrilla limits available spawning and foraging space for fish and creates a non-suitable environment for zooplankton and phytoplankton, the primary food for many juvenile fish. Additionally, the thick, dense mats that Hydrilla can create, restrict boating and swimming, clog drinking-water systems and other submerged infrastructures, leading to increased costs and maintenance and reduced water flow.

The Lake County Water Resources Department has issued stop-order notices for all mechanical harvesting and other activities in the Keys, and is also requesting that the public reduce any unnecessary boat traffic from the Keys to Clear Lake, at least until CDFA has completed the necessary treatments. By reducing mechanical harvesting and limiting boating traffic, the probability of transporting a Hydrilla fragment from the Keys to another location in the lake can be significantly reduced. Hydrilla, much like other invasive aquatic plant species, can rapidly reproduce from a small fragment, which can flow through lake currents or get picked up by a boat, travelling to another part of the lake. Even a 1” fragment can grow over an inch in length in a day and some Hydrilla in other waterbodies has been shown to grow up to 30ft long!

Treatment plans, conducted and monitored by the CDFA, usually consist of an immediate copper sulfate treatment to kill any existing Hydrilla plants or fragments, followed by SONAR Q (Fluridone) pellets that sink to the bottom of the immediate and surrounding area and serve as a pre-emergent preventing the sprouting of any remaining Hydrilla tubers. All work completed by CDFA follows Clean Water Act NPDES (National Pollutant Discharge Elimination System) requirements.

The Water Resources Department will be providing support and assistance to CDFA as needed to assure that continued work is successful in eradicating any and all Hydrilla in Clear Lake. Water Resources would also like to remind the public that the removal or control of any aquatic plants in Clear Lake, whether by hand-pulling, mechanical harvesting, or chemical treatment, requires a permit. A Clear Lake Aquatic Plant Management Permit, can be found on the “Aquatic Plant Management” tab on the County of Lake Water Resources Website and can be printed and filled out in hard copy or downloaded electronically and emailed to the department.

Department of Food and Agriculture, in cooperation with efforts by Lake County Agriculture Office, Department of Boating and Waterways, and CDFW is presently undertaking an eradication effort that may impact access to some areas frequented by anglers. Hydrilla, if left unchecked in growth, can spread so densely as to occlude waterways, shore access, and damage fish and wildlife resources. As the problem becomes severe in coming years, greatly restricting angler access, CDFW will support balanced management practices.

As a result of chemical treatment of the Hydrilla infestation with applications of an aquatic herbicide known as Komeen ®, initial reports of a decline in aquatic microorganisms (Buckman pers. comm. in Bairrington 2000), as well as impacts of aquatic invertebrates such as snails and crawdads in treatment areas, have been observed. While applied concentrations of Komeen ® does not kill fish directly (B. Finlayson pers. com. in Bairrington 2000), the deletion of the bottom of the food chain may kill fish indirectly (M. Rugg pers. comm. in Bairrington 2000). Under certain natural conditions a synergism may exist between copper and mercury which increases the toxicity of each acting alone. The threshold concentrations of copper for freshwater fish and aquatic life is 0.02 ppm (M. Rugg pers. comm. in Bairrington 2000), however the
The threshold concentration for Hydrilla is between 0.75 and 1.0 ppm according to the manufacturer. Decreases in DO may also be an indirect impact. The Action Plan For Hydrilla Eradication In Lake County (June 1995) is based in part on CDFW studies on Hydrilla and Komeen® in Eastman reservoir and in the Imperial Valley in 1984. Those studies were based in part upon studies carried on by Florida Department of Game and Fish. Due to the emergency nature of the Hydrilla infestation, in which timing was critical, there was no time available to test whether the extrapolations of results from the Florida studies and the Imperial Valley studies in California were appropriate for Clear Lake. In the larger perspective, it may be better to lose a part or all of Clear Lake temporarily in order to control Hydrilla with Komeen® as opposed to permanently losing Clear Lake and the ultimate drainage into the Sacramento Delta due to the choking uncontrolled growth of Hydrilla.

Aquatic herbicides, such as Sonar®, which are less toxic, do not use an ion of copper as part of the active ingredient, and are effective in the control of Hydrilla. As a systemic herbicide, Sonar® treatments require a longer residence time on the hydrosoil surface for uptake by the target plant, than contact herbicides like Komeen® Therefore the application of Sonar® is limited to areas of the lake shoreline that do not have strong underwater currents. Sonar® became registered in California in 1996 and was applied that same summer. While Sonar® is less toxic to aquatic life than Komeen®, as a systemic herbicide the effects of treatments for Hydrilla are also reflected in the other non-targeted vascular aquatic plants such as tule.

It was essential to monitor the application of both Komeen® and Sonar® to ensure the precise adherence to the procedures and protocols for its effective use. Biological monitoring programs were designed to analyze the effect of the chemical treatments on vascular aquatic plants, vertebrate and invertebrate biota, and microbiota within and outside of the treatment sites, in addition to the original protocols for testing for the presence of copper in water samples in the treatment sites. As of 1998, and an analysis of three years of data, the previously unknown effects that these treatments have had, presently have, or will have on the game and nongame fisheries in Clear Lake are better understood. While each of these chemicals were effective to eradicate Hydrilla, their short-term effects on non-target animal species has been determined to be minimal. Komeen® applications have been shown to cause a sharp decline in zooplankton populations within the treatment site in the first day following application but the toxicity decays rapidly, within 96 hours, (Trumbo 1997; Trumbo 1998).

Post-Komeen® treatment electrofishing surveys have even shown an increase in the number and abundance of fish species, probably in response to the initial mortality of invertebrate prey items such as snails. Since snails graze upon the surface of the hydrosoil, they would encounter a higher concentration of toxic copper compounds settling to the bottom of the lake than animals that can retreat into burrows within the hydrosoil. Critically low levels of dissolved oxygen for fish respiration did not appear in response to the decay of plant material killed by the Komeen® treatments.

The effect on tule beds in the areas treated by Sonar® is still being analyzed; however preliminary evidence shows the extent of the tule beds to be receding during the season of treatment (Buckman pers. comm. in Bairrington 2000). The hope is that the tule and their tubers will survive longer than the Hydrilla, and that after the final herbicidal applications, the tule
density and surface area will return to pre-treatment levels. Meanwhile there may be a short-term negative effect on grebes nesting in the tule beds.

Finally, the effectiveness of the chemical applications to eradicate Hydrilla seem to be successful as the density and distribution of the plants in Clear Lake continue to be dramatically reduced. There will always be a threat of reintroduction of Hydrilla so a continual education and monitoring program is expected to be maintained.

The vascular aquatic plants other than Hydrilla have been of concern in Clear Lake too. Especially with the restrictions on physical or mechanical removal of these plants during the Hydrilla eradication program, local citizens complained that there was no effective way to keep their waterways open to boating. Mechanical harvesting is an unacceptable, non-chemical, method of controlling weeds within a 1/4 mile of a Hydrilla plant find because it may result in the fragmentation and inadvertent spread of Hydrilla. During the 2018 season, CDFA selectively allowed private mechanical harvesting permits due to a Hydrilla treatment area. No county-contracted mechanical harvesting was permitted in 2018 within Hydrilla management unit boundaries.

Even though citizens may complain about the vascular aquatic plants choking the shallow coves for boat access around the lake, and others may complain about the non-vascular plants, such as macroalgae and free floating-algae, the importance of the perimeter of emergent vascular aquatic plants such as the tule beds is crucial to the healthy ecosystem of the lake. The beds of emergent and submergent plants and the wetlands provide the biological filter for the lake, help reduce shoreline erosion, and provide nursery grounds for juvenile fish. Since approximately 72% of the tules and associated wetlands have been removed from around the lake for aesthetic purposes, a better view, or agricultural development, there is a continual need to restore that part of the ecosystem to pre-urban and pre-agricultural development levels.

Lake County Water Resources Department manages the Clear Lake Integrated Aquatic Plant Management Program that manages the issuing of private permits for aquatic herbicide treatments and provides aquatic herbicide treatments for public use areas such as beaches, boating lanes, and public-use shorelines. Throughout the treatment season, Water Resources staff randomly sample herbicide treatments prior to treatment (pre), immediately after treatment (during), and one week following treatment (post) to identify the longevity and endurance of herbicide chemicals in the water and if there are lingering in the water column at levels higher than EPA thresholds recommended for wildlife and public use. During 2017 and 2018, no treatment-specific sampling resulted in concentrations of non-detects. For both 2017 and 2018, less than 1% of Clear Lake surface area was treated through the Lake County Aquatic Plant Management program, through private or public permits. Annual reports for this program are available online at the Lake County Aquatic Plant Management Website.

4.5 Naturally Occurring Phenomena

4.5.1 Climate Change
The terms “climate” and “climate change” are defined by the Intergovernmental Panel on Climate Change (IPCC). “Climate” refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements (IPCC
The term “climate change” thus refers to a change in the mean or variability of one or more measures of climate (for example, temperature or precipitation) that persists for an extended period, whether the change is due to natural variability or human activity (IPCC 2013a).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has been faster since the 1950s. Examples include warming of the global climate system, and substantial increases in precipitation in some regions of the world and decreases in other regions (for these and other examples, see Solomon et al. 2007; IPCC 2013b; IPCC 2014). Results of scientific analyses presented by IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is “very likely” (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (Solomon et al. 2007; IPCC 2013b).

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of greenhouse gas emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (e.g., Meehl et al. 2007; Ganguly et al. 2009; Prinn et al. 2011). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that greenhouse gas emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of greenhouse gas emissions (Meehl et al. 2007; Ganguly et al. 2009; Prinn et al. 2011; IPCC 2013b). See IPCC 2013b, for a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation.

Global climate projections are informative, and, in some cases, the only scientific information available for us to use. However, projected changes in climate and related impacts can vary substantially across and within different regions of the world (IPCC 2013b). Therefore, “downscaled” projections are used when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant to spatial scales used in the analyses of a given species (see Glick et al. 2011 for a discussion of downscaling).

Hayhoe et al. (2004) produced down-scaled climate change models for California using climate data from the period from 1961–1990 to predict future temperatures and precipitation for the period 2070–2099. They used two different climate models to run two scenarios, one which assumed that greenhouse gas concentrations would increase substantially (SRES A1Fi), and one which assumed that concentrations would stabilize by the end of the century (SRES B1). Their projections indicate an increase in both winter and summer temperatures along the northern portion of the state, although the temperature increase is more pronounced to the east (Hayhoe et
al. 2004). Three of their projections also indicate a decrease in winter precipitation concentrated along the north coast, although one projected a small increase in precipitation by 2099 (Hayhoe et al. 2004).

Pierce et al. (2013) used different methods to produce down-scaled climate change models for California, using climate data from the period of 1985 to 1994, and predicted future temperature and precipitation changes for the future period of 2060 to 2069. The models were run under one emissions scenario (SRES A2) and the results suggest that by the 2060s, average temperatures within the range of the CLH could increase 2.2°C, with average spring temperatures rising about 1.9°C and average summer temperatures rising 2.9°C (Pierce et al. 2013). The average annual change in precipitation within the range of the hitch is projected to be zero; however, there are projected seasonal changes with wetter conditions in the winter and drier conditions throughout the rest of the year (Pierce et al. 2013). Precipitation projections also suggest there will be increased chances of flooding due to an increase in the 3-day maximum precipitation rate, especially in the northern portion of the state within the range of the CLH. It should be recognized that under all of the model projections, the projected seasonal changes are relatively small when compared to the state’s natural variability (Pierce et al. 2013).

Downscaled climate projections were also completed for several regions throughout California for California’s Fourth Climate Change Assessment, including the North Coast Region where Lake County is located (Grantham 2018). Ten global climate models were used for the regional assessments and each model considered two different emissions scenarios, one in which greenhouse gas emissions continue to increase into the next century (RCP 8.5, similar to SRES A2) and one in which greenhouse gas emissions stabilize by mid-century and then decline to levels seen in the 1990s by the end of the century (RCP 4.5) (Grantham 2018). Under both emissions scenarios, annually averaged maximum temperatures in Lake County are expected to increase. Under RCP 8.5, annually averaged maximum temperatures are projected to increase by almost 3°C (4-5°F) by mid-century (period between 2040 and 2069) and about 4°C (7-8°F) by the end of the century (period between 2070 and 2099). Under emissions scenario RCP 4.5, annually averaged maximum temperatures are projected to increase by about 2°C (3-4°F) by mid-century and 3°C (4-5°F) by the end of the century (Grantham 2018).

In addition to temperature projections, the downscaled models for California’s Fourth Climate Change Assessment also assessed future changes in precipitation, both the amount and the timing. The precipitation changes projected by the models were much more complex than the predicted temperature changes, mostly because the predicted changes are within the range of historical variation (Pierce et al. 2018; Grantham 2018). There is also less difference between the two different emissions scenarios than was seen for the temperature predictions (Pierce et al. 2018). The downscaled models for the North Coast Region predict the amount of annual precipitation within that area is within the range of historical variation, although with a slightly increasing trend. Within Lake County in particular, annual precipitation projections under both emissions scenarios show a similar, 4-8% increase in annual precipitation by mid-century. However, late century projections suggest a 6-10% increase in annual precipitation for RCP 4.5, while RCP 8.5 suggests an increase of 10-16% (Grantham 2018).

This increase in precipitation will mostly occur during the winter months, with either no change or a decrease in precipitation during the spring (Pierce et al. 2018). Specifically, under RCP 4.5...
the average precipitation change is projected to increase 8-16% during the winter during both the mid-century and late century time periods, but is projected to decrease 4-8% during the spring over the mid-century time period. Under RCP 4.5, there is a 0-4% predicted change in precipitation during the spring months for the late century time period. Under RCP 8.5, winter precipitation is projected to increase 8-12% during the mid-century time period and 20% or more into the late century. Spring precipitation under RCP 8.5 is projected to increase 0-4% mid-century and decrease 0-4% late century (Pierce et al. 2018). In general, the winter months (December–February) are projected to be wetter and the spring months (March–May) are projected to be drier. The increase in precipitation in the winter is also likely to be compressed into a shorter wet season in the winter, which will result in earlier drying in the spring (Grantham 2018). Likewise, streamflow will likely increase during the wet season but decrease in the dry season, with the greatest increase in flow during the month of January and the greatest decrease in flow during the month of May (Grantham 2018). In addition, the number of drought years are projected to increase under both scenarios, but under RCP 8.5 it almost triples into the end of the century (Pierce et al. 2018).

Because the CLH has such a narrow geographic range, any changes in climate will likely be uniform across the range. Projected climate change effects are likely to impact the amount of water retained within tributary streams and wetland habitats, potentially reducing reproduction and recruitment by eliminating or greatly reducing spawning within certain tributary streams and reducing the amount of rearing habitat available. In addition, these effects may also impact the growth of riparian and emergent vegetation, further reducing reproductive success and recruitment, and potentially increasing predation pressure during early life stages. Although the increase in precipitation during the winter will increase tributary inundation, the degraded tributary streams are unlikely to retain the extra flow into the spring when it would benefit spawning runs. In addition, the increase in winter flows may exacerbate the transport of sediments and nutrients into Clear Lake. The ability to spawn in the lake provides an alternative to stream reproduction during the spawning season, but it is unknown whether this reproductive strategy can maintain a viable population of hitch in Clear Lake over the long-term. Having a longer life-span is likely an adaptation to variable environmental conditions within the Clear Lake area; however, prolonged drought conditions can greatly impact the overall population, especially in conjunction with other factors that are currently acting on the hitch. Moyle et al. (2013) conducted an assessment to determine the CLH’s vulnerability to the effects of climate change. They determined that the hitch was “critically vulnerable” to the effects of climate change (specifically, the change in spring hydrograph) and that the hitch “…is extremely likely to be driven to extinction by year 2100 without conservation measures (Moyle et al. 2013).”

4.5.2 Wildfire
There is evidence that wildfire can have significant impact on aquatic resources (Bixby et al. 2015) however the research specific to lakes is less known (McCullough et al. 2019). There has not been directed research in Lake County specifically to identify impacts of wildfire on the hitch or other aquatic species, and this remains a substantial research gap. Lake County has a history of wildfire activity, with at least 33 fires recognized by CalFire since 1925, occurring in the Clear Lake watershed. In 2018, the Mendocino Complex fire, comprised of the River (48,920 acres) and Ranch (410,182 acres) fires, burned about 40% of the Clear Lake watershed. Both fires burned landscape around two of the most significant tributaries to Clear Lake; the River Fire surrounded the upper and middle Scotts Creek sub-watersheds and the Ranch Fire burned
significant portions of the Middle Creek sub-watershed. There is current research being conducted by the UC Davis/Tahoe Environmental Research Center to identify how the Mendocino Complex fire impacted the water quality of Clear Lake and its tributaries (UC Davis 2018-2019). Hopefully this information will provide some glimpse of the potential wildfire-derived impacts to the water quality and habitat the hitch depends on.

4.5.3 Cyanobacteria

With the loss of the extensive tule expanses within the lake’s nearshore habitat, there has been an increase in the amount of sedimentation and nutrients entering the lake (Prine et al. 1975). Wetlands act as a filter for sediments and nutrients transported from the tributaries into the lake and the loss of these large wetland complexes directly surrounding the lake has had negative consequences to Clear Lake’s water quality (Richerson et al. 1994; Suchanek et al. 2003). One of the issues in Clear Lake are the cyanobacteria “blue-green algae” blooms that periodically occur. Early accounts suggest these algae blooms may have occurred historically, but the current increased incidence of these blooms is likely indirectly caused by this wetland loss (Stone 1876; Suchanek et al. 2003; Richerson et al. 1994).

The algae, which is actually a cyanobacteria and not an actual algae, will float to the surface of the lake during the day and can form large mats or scums. It will either be broken up or re-submerged into the lake via wind action, or will begin to die from sun exposure. When the algae does die off, it gives off an unpleasant odor of dead fish and releases pigments that can change the color of the lake. A *Microcystis* bloom in the fall of 1990 was so bad that boats could not navigate through it and was estimated to cover tens of acres at up to 1 meter thick (Richerson et al. 1994). Blue-green algae blooms are the result of phosphorus input from sewage discharge and erosion. Within the Clear Lake watershed, phosphorus input from sewer discharge is low and the primary input is from tributary erosion (Richerson et al. 1994). Phosphorus is found naturally in underlying sediments within the Clear Lake watershed (Richerson et al. 1994) and the degradation of tributary streams have exposed those sediments, allowing for transport into the lake during rain events. Furthermore, increased temperatures due to climate change will likely increase the incidence of blue-green algae blooms in Clear Lake (Grantham 2018). Blue-green algae blooms can be toxic to fish (Gorham 1960; Prine et al. 1975; Richerson et al. 1994); however, it is unknown what impact they have on the CLH.

Most methodologies to control or eradicate algae are detrimental to fish; however, Lake County and UC Davis' Clean Lakes Program is studying biologically sensitive methodologies to control erosion and lake sedimentation which contribute to the problem. These problems in small lagoons and channels at Clear Lake, relative to the entire lake ecosystem, appear to be minimal from a biological perspective. However, from a sociological perspective, these issues are important. What does pose a threat, on the other hand, are the various methods often proposed to control algae (e.g., copper sulfate, aluminum sulfate, or other chemical controls). Many of these chemicals are toxic to aquatic life and limit productivity. Past chemical treatments to control pests (primarily algae and gnats) have produced undesirable effects such as pesticide biomagnification or eventual immunity to the chemical by the target species. In addition, application of chemicals to control aquatic plants and algae may cause sudden drops in DO levels as the dying plant material undergoes bacterial decomposition. Sudden drops in dissolved oxygen have resulted in fish kills in the Clear Lake Oaks Keys and other areas of poor water circulation around the lake. CDFW encourages mechanical or biological rather than chemical means of
algae control. To understand the reasons behind this, one must first understand the life cycle of blue-green algae.

Blue-green algae normally moves up and down from the bottom to the surface of the lake during its daily cycle, producing oxygen during the day and using it at night. During the summer and early fall, warm temperatures cause heavy algal blooms. If not allowed to mix properly—that is, cycle up and down—either because of low wind activity on the lake or because they are confined to a small area such as a lagoon or cove (e.g., the Oaks Keys), the algae become trapped on the surface, the sun kills them, their cells split, and an odorous, oily substance is emitted. This odor may become increasingly unpleasant if large algal mats begin anaerobic decomposition. When algae die, they produce no oxygen; they only use it in decomposition.

One way to prevent odorous, anoxic conditions is to keep the algae alive in their normal cycle by agitating the surface in order to break up the trapped algae and help them sink (in other words, to do mechanically what the wind normally does). This can be done with a high-pressure hose and nozzle, a pump and sprinkler, even a garden hose, depending on the size of the area. Lake County purchased an airboat for use by Lakebed Management in breaking up the algae, which showed positive results in the past; however, although Lake County still owns an airboat, they do not utilize it for algae mitigation anymore. Due to a lack of resources and funding, Lake County is currently not implementing any algae mitigation. They do continue to work with County Public Health, Environmental Health, and the local Tribes to conduct cyanobacteria outreach, distribute press releases, install signage, and provide public education.

4.6 Commercial and Recreational Fishery

Commercial fishing in Clear Lake began in the early 1900s and has been shut down and reinstated several times for different fish species (Murphy 1951; Moyle and Holzhauser 1978; Thompson et al. 2013). Since hitch were often not the target species, most documentation of hitch caught during trawls are incidental catch records, which are only available from the time period between 1961 and 2001 (CDFG Commercial Catch Records 1961-2001). Because commercial fishing operators were primarily harvesting species that would be targeted within the open water of the lake (blackfish, carp, and goldfish), any hitch incidentally caught were likely adults (Bairrington 2000; CDFW 2014). There is one record from 1976 that documented the catch and sale of over 1,500 pounds (lbs.) of hitch from Clear Lake; however, due to low marketability and price point, there were likely no other commercial operators collecting and attempting to sell the CLH (CDFG Commercial Catch Records 1961-2001; CDFW 2014). Although there is a documented instance of the CLH being caught commercially, it likely did not occur very often other than that occurrence, and therefore, did not have a population-level effect on the species. Furthermore, commercial fishing operations are currently not occurring on Clear Lake (CDFW 2014).

Clear Lake is known for its recreational fishery, with largemouth bass (*Micropterus salmoides*) being the dominate fish species caught. During a Clear Lake angler survey in 1988, centrarchids (sunfish family) dominated the catch with largemouth bass comprising 67% of reported catch, bluegill 15%, and crappie 6% (Macedo 1991). Hitch comprised 2% of the reported catch and all of the hitch caught were in the southern portion of the lake (Macedo 1991). Centrarchids also dominated the catch in 1969; however, crappie (56%) and bluegill (23%) were the dominate species caught and no hitch catch was reported (Macedo 1991). Because Clear Lake is known for
its excellent bass fishing, there are numerous bass fishing contests or tournaments that occur fairly regularly on the lake. Fishing contest permits for Clear Lake must be approved by CDFW and a 2019 review of submitted fishing contests showed that for the period between August 14, 2019, and December 5, 2020, there were 66 fishing contests that had been approved and 2 that were pending (CDFW 2019). Since the majority of fishing contests and recreational anglers are targeting bass, it is likely only a negligible amount of hitch are incidentally caught (CDFW 2014).

4.7 Conservation Actions to Date
A detailed description of projects completed by each of the five Lake County Tribes can be found in Section 3.1 above. Other conservation efforts are described below.

Clear Lake Integrated Watershed Management Plan (CLIWMP)
The local resource conservation districts developed the Clear Lake Integrated Watershed Management Plan (CLIWMP) to document the historical and current conditions of the Clear Lake watershed and any management actions that have or are currently being implemented. Opportunities to enhance and/or protect the watershed are then identified using that background information. The CLIWMP is a watershed management program that describes specific implementation actions needed to create an environmentally and economically healthy watershed, both for the benefit of the existing local community and for future generations (County of Lake et al. 2010a). In addition to the CLIWMP, the local conservation districts also developed watershed assessments for Scotts, Middle, and Kelsey Creeks. The purpose of those assessments are similar to the CLIWMP, they document the historical and current conditions of those watersheds and any management actions implemented. The assessments will aid in educating watershed users and landowners on the condition of that particular watershed, the management and restoration actions that need to be implemented to improve conditions, and how the conditions of those particular watersheds impact the condition of Clear Lake (County of Lake et al. 2010b; County of Lake et al. 2010c; County of Lake et al. 2010d).

Aggregate Resources Management Plan
Lake County developed an Aggregate Resources Management Plan (County of Lake 1992) to address concerns about the impacts of gravel mining on the watershed. The plan describes the policies regarding mining in specific areas, identifies areas deemed as suitable for future mining projects, and informs the public about mining in Lake County. The plan calls for a moratorium on mining in certain creeks and limits mining activities to certain areas (County of Lake 1992). The regulation of gravel mining in the county has reduced the rate of erosion in the tributary streams and increased the amount of riparian habitat along the stream channels. Although in-stream sources of gravel are no longer the primary source of aggregate in Lake County since gravel is now acquired from other sources, illegal gravel mining or extraction has been known to occur in the watershed without enforcement (CEPA 2008; B. Ewing in litt. 2020).

Middle Creek Flood Damage Reduction and Ecosystem Restoration Project
The Middle Creek Flood Damage Reduction and Ecosystem Restoration Project (Middle Creek Project) is both a flood risk reduction project for urban and agricultural areas along the northern end of Clear Lake and an ecosystem restoration project that will improve degraded wetland habitat and water quality in Clear Lake. The Middle Creek Project area is much of the original floodplain along Rodman Slough’s northeast bank, which was once approximately 1,400 acres of
wetland habitat that was lost in the early 1900s through the construction of levees and conversion to agricultural use. The entire eastern edge of Rodman Slough is a levee that contains floodwaters within the slough and the fertile floodplain to the east has been farmed since. Scotts, Middle, and Clover Creeks flow into the slough, and these creeks have been straightened and channeled by levees on both east and west banks.

Although these levees once protected agricultural lands, residents, and the community of Upper Lake, they also blocked natural flow and filtration of the northern Clear Lake watershed. Because these levees are no longer functional and there is an urgent need to restore surrounding wetland habitats to improve the lake and the watershed, Lake County requested the Corps’ assistance to evaluate the project in 1995. The Middle Creek Project consists of acquiring reclaimed land, breaching existing levees to flood historical wetland and floodplain areas, and reconnecting Scotts and Middle Creeks. Levees to the north will remain and control reaches of Scotts Creek and much of Middle Creek. Historically Scotts and Middle Creeks and their feeder streams, including flooded fields and marshes, offered possibly hundreds of acres of migration and spawning habitat that CLH used.

NEPA and CEQA review was completed in 2003 and 2004 respectively, and the Middle Creek Project was authorized by the Water Resources Development Act in 2007. Federal funding for the Middle Creek Project has not yet been appropriated to start project design; however, funding for land acquisition has been acquired (County of Lake 2012). The NEPA process will be completed once the Corps approves the Record of Decision. The Middle Creek Project will benefit the Clear Lake watershed by reducing the amount of sediment and nutrients entering Clear Lake, improving overall water quality. If the Middle Creek Project were to be implemented it would benefit adult hitch by improving the water quality of Clear Lake, which would likely reduce the incidence of large fish kills. The Middle Creek Project would also greatly benefit juvenile hitch by increasing the amount of wetland habitat surrounding the lake, providing increased cover from predators and competitors, and increased prey abundance.

The Middle Creek Project, once completed, will recreate the historic Robinson Lake at the confluence of Scotts and Middle Creeks, and restore approximately 1,650 acres of natural habitat consisting of 765 acres of wetlands, 230 acres of riparian habitat, 405 acres of open water, and 250 acres of upland habitat (Army in litt. 2004). It will also increase the existing amount of wetland habitat within the Clear Lake watershed by approximately 79 percent (County of Lake 2012).

The Middle Creek Project Committee
The Middle Creek Project Committee was created by the County in 2019 with Committee members including two (2) County of Lake Board of Supervisors, two (2) members of the Middle Creek Coalition and one (1) representative from the Lake County Watershed Protection District to ensure progress is being made towards the completion of the Middle Creek Project. The Committee holds monthly public meetings and coordinates outreach efforts with local, state, and federal representatives including but not limited to; parcel owners within the project area, California Assembly 4th District, U.S Third Congressional District, U.S. Fifth Congressional District, the Corps, the Blue Ribbon Committee, local non-profits, Tribal representatives, the Pacific Gas and Electric Company (PG&E), and the CalTrans.
The goals of the Committee are to: keep the Board of Supervisors, Tribes and the public informed on the progress of the Middle Creek Project; conduct oversight of the acquisition of the private properties within the project boundaries; pursue ways and means to elevate State Highway 29, upgrade PG&E transmission lines through the project area, and procure funding to complete the design and construction of the project; encourage the Corps and other federal, state and local governmental agencies to perform their tasks expeditiously to complete the project; petition federal and state legislators to use best efforts to procure funds for the design and construction of the project and to expedite performance of their tasks by governmental agencies; and conduct such other activities deemed appropriate and necessary by the Committee to fulfill its mission (County of Lake 2020). Information on the Middle Creek Project Committee can be found on the Lake County Water Resources website: [http://www.lakecountyca.gov/Government/Directory/WaterResources/Programs___Projects/MiddleCreek.htm](http://www.lakecountyca.gov/Government/Directory/WaterResources/Programs___Projects/MiddleCreek.htm).

**Miscellaneous**

Lake County, CalTrans, US Forest Service, and BLM have undertaken various actions to prevent or reduce nutrients and contaminants from entering Clear Lake (West Lake Resource Conservation District, undated; CDFW 2014). These actions include the Eightmile Valley Sediment Reduction and Habitat Enhancement Project, which BLM and Scotts Valley Band of Pomo Indians have recently received a grant for (CDFW 2014). CDFW has two Conceptual Area Protection Plans (CAPP) that cover different portions of the Clear Lake watershed. A CAPP allows different organizations and agencies to apply for land acquisition funding through the Wildlife Conservation Board. Both plans focus on the protection of wetland and riparian habitats, which would benefit the CLH during early life stages (CDFW 2014).

### 4.8 Current Regulatory Mechanisms

**California Endangered Species Act (CESA)**

On August 6, 2014, the California Fish and Game Commission determined the CLH warranted listing as a threatened species under the California Endangered Species Act (CESA). Fish and Game Code § 2067 states a “(t)hreatened species” means a native species or subspecies of bird, mammal, fish, amphibian, reptile, or plant that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by this chapter. As a threatened species under CESA, the take of individuals is prohibited unless the take is authorized by a permit. CESA regulations only apply to the take of individuals and not habitat.

**California Environmental Quality Act (CEQA)**

California Environmental Quality Act of 1970 (CEQA) does not regulate land use, but requires all local and State agencies to avoid or minimize environmental damage, where feasible, during the course of proposed projects. CEQA provides protection for species that are state- or federally-listed as endangered, threatened, or rare. CEQA may be required for watershed restoration work and any restoration work that requires a Lake and Streambed Alteration Agreement, a.k.a. 1600 Agreement, (Section 1600 of Fish and Game Code), is also required to comply with CEQA.
California Code, Fish and Game Code - FGC § 1600
The Legislature finds and declares that the protection and conservation of the fish and wildlife resources of this state are of utmost public interest. Fish and wildlife are the property of the people and provide a major contribution to the economy of the state, as well as providing a significant part of the people's food supply; therefore their conservation is a proper responsibility of the state. This chapter is enacted to provide conservation for these resources.

California Code, Fish and Game Code - FGC § 1602
Requires any person, state or local governmental agency, or public utility to notify CDFW prior to beginning any activity that may do one or more of the following:
- Divert or obstruct the natural flow of any river, stream, or lake;
- Change the bed, channel, or bank of any river, stream, or lake;
- Use material from any river, stream, or lake; or
- Deposit or dispose of material into any river, stream, or lake.

Please note that "any river, stream, or lake" includes those that are dry for periods of time as well as those that flow year-round.

California Code, Fish and Game Code - FGC § 5937
The owner of any dam shall allow sufficient water at all times to pass through a fishway, or in the absence of a fishway, allow sufficient water to pass over, around or through the dam, to keep in good condition any fish that may be planted or exist below the dam. During the minimum flow of water in any river or stream, permission may be granted by the department to the owner of any dam to allow sufficient water to pass through a culvert, waste gate, or over or around the dam, to keep in good condition any fish that may be planted or exist below the dam, when, in the judgment of the department, it is impracticable or detrimental to the owner to pass the water through the fishway.

California Global Warming Solutions Act
The state of California passed Assembly Bill 32 (AB 32), the California Global Warming Solutions Act of 2006, to reduce the amount of greenhouse gas emissions within the state to 1990 levels by 2020. AB 32 requires the California Air Resources Board to adopt regulations for reporting and verifying statewide greenhouse gas emissions and for monitoring and enforcing compliance with the program.

Sustainable Groundwater Management Act (SGMA)
The Sustainable Groundwater Management Act (SGMA) is a California state law which provides a framework for sustainable, groundwater management in California. Based on California Water Code Section 10933(B), ground water basins throughout the state have been classified into four categories of prioritization (high, medium, low, very low). Phase 1 of the categorization process was finalized in January 2019 and 458 basins were prioritized during that phase. Fifty-seven basins have been categorized under Phase 2; however, their prioritization has not yet been finalized (DWR 2019a). The law will require water agencies and governments of high and medium priority basins to halt overdraft and bring groundwater basins into balance. Several groundwater basins in the Clear Lake watershed have been prioritized during the Phase 1 prioritization. The Big Valley basin to the southwest of Clear Lake received a medium prioritization, whereas the other eight basins in the watershed were given a low priority (Scotts
Valley, Upper Lake Valley, Middle Creek, Long Valley, High Valley, Clear Lake Cache Formation, Burns Valley, and Lower Lake Valley). The medium and high priority basins will be managed by a group of local agencies, referred to as Groundwater Sustainability Agencies, and they will be tasked with reaching sustainability in their basin within 20 years of implementing their Groundwater Sustainability Plans. A Groundwater Sustainability Agency has been formed for the Big Valley basin and a Groundwater Sustainability Plan is currently being developed (DWR 2019b; DWR 2019c; DWR 2019d; LCWPD 2021). SGMA is relevant to hitch habitat protection and tributary flows as it requires consideration of Groundwater Dependent Ecosystems (GDEs), Interconnected Surface Waters (ISW), and beneficial users, including hitch. Reducing the potential for overdraft from groundwater pumping in the Big Valley basin could improve flow conditions in Thompson Creek, Adobe Creek, Kelsey Creek, and Cole Creek.

Clear Lake Shoreline Ordinance
The destruction of woody species and tules on residential properties along the shoreline around Clear Lake is prohibited under Section 23-15 of the Clear Lake Shoreline Ordinance. These types of vegetation can be managed via mowing, pruning, or trimming, but those activities cannot result in the death of the plant. In addition, there is a no-net-loss program for commercial, resort, or public properties that requires mitigation for any areas of vegetation cleared by providing replacement plantings, although this ordinance is not always enforced (County of Lake et al. 2010a; CDFW 2014; B. Ewing in litt. 2020). These ordinances benefit the CLH by providing a consistent amount of tule habitat for juveniles.

Clean Water Act (CWA)
The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1972.

Section 518(e) of the CWA expressly provides for Indian tribes to play essentially the same role in Indian country that states do within state lands, authorizing EPA to treat eligible federally recognized Indian tribes with reservations in a similar manner to states (TAS) for implementing and managing certain environmental programs. This section of the Clean Water Act that enables Tribes to take on the powers and responsibilities of the federal Clean Water Act on the Tribe's lands. The Big Valley Rancheria of Pomo Indians and Elem Indian Colony are currently implementing water quality programs through section 106 of the CWA (Water Quality Ordinances).

National Environmental Policy Act (NEPA)
The National Environmental Policy Act of 1970 (NEPA) (42 U.S.C. 4371 et seq.) requires that all activities undertaken, authorized, or funded by Federal agencies be analyzed for potential impacts to the human environment prior to implementation. However, NEPA does not require adverse impacts be fully mitigated, and some impacts could still occur. Additionally, NEPA is only required for projects with a Federal nexus, and, therefore, actions that do not require a Federal permit or that occur on private land are not required to comply with this law.
United States Forest Service (USFS)
The CLH has been designated a United States Forest Service (USFS) sensitive species. Species identified as sensitive by the USFS are species in which population viability is a concern, as evidenced by significant current or predicted downward trends in population numbers or density, and/or significant current or predicted downward trends in habitat capability that would reduce a species’ existing distribution. The designation of sensitive species will ensure the Forest Service is: assisting States, including California, in achieving their goals for conservation of endemic species; as part of the NEPA process, review programs and activities, through a biological evaluation, to determine their potential effect on sensitive species; avoid or minimize impacts to species whose viability has been identified as a concern; if impacts cannot be avoided, analyze the significance of potential adverse effects on the population or its habitat within the area of concern and on the species as a whole; establish management objectives in cooperation with the States when projects on National Forest System lands may have a significant effect on sensitive species population numbers or distributions; and establish objectives for Federal candidate species, in cooperation with the Service or National Marine Fisheries Service, and the States.

Chapter 5. Conservation Goals, Objectives, and Actions

The desired condition for CLH is to have a self-sustaining population with high quality tributary, wetland, and lacustrine habitat to ensure the species can persist into the future, even in light of climate change. The purpose of this strategy is to not only prevent further degradation in the watershed, but to improve conditions throughout. The CLH is an indicator species for the health of Clear Lake, and therefore, the current status of both the watershed and the hitch is considered to be at a low threshold that should not continue to decline and that requires restoration to improve. The optimal condition for the CLH include fully accessible tributary streams surrounding the lake that support migration and spawning, sufficient tributary flow over the entire spawning season to ensure adults and juveniles can migrate back to the lake, access to abundant marshy and nearshore areas for spawning and rearing, and a healthy Clear Lake which offers food and cover for maturing and adult hitch. Meeting and maintaining these conditions combined with the set population target is intended to ensure the species is able to remain viable into the future. Because this strategy is to maintain a sustainable population based on adaptive management, actions may be removed, added, or adjusted as new information is gathered.

Conservation actions that will significantly contribute to the restoration and protection of CLH have been identified and prioritized for each goal of this strategy. An overview of the implementation of these actions, their priority, and agencies responsible for implementation is described below.

5.1 Goal 1. Provide for increased reproduction and survival
A primary threat to CLH is the lack of successful reproduction and recruitment, primarily because early life stage survival is likely very low. The following actions have been planned, developed and/or are currently being implemented to increase the likelihood of successful reproduction and recruitment. Multiple projects, assessments, and studies have been developed to complement and/or guide these efforts and are addressed in Goals 1, 2, and 3 of this chapter.
Objective 1.1 Population target
The CLH population in Clear Lake is considered an independent population or “stock” as defined by Ricker (1972): “…an independent population is a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season.” In order to set a population target for the CLH, a viable CLH population must be defined. For the purposes of this strategy, a viable CLH population is defined as an independent population of CLH that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over time.

McElhany et al. (2000) developed the following set of guidelines for assessing the adequacy of a salmonid population’s abundance, but is also relevant to CLH:

1. A population should be large enough to have a high probability of surviving environmental variation of the patterns and magnitudes observed in the past and expected in the future.
2. A population should have sufficient abundance for compensatory processes to provide resilience to environmental and anthropogenic perturbation.
3. A population should be sufficiently large to maintain its genetic diversity over the long term.
4. A population should be sufficiently abundant to provide important ecological functions throughout its life-cycle.
5. Population status evaluations should take uncertainty about abundance into account.

An additional guideline should be included to assess the adequacy of the CLH’s population abundance:

6. A population should be sufficiently abundant to provide traditional harvest for native Tribes.

In order to set a population goal and monitor population size, current survey efforts (described above in section 2.6) will need to continue to be implemented. The information used to develop this population target includes: CDFW’s visual surveys on the Big Valley tributaries; a population estimate from Soda Bay, State Park, Konocti Casino, and Holiday Harbor; and a general fish survey of Clear Lake.

CDFW initiated visual spawning surveys during the spring of 2014 on seven different tributaries to Clear Lake (McGaugh Slough, Adobe Creek, Hill Creek, Kelsey Creek, Cole Creek, Manning Creek, and Thompson Creek). Surveys were repeated again each year from 2016 through 2020. The number of tributaries being utilized by spawning hitch and the number of hitch seen in each tributary or at each observation location varied each year. During the last survey effort in 2020 only 5 surveys were completed covering 21 sites before the survey was cancelled due to the COVID-19 pandemic. However, although the final three weeks of the survey were never conducted in 2020, and all sites were not visited due to a lack of water flow, the greatest number of hitch were captured in 2020 over the shortened survey period compared to previous years. All
individuals were observed on April 14th at one site on Kelsey Creek (Soda Bay Road). The total number of hitch seen during CDFW’s Big Valley tributary visual surveys is summarized here:

<table>
<thead>
<tr>
<th>Year</th>
<th># of Hitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>1,119</td>
</tr>
<tr>
<td>2016</td>
<td>693</td>
</tr>
<tr>
<td>2017</td>
<td>517</td>
</tr>
<tr>
<td>2018</td>
<td>1,153</td>
</tr>
<tr>
<td>2019</td>
<td>612</td>
</tr>
<tr>
<td>2020</td>
<td>1,672</td>
</tr>
</tbody>
</table>

The population estimate is based on electrofishing surveys conducted by CDFW in Holiday Harbor, Konocti Casino Harbor, Clear Lake State Park, and Soda Bay (Figure 7) from March 17, 2020 through April 15, 2020. Although surveys were also conducted in 2019, a population estimate could not be made for that year because none of the marked individuals were recaptured (Ewing 2019c). The number of CLH captured during the electrofishing surveys, by location and year, is summarized in Table 4.

Table 4. Summary of locations and number of CLH collected for electrofishing surveys conducted by CDFW in Clear Lake

<table>
<thead>
<tr>
<th>Location</th>
<th>2019</th>
<th>2020</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holiday Harbor</td>
<td>2</td>
<td>97</td>
<td>184</td>
</tr>
<tr>
<td>Konocti Casino Harbor</td>
<td>27</td>
<td>129</td>
<td>155</td>
</tr>
<tr>
<td>Clear Lake State Park</td>
<td>155</td>
<td>34</td>
<td>171</td>
</tr>
<tr>
<td>Soda Bay</td>
<td>0</td>
<td>171</td>
<td>171</td>
</tr>
<tr>
<td>Total</td>
<td>184</td>
<td>431</td>
<td>615</td>
</tr>
</tbody>
</table>

Population estimates were calculated using the Schnabel and Schumacher-Eschmeyer methods. The data used for the population estimate calculations is shown in Table 5 and the calculations for each estimate are shown below. The relative population estimate at Soda Bay, Clear Lake State Park, Konocti Casino, and Holiday Harbor for 2020 was approximately 12,770 and 15,195 (Ewing 2020b). Due to the COVID-19 pandemic, the 2020 effort was limited to only four sampling efforts and it is possible additional CLH could have been captured if the survey continued for an additional four weeks.

Table 5. Summary of data used for population estimates

<table>
<thead>
<tr>
<th>Sample # (t)</th>
<th># of individuals captured in sample t (Ci)</th>
<th># of previously marked individuals captured in sample t (Ri)</th>
<th># of individuals captured and marked in sample t (Ui)</th>
<th>Total # of individuals marked in the population at sample t (Mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>164</td>
<td>--</td>
<td>164</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>56</td>
<td>1</td>
<td>55</td>
<td>164</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>4</td>
<td>56</td>
<td>219</td>
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<tr>
<td>4</td>
<td>151</td>
<td>0</td>
<td>151</td>
<td>275</td>
</tr>
<tr>
<td>Total:</td>
<td>431</td>
<td>5</td>
<td>426</td>
<td>658</td>
</tr>
</tbody>
</table>
Schnabel:

\[
N = \frac{(C_{t=1} \cdot M_{t=1}) + (C_{t=2} \cdot M_{t=2}) + (C_{t=3} \cdot M_{t=3}) + (C_{t=4} \cdot M_{t=4})}{R_{\text{total}}} = \frac{(164 \cdot 0) + (56 \cdot 164) + (60 \cdot 219) + (151 \cdot 275)}{5} = 12.769.8
\]

Schumacher-Eschmeyer:

\[
N = \frac{(C_{t=1} \cdot M_{t=1}^2) + (C_{t=2} \cdot M_{t=2}^2) + (C_{t=3} \cdot M_{t=3}^2) + (C_{t=4} \cdot M_{t=4}^2)}{(R_{t=1} \cdot M_{t=1}) + (R_{t=2} \cdot M_{t=2}) + (R_{t=3} \cdot M_{t=3}) + (R_{t=4} \cdot M_{t=4})} = \frac{(164 \cdot 0^2) + (56 \cdot 164^2) + (60 \cdot 219^2) + (151 \cdot 275^2)}{(0 \cdot 0) + (1 \cdot 164) + (4 \cdot 219) + (0 \cdot 275)} = 15.195.4
\]

Figure 7. Survey locations for CDFW’s CLH population survey (CDFW 2020)
From July 2014 through June 2015, CDFW conducted a year-long general fish survey of the entirety of Clear Lake. Every month CDFW would electrofish the shore of the lake at 18 randomly selected locations. The purpose of the survey was to: determine species composition and relative abundance; identify any correlation between habitat type and species presence; analyze the gut contents of black bass and catfish species to determine what they were feeding on throughout the year; and to determine the health and size class composition of black bass in the lake. CLH made up 2.0% of the entire species composition collected and were ranked 7th out of the 16 total species collected.

The proposed initial population goal, using the metrics described above is as follows:

- 8,360 individuals for a visual survey season in-stream (Big Valley tributaries)\(^1\);
- 75,000 for a population estimate in the four locations listed above; and
- #5 or better on the species composition list during the general fish survey\(^2\).

If all three of these targets are met for 6 straight years, this goal would be considered accomplished. If even one of these targets were not met for 6 straight years, all three targets would be reset to a zero starting year. Furthermore, if the CLH population shows 6 consecutive years of population decline, then the population conditions should be re-evaluated. Meeting all three of these goals for 6 straight years would incorporate variances such as drought, which are common in the Clear Lake basin. The visual and population survey goals are 5 times greater than has been seen for each respective survey.

**Action 1.1.1:** Set an initial population target for the hitch. As more information is learned about hitch ecology and demographics, this number may be adjusted.

*Priority:*
*Agency:*
*Status:*

**Action 1.1.2:** Continue targeted monitoring efforts (i.e., various lake surveys) with a tagging component. Although mark-recapture efforts have had limited success in the past, additional efforts should continue and/or new tagging methods (i.e., acoustic) should be implemented.

*Priority:*
*Agency:*
*Status:*

**Action 1.1.3:** Continue visual spawning surveys within the tributary streams. These surveys should attempt to quantify the number of individuals attempting to spawn over

\(^1\) The visual survey season begins when the first sighting of CLH is reported to CDFW and ends two weeks after CLH are no longer seen in the tributaries. There are a total of 21 sites on McGaugh Slough, Adobe Creek, Hill Creek, Kelsey Creek, Cole Creek, Manning Creek, and Thompson Creek. At each site, the surveyor makes an upstream and downstream visual count of CLH starting at a specific location. The time it takes to conduct a count at each site depends on the number of CLH observed, and surveyors record a start and stop time.

\(^2\) This metric is also an indicator of the lake’s condition in general. The composition list should include all fish species.
any given spawning season. Research additional methods to estimate the total number of spawning individuals.

Priority:
Agency:
Status:

Action 1.1.4: Verify permanent removal of barriers to hitch migration on Kelsey, Manning, Scotts, Clover, and Middle Creeks, and their secondary tributaries, and confirm subsequent successful spawning above the locations of those barriers over an entire normal precipitation cycle.³

Priority:
Agency:
Status:

Action 1.1.5: Develop a restoration plan to restore gravel spawning beds in Kelsey Creek extending upstream from the Main Street Bridge in Kelseyville for approximately 3.5 miles. Once implemented, verify use of said beds for spawning by hitch.

Priority:
Agency:
Status:

Objective 1.2 Increase the survival of juvenile hitch (recruitment)
Increase juvenile survival and the likelihood of recruitment by supporting, developing, funding, and participating in restoration efforts to increase the amount of wetland and marsh habitat surrounding the lake. By actively supporting these restoration efforts, it will increase the amount of habitat (i.e., tules and other emergent vegetation) juveniles utilize for cover and prey, increasing their likelihood for survival. In addition, because wetland and marsh habitats surrounding the lake act as filter, an increase in these habitat types will benefit the entire watershed by reducing the amount of sediment and nutrients entering Clear Lake, improving overall water quality. “Actively support” means for the federal, state, and local governmental agencies, Tribes, and other entities listed in this strategy to advocate for Congressional funding for the design and construction of the projects in conjunction with the Lake County Board of Supervisors, the Lake County Watershed Protection District, the Middle Creek Restoration Coalition, and other partners.

Two projects that are already in progressed stages of development that the signatories of this strategy fully support and will advocate for include the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project (Middle Creek Project) and the restoration of Tule Lake. The Middle Creek Project is both a flood risk reduction project for urban and agricultural areas along the northern end of Clear Lake and an ecosystem restoration project that will improve degraded wetland habitat and water quality in Clear Lake. The Middle Creek Project area was once

³ A normal precipitation cycle is defined as a series of years that encompass average, above-average, and below-average rainfall conditions, starting and ending with average precipitation. Populations must demonstrate the ability to survive both precipitation extremes.
approximately 1,400 acres of wetland habitat that was lost in the early 1900s through the construction of levees and conversion to agricultural use. Because these levees are no longer functional and there is an urgent need to restore surrounding wetland habitats to improve the lake and the watershed, Lake County requested the Corps’ assistance to evaluate the project in 1995. The Middle Creek Project consists of acquiring reclaimed land, breaching existing levees to flood historical wetland and floodplain areas, and reconnecting Scotts and Middle Creeks with the historic Robinson Lake. A total of 1,650 acres of wildlife habitat, including 1,170 acres of open water and wetlands and 480 acres of riparian habitat and uplands will be restored. It is expected to increase the existing amount of wetland habitat within the Clear Lake watershed by approximately 79 percent (County of Lake 2012). NEPA and CEQA review was completed in 2003 and 2004 respectively, and the Middle Creek Project was authorized by the Water Resources Development Act in 2007. Federal funding for the Middle Creek Project has not yet been appropriated to start project design; however, funding for land acquisition has been acquired (County of Lake 2012). The NEPA process will be completed once the Corps approves the Record of Decision.

The Middle Creek Project will benefit the Clear Lake watershed and the CLH in multiple ways. It will benefit the entire lake by reducing the amount of sediment and nutrients entering Clear Lake, improving overall water quality. This would benefit adult and juvenile hitch by improving the water quality of Clear Lake. In addition, Middle and Scotts Creeks will flow through this restored area, carrying juvenile hitch from their natal streams into expanded tule habitat that will provide increased protection from predators and increased prey abundance.

The restoration of Tule Lake is a project that could be implemented immediately and would result in the restoration of the second largest contiguous tract of wetlands surrounding Clear Lake. In 2015, the USDA Natural Resources Conservation Service (NRCS) acquired a conservation easement over the entirety of Tule Lake for the restoration of approximately 600 acres of wetlands. Tule Lake’s wetland function can be restored by re-planting tules and modifying the existing diversion channel, which will directly benefit juvenile hitch migrating from Scotts and Dayle Creeks, both of which flow through Tule Lake. The restored wetland habitat will provide for increased protection from predators and increased prey abundance, and similar to the Middle Creek Project described above, the restoration of Tule Lake will also improve Clear Lake water quality, benefiting both adult and juvenile hitch. Restoration projects similar to this, especially those that increase tule habitat surrounding the mouth of tributary streams, will also increase juvenile survival and the likelihood for recruitment.

Action 1.2.1: Middle Creek Project: Assist current efforts that increase awareness and provide support for the implementation and construction of the Middle Creek Project. Increased information, education, and where allowed, lobbying, in support of the project can be accomplished via coordination with the Middle Creek Restoration Coalition and the Lake County Board of Supervisors’ Middle Creek Restoration Project Committee. When the project is funded and construction begins, coordinate local outreach to educate the public about the benefits and specifics of the project.

Priority:
Agency:
Status:
Action 1.2.2: Tule Lake restoration: Assist NRCS with the restoration of Tule Lake. Tasks that need to be accomplished to realize the full benefits of this restoration effort include, but are not limited to planting tules, modifying the diversion channel, and reconnecting the lower wetland area of Tule Lake with Scotts Creek (i.e., concentrate flow through Tule Lake vs. the diversion channel). Monitoring should be conducted to see how different flow conditions can change the direction of flow. When the restoration effort begins, coordinate local outreach to educate the public about the benefits and specifics of the project.

Priority:
Agency:
Status:

Action 1.2.3: Restore wetlands at the mouth of Manning Creek: Lake County Land trust is currently working on an approximately 32 acre project on one half of the mouth of Manning Creek. Funding will need to be acquired to restore connectivity with Clear Lake and to replant tules. Pursue the acquisition of the property containing the other half of the mouth of Manning Creek and initiate restoration efforts.

Priority:
Agency:
Status:

Action 1.2.4: Restore wetland habitat at the mouth of other tributaries, with Kelsey and Adobe Creeks being the primary targets. Restoration will likely require the acquisition of habitat and/or the placement of a conservation easement. Efforts should focus on the restoration of wetland function and should include a monitoring component to ensure it is functioning as intended. All restoration efforts should include local outreach to educate the public about the benefits and specifics of the project.

Priority:
Agency:
Status:

Action 1.2.5: Institute a program for capture and release of fry and adults stranded in tributaries.

Priority:
Agency:
Status:

Objective 1.3 Identify and address any migration barriers in the watershed
There are numerous physical barriers to CLH migration throughout the Clear Lake watershed (see Figure 5). Some of these barriers are likely only partial barriers, restricting passage only under specific flow conditions. Project designs need to be developed for these barriers prior to removal or modification, preferably utilizing barrier remediation projects that have been
successful within the watershed as a basis. These barriers are currently a primary priority since barriers throughout the watershed currently limit reproduction and recruitment.

**Action 1.3.1:** Watershed wide assessment of barriers under different flow conditions. Existing flow data should be compared to observational data collected during the spawning season (Chi Council for the Clear Lake Hitch, CDFW) to see if there is a correlation between flow stage and spawning observations. Existing flow data should also be compared to the lake monitoring effort to determine any correlation between flow and population size, and flow and age structure.

*Priority:*  
*Agency:*  
*Status:*

**Action 1.3.2:** Design appropriate passage for each of the identified barriers using the design criteria from Objective 1.4 below. See Appendix B for a description of currently known or suspected barriers.

*Priority:*  
*Agency:*  
*Status:*

**Action 1.3.3:** Design an upgrade to allow hitch passage through the Detention Structure in Kelsey Creek.

*Priority:*  
*Agency:*  
*Status:*

**Action 1.3.4:** Restore hitch passage between Scotts Creek and the Blue Lakes.

*Priority:*  
*Agency:*  
*Status:*

**Objective 1.4 Develop passage design criteria for hitch**

Passage design criteria for hitch can be utilized when designing future projects that may create a potential barrier or when addressing existing or potential barriers identified throughout the watershed. Applying constant, successful criteria, and adaptively changing the criteria as new techniques are developed, will ensure hitch can migrate both up- and downstream over the spawning season when flow conditions allow. Criteria should initially be developed by reviewing past projects to see which methods or approaches were most successful and what was ineffective, and should consider the available visual spawning survey data to inform precise design criteria for specific creeks.

**Action 1.4.1:** Develop passage design criteria for hitch. These criteria can be utilized when designing future projects that may create a potential barrier or when addressing existing or potential barriers identified throughout the watershed. Applying constant,
successful criteria, and adaptively changing the criteria as new techniques are developed, will ensure hitch can migrate both up- and downstream over the spawning season when flow conditions allow. Criteria should initially be developed by reviewing past projects (e.g., Seigler Canyon Creek passage project) to see which methods or approaches were most successful and what was ineffective, and should consider the available visual spawning survey data to inform precise design criteria for specific creeks.

**Priority:**

**Agency:**

**Status:**

5.2 Goal 2. Provide suitable habitat conditions in tributaries

Beginning in the mid-1800s when Euro-Americans first started to settle in the area, the Clear Lake watershed began to undergo numerous changes. Various forms of past mining activities, agricultural and urban development, increased fire activity, past deforestation, and historical overgrazing practices have all contributed to the degradation of the Clear Lake watershed. The degradation of tributary streams has changed their hydrology, reducing the amount of water retained in the streams over the Clear Lake hitch’s spawning season. This loss of flow earlier in the season and the presence of numerous passage barriers in the tributary streams have greatly reduced reproduction and early life stage survival. Although many of the activities that have resulted in the tributary degradation are no longer occurring, they continue to have legacy effects on the watershed and the hitch without remediation and restoration.

Objective 2.1 Restoration of Kelsey Creek

The Kelsey Creek watershed originates at the summit of Cobb Mountain, flows through the agriculturally productive Big Valley, and eventually drains into Clear Lake. Kelsey Creek enters Clear Lake’s Upper Arm and is the third largest tributary to Clear Lake, accounting for approximately 16% of streamflow to Clear Lake (County of Lake et al. 2010d). Like many of the creeks throughout the Clear Lake watershed, Kelsey Creek has been degraded and requires restoration. In 2010, the County of Lake, West Lake Resource Conservation District, and East Lake Resource Conservation District developed the Kelsey Creek Watershed Assessment. The assessment is intended to be utilized as a tool to educate landowners on the condition of the Kelsey Creek watershed and to describe management needs. The assessment identifies data gaps in our understanding of the watershed’s processes and identifies key restoration and management projects. This assessment should be used as the basis for any restoration plan for Kelsey Creek and should be updated as new information becomes available about the watershed. Of particular concern since the restoration plan was published is the absence of gravel beds suitable for spawning in a 3.6 mile section upstream from the Main Street bridge in Kelseyville.

**Action 2.1.1:** Review past literature, and develop and/or establish a restoration plan for Kelsey Creek. The restoration plan should consider the guidance from Objective 2.5 below. Any restoration plan should include a monitoring component to assess the success of implemented efforts and should follow a set monitoring protocol, as described in Objective 2.6. Any restoration plan should include the restoration of gravel spawning beds in the sections of the creek where the gravel beds have been lost to erosion.

**Priority:**
Objective 2.2 Restoration of Scotts Creek
The Scotts Creek watershed originates at the summit of Cow Mountain, flows through Scotts Valley, Bachelor Valley, and Tule Lake, and eventually drains into Middle Creek. Scotts Creek is the largest tributary to Clear Lake, accounting for approximately 24% of streamflow to Clear Lake (County of Lake et al. 2010b). Like many of the creeks throughout the Clear Lake watershed, Scotts Creek has been degraded and requires restoration. In 2010, the County of Lake, West Lake Resource Conservation District, and East Lake Resource Conservation District developed the Scotts Creek Watershed Assessment. The assessment is intended to be utilized as a tool to educate landowners on the condition of the Scotts Creek watershed and to describe management needs. The assessment identifies data gaps in our understanding of the watershed’s processes and identifies key restoration and management projects. This assessment should be used as the basis for any restoration plan for Scotts Creek and should be updated as new information becomes available about the watershed.

Action 2.2.1: Review past literature, and develop and/or establish a restoration plan for Scotts Creek. The restoration plan should consider the guidance from Objective 2.5 below. In those areas near Tule Lake, the restoration plan should take into consideration the restoration of Tule Lake, both as an opportunity to increase the benefits of any particular project, but also to increase watershed function, particularly within the transition zones of one habitat type into another (tributary to wetland, wetland to tributary). Any restoration plan should also include a monitoring component to assess the success of implemented efforts and should follow a set monitoring protocol.

Objective 2.3 Restoration of Middle Creek
The highest point of the Middle Creek watershed is 4,840 feet elevation at High Glade Lookout. The east and west forks of Middle Creek originate at 4,200 and 3,040 feet elevation, respectively, and merge at their confluence at around 1,480 feet elevation. Middle Creek then flows past the town of Upper Lake, which is near where Clover Creek drains into Middle Creek, and then continues to flow into Rodman Slough and Clear Lake. Middle Creek is the second largest tributary to Clear Lake, accounting for approximately 21% of streamflow to Clear Lake (County of Lake et al. 2010c). Like many of the creeks throughout the Clear Lake watershed, Middle Creek has been degraded and requires restoration. In 2010, the County of Lake, West Lake Resource Conservation District, and East Lake Resource Conservation District developed the Middle Creek Watershed Assessment. The assessment is intended to be utilized as a tool to educate landowners on the condition of the Middle Creek watershed and to describe management needs. The assessment identifies data gaps in our understanding of the watershed’s processes and identifies key restoration and management projects. This assessment should be used as the basis for any restoration plan for Middle Creek and should be updated as new information becomes available about the watershed.
**Action 2.3.1:** Review past literature, and develop and/or establish a restoration plan for Middle Creek. The restoration plan should consider the guidance described from Objective 2.5 below and should take into consideration the construction of the Middle Creek Project, which could provide opportunities for coordination that may further increase the benefit of any particular project. Any restoration plan should include a monitoring component to assess the success of implemented efforts and should follow a set monitoring protocol.

*Priority:*
*Agency:*
*Status:*

**Objective 2.4 Assess other streams throughout the watershed**
In addition to those tributaries specifically identified in Objectives 2.1-2.3, many of the other tributary streams throughout the watershed are also degraded and require restoration. Although the three tributaries above should be given restoration priority, the restoration of other streams would also benefit the CLH. Therefore, other streams throughout the Clear Lake watershed should be assessed and restoration projects identified.

**Action 2.4.1:** Assess other tributaries throughout the watershed not identified above for restoration needs. Review past literature, and potentially develop and/or establish a restoration plan for that tributary if deemed necessary. Any restoration plan should consider the guidance described from Objective 2.5 below. Any restoration plan should include a monitoring component to assess the success of implemented efforts and should follow a set monitoring protocol.

*Priority:*
*Agency:*
*Status:*

**Objective 2.5 Tributary restoration guidance**
Basic tributary restoration guidance for the Clear Lake watershed should be developed in order to help guide priority actions/projects and to aid in the permitting process. This guidance will also help in providing some consistency across restoration efforts.

**Action 2.5.1:** Develop basic tributary restoration guidance that should be considered when developing a tributary restoration plan. This guidance will prioritize barrier removal/mitigation efforts (see above), the restoration of gravel spawning beds, encourage the development and maintenance of riparian buffers, and provide best management practices for revegetation, which can provide consistency for the streambank permitting process.

*Priority:*
*Agency:*
*Status:*
Objective 2.6 Implement the Adobe Creek Conjunctive-Use Project
The Adobe Creek Conjunctive-Use Project would increase the amount of flow within Adobe Creek during the spring, which would benefit hitch and replace depleted groundwater. This project would modify the Highland Springs Reservoir’s principal spillway to provide for increased storage of winter inflow and reduced draw-down in the fall. Modifying reservoir operation would increase water storage by 986 acre-feet, 200 acre-feet of which would be used to increase spring stream flows and approximately 750 acre-feet for groundwater recharge during the summer and fall (a small amount would be lost due to evaporation). This project would directly benefit hitch by providing increased flow during the spawning season and would also improve the condition of the watershed by recharging groundwater levels. A feasibility study was completed for the project and it was found to be feasible. Final project design and additional environmental review are still needed (County of Lake et al. 2010a).

Action 2.6.1: Assist current efforts that increase awareness and provide support for the implementation and construction of the Adobe Creek Conjunctive-Use Project. If the project is funded and construction begins, coordinate local outreach to educate the public about the benefits and specifics of the project.

Priority:
Agency:
Status:

5.3 Goal 3. Provide suitable habitat conditions in Clear Lake
In addition to the degradation seen in the tributary streams beginning in the mid-1800s, impacts from wetland habitat loss and contamination from mercury and other chemicals drastically reduced the lake’s water quality, causing toxic cyanobacteria blooms and periodic fish kills in the lake. The conversion of wetland habitats surrounding the lake not only negatively impacted Clear Lake’s water quality, but it also reduced the amount of rearing habitat for any juvenile hitch that are able to migrate to the lake from their natal stream. This loss of rearing habitat also reduces early life stage survival (juvenile), further reducing the likelihood of recruitment (see Goal 1 above). The impacts to Clear Lake’s water quality impact adult hitch survival, especially when poor lake conditions result in large fish kills. In addition to the Objectives and Actions listed below, implementation of the Middle Creek and Tule Lake Projects (see Objective 1.2) would also help in achieving this goal.

Objective 3.1 Increase the extent and protect existing wetlands
The purpose of this objective is to target those areas with remnant wetlands. Restoration of areas with remnant wetlands or working with private landowners to allow vegetation to grow will expand the extent of these habitats, providing connectivity and increased cover from predators and likely an increased abundance of prey items that also depend on these habitat types. In addition to restoration, areas containing wetlands should be pursued for acquisition, if applicable, and protected through a conservation easement or other means.

Action 3.1.1: General restoration of wetlands on public land and targeted outreach to private landowners to allow wetland vegetation to grow on their land.

Priority:
Objective 3.2 Acquire, protect, and restore historical wetlands

The purpose of this objective is to target those areas that once supported wetland habitat and no longer do, but have restoration potential. Initially, these areas should be pursued for acquisition and protected through a conservation easement or other means, and then restored. The successful restoration of these areas will further increase the extent of wetland habitat within the watershed, providing increased cover from predators and likely an increased abundance of prey items that also depend on these habitat types.

Action 3.2.1: Identify parcels of land that once supported wetland habitat and have the potential for restoration.

Priority:
Agency: Lake County Trust, NRCS
Status:

Action 3.2.2: Acquire and/or protect parcels of land identified in Action 3.2.1 as having restoration potential, and restore the parcel back to wetland habitat.

Priority:
Agency: Lake County Trust, NRCS
Status:

5.4 Goal 4. Continue and expand research and monitoring

In order to adaptively manage CLH, pertinent research and monitoring must be continued and expanded to improve our understanding of the status of the ecology of CLH and to guide future management decisions. Many of the conservation objectives and actions outlined herein require monitoring or evaluation prior to implementing projects. The objectives and actions below have been identified as key areas of study to determine project efficacy, document existing conditions, and provide information to guide existing conservation actions and develop future actions.
Objective 4.1 Effects of water quality
Both within the lake itself and within the tributary streams, poor water quality likely affects survival at all life stages, influencing reproductive success and recruitment. However, it is known what extent water quality is currently having on the CLH or what specific parameters are having the largest influence.

Action 4.1.1: Continue lake water quality monitoring within the littoral and limnetic zones of Clear Lake.
Priority: 
Agency: Big Valley Rancheria, CDFW, USGS, Lake County in coordination with DWR 
Status: 

Action 4.1.2: Review the available literature and initiate water quality monitoring in the creeks and streams throughout the watershed that are known to support CLH. Monitoring should include physical, chemical, and biological components.
Priority: 
Agency: 
Status: 

Action 4.1.3: Compare water quality monitoring data from Actions 4.1.1 and 4.1.2 with population monitoring data from Action 1.1.2 to assess whether water quality in either the tributary streams or the lake is having a negative impact on the CLH and to what extent. Identify what specific parameters are having the largest negative impact.
Priority: 
Agency: 
Status: 

Objective 4.2 Effects from non-native fish species
Predation and competition due to the introduction of non-native fish is often cited as one of the primary factors influencing the CLH. However, although predation and competition are likely having an impact on the CLH by reducing survival, reproductive success, and likelihood of recruitment, it is not known to what extent. Another factor is whether the predatory behavior of the largemouth bass toward the hitch when the hitch aggregate in schools to enter a tributary to spawn disrupts the habits of the hitch to the extent that some number do not enter the tributary and spawn.

Action 4.2.1: Determine the food web structure of Clear Lake. In order to better understand how and to what extent predation and competition by non-native fish species is having on the CLH, additional information about the food web structure of Clear Lake is needed.
Priority: 
Agency: 
Status:
Action 4.2.2: Develop a model to determine what impact both predation and competition are having on the CLH.

Priority:
Agency:
Status:

Objective 4.3 Effects from water extraction
Water extractions are also often cited as one of the primary reasons for the reduction in the Clear Lake hitch’s population. However, although stream gauges are installed in some of the tributary streams, no studies have been conducted on the effects water extraction is having on the Clear Lake hitch.

Action 4.3.1: Develop a model or integrate any modeling completed for SGMA to determine what effect, if any, water extraction is having on the hitch during the spawning period. Initial efforts should review existing literature, monitoring reports, and agricultural production data in conjunction with available observational data collected over the spawning season (Chi Council for the Clear Lake Hitch, CDFW).

Priority:
Agency:
Status:

Objective 4.4 Other research
Other research, including the use of alternative technologies to aid in monitoring, research, or habitat assessment efforts.

Action 4.4.1: Identify Clear Lake’s undisturbed shoreline.

Priority:
Agency:
Status:

Action 4.4.2: Research the effectiveness and legality of using drones for monitoring efforts and to assess habitat conditions in areas that are typically inaccessible.

Priority:
Agency:
Status:

Action 4.4.3: Determine the benefits and feasibility of carp removal on water quality and CLH abundance.

Priority:
Agency:
Status:

Action 4.4.4: Determine the feasibility of a hitch hatchery or head-starting program.
Identify suitable ponds within the Clear Lake watershed where hitch can be planted and raised.

5.5 Goal 5. Increase outreach and education programs
The protection and conservation of California’s natural resources and native species will provide future generations with lasting legacy benefits that are immeasurable. Resource management agencies and involved parties need to better articulate that message so that public support can be garnered and greater emphasis placed on the inherent value of California’s diverse native flora and fauna. The best way for resource management agencies and involved parties to articulate this message is to develop education and outreach opportunities related to the uniqueness and value of the Clear Lake hitch and the Clear Lake watershed as part of California’s heritage.

Objective 5.1 Expand educational efforts to increase public awareness
During the spawning migration, people are sometimes attracted to the tributary streams to observe the migrating CLH as well as their spawning activities. Well used observation areas that are easily accessed provides an excellent opportunity for resource managers and involved parties to interface with and educate the public. The spawning run should be more widely advertised as a valuable and worthwhile event for the public to observe, including inviting local elementary school groups to observe the spawning events. In addition, providing best management practices to private landowners that they can implement will help increase the public’s awareness on how they can improve the watershed. Increased public knowledge and interest could be generated for the Clear Lake watershed and CLH, with outreach and an educational campaign.

Action 5.1.1: Develop and expand the outreach program for local schools and assist with funding, as needed, to support field trips to observe the spawning run.

Action 5.1.2: Provide opportunities for youth to participate in stranded hitch rescue efforts.

Priority:
Agency:
Status:
**Action 5.1.3:** Develop and distribute best management practices that the public can implement to improve the condition of the watershed. (Environmental education – Landowner responsibilities).

*Priority:*
*Agency:*
*Status:*

**Action 5.1.4:** Coordinate with Lake County Public Works and the Board of Supervisors on issues within the watershed, such as low flow crossings, that can be addressed by that entity. This may include sending correspondence to these entities on issues the Conservation Strategy Team has identified as major impacts to the hitch and its habitat.

*Priority:*
*Agency:*
*Status:*

**Objective 5.2 Increase public engagement**
In addition to expanding the public awareness of the CLH and the Clear Lake watershed, the opportunities for public engagement in the conservation of the species and its habitat should also increase. To increase public engagement, community creek clean-up events or other similar efforts should be organized and implemented throughout the watershed. These efforts could be announced through radio, newspaper, and other media advertisements, as well as maintaining an email list to notify individuals who have participated in previous events.

**Action 5.2.1:** Organize volunteer events to clean up and restore local creeks. Trash, vegetation clippings, and other debris are periodically dumped and abandoned along the local creeks and banks. These events will not only clean-up portions of the watershed, but will increase the number of opportunities for the public to be engaged and invest in their community.

*Priority:*
*Agency:*
*Status:*

**Action 5.2.2:** Increase outreach opportunities by coordinating with other relevant local agencies/entities (BLM, other local Tribes, Lake County RCD’s, UC Davis, Middle Creek Restoration Project Committee Board of Supervisors).

*Priority:*
*Agency:*
*Status:*

**Action 5.2.3:** Create an interactive online presence with an area for communication, for GIS maps, documents, articles, and links to more information, and an internet-based data bank into which people can enter information about hitch migration events, sightings of spawning events, dates, times, and comments that can be viewed by all. Year-to-year comparisons will help to determine actual populations and spawning locations that need
to be protected and expanded. Online communication will help keep stakeholders and interested parties up to date with communications and additions and will offer information to others seeking it.

Priority:
Agency:
Status:

5.6 Incorporating local support – future regulatory coordination

Lake and Streambed Alteration Program
Department of Fish and Wildlife
North Central Region
1701 Nimbus Road, Suite A
Rancho Cordova, CA 95670
Attn: Stream and Lakebed Alteration Program
Phone: (916) 358-2885
Fax: (916) 358-2912
Email: R2LSA@wildlife.ca.gov

California Endangered Species Act (CESA)
Department of Fish and Wildlife
North Central Region
1701 Nimbus Road, Suite A
Rancho Cordova, CA 95670
Attn: Region 2, CESA desk
Phone: (916) 358-2930
Fax: (916) 358-2912
Email: R2CESA@wildlife.ca.gov
Literature Cited


California Department of Fish and Game (CDFG). 1955. Field Notes. Kelsey Creek, Lake County.


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In Litteris


Rogers, Dean. 2017. California Natural Diversity Database California Native Species Field Survey Form for Clear Lake hitch sighting on Kelsey Creek on May 11, 2017.


___________. 2021. The Loss of Gravel in Kelsey Creek Essential for Hitch Spawning
Appendix A – Conservation Strategy Agreement

This Conservation Agreement (Agreement) and associated Conservation Strategy (Strategy) have been developed to expedite implementation of conservation measures for the Clear Lake hitch (CLH) in Lake County, California, as a collaborative and cooperative effort among local Tribes, resource agencies, and other interested parties. The purpose of the Strategy is to serve as a framework for the conservation and protection of the CLH and to contribute to the species’ persistence into the future. The Strategy identifies conservation actions that will be implemented to reduce and/or eliminate the threats that are impacting spawning and rearing of CLH and preserve the uniqueness of the subspecies. The Strategy describes current conditions and threats, identifies specific conservation actions needed to establish a stable population, provides a timeline for accomplishing each conservation action, and identifies the roles and responsibilities of collaborating partners for each action.

In signing the Strategy, the signatory indicates its agreement of the value in conserving the Clear Lake hitch. Signature indicates the entity’s intent to support the implementation of priority actions identified in the Strategy, as feasible within individual budget and policy constraints. The signatories value the meaningful participation and technical and scientific expertise of partner staff, as available, to implement Strategy actions and identify potential funding sources; however, it is understood that signature of the Strategy is not a commitment to providing staff resources. In certain cases, conservation actions are constrained by current ecological, logistical, or socio-political conditions, and restoration options can be limited. Final actions, commitments, and resource allocations will be determined by individual partners.

Conservation Goals and Objectives

The desired conditions for CLH will have been met upon completion of these conservation actions. However, because this Strategy is based on adaptive management, actions may be removed, added, or adjusted as new information is realized, and thus incorporated into the Strategy for conservation and management of CLH.

Conservation actions that will significantly contribute to the protection and restoration of CLH have been identified for each goal of this Strategy. Chapter 5 of the Strategy provides an overview of the implementation of these actions and details the objectives, actions, action priority, and agencies or non-governmental organizations responsible for implementation of the actions. Here is a summary of Goals and Objectives identified in the Strategy:

- **Goal 1. Provide for increased reproduction and survival**
  - Objective 1.1 Population target
  - Objective 1.2 Increase the survival of juvenile hitch (recruitment)
  - Objective 1.3 Identify and address any migration barriers in the watershed
  - Objective 1.4 Develop passage design criteria for hitch

- **Goal 2. Provide suitable habitat conditions in tributaries**
  - Objective 2.1 Restoration of Kelsey Creek
  - Objective 2.2 Restoration of Scotts Creek
  - Objective 2.3 Restoration of Middle Creek
• Objective 2.4 Assess other streams throughout the watershed
• Objective 2.5 Tributary restoration guidance
• Objective 2.6 Implement the Adobe Creek Conjunctive-Use Project

• Goal 3. Provide suitable habitat conditions in Clear Lake
  • Objective 3.1 Increase the extent and protect existing wetlands
  • Objective 3.2 Acquire, protect, and restore historical wetlands

• Goal 4. Continue and expand research and monitoring
  • Objective 4.1 Effects of water quality
  • Objective 4.2 Effects of predation and competition from non-native fish species
  • Objective 4.3 Effects from water extraction
  • Objective 4.4 Other research

• Goal 5. Increase outreach and education programs
  • Objective 5.1 Expand educational efforts to increase public awareness
  • Objective 5.2 Increase public engagement

Authority

1. This Agreement is subject to, and is intended to be consistent with, all applicable federal, Tribal, state, and local laws and interstate compacts.
2. All parties to this Agreement recognize that they may each have specific statutory responsibilities that cannot be delegated, particularly with respect to the management and conservation of wildlife and its habitat.
3. This Agreement does not restrict the parties from participation in similar activities with other public or private agencies, organizations, or individuals.
4. All parties to this Agreement do not waive any immunity provided by federal, state, local or Tribal laws by entering into this agreement and each fully retains all immunities and defenses provided by law with respect to any action based on, or occurring as a result, of the Agreement.
5. Modifications to the Agreement must be mutually agreed upon by all signatories to the Agreement. Such changes shall be executed as an addendum to the original agreement.

Conservation Action Implementation

The Strategy outlines the actions to be implemented for the conservation of the CLH. In addition, the following administrative actions outlined below will be implemented:

A. Coordinating Conservation Actions
  • The Strategy Team (Team) will implement the Strategy that encompasses the goals, objectives, and actions.
  • Administration of the Agreement will be conducted by the Strategy Team. The Team shall consist of, at a minimum, one designated representative and an alternate from each signatory agency. In addition, the Team may include other stakeholders as deemed necessary by the signatories.
• Responsibilities of the Team will include coordinating all the conservation activities.
• The Team will meet at least quarterly to document progress toward achieving Strategy goals and objectives, develop priorities, and review any other elements related to planning or implementation of the Strategy as necessary.
• Regular Team meetings will not be open to the public; however, an annual public meeting will help to update the public about the Team’s progress on the Conservation Strategy.

B. Implementation
• Each signatory will coordinate, implement, and monitor actions in the Strategy for which they and their cooperators are responsible. Accomplishments will be presented at Team meetings.
• All funds required for and expended in accordance with this Agreement are subject to approval by the appropriate state or federal appropriations. This Agreement is not a fiscal obligation document.

Duration of Agreement
The term of this Agreement shall be 15 years. If, after each 5 year assessment, continued progress has been made toward the benefit of CLH, then the Agreement will be reviewed, updated as necessary, and reauthorized. Any party may withdraw from the Agreement with sixty working days written notice to the other parties. The basis for the withdrawal shall be provided to the signatories.

Decision Making and Regulatory Signatories to the Clear Lake Hitch Conservation Strategy

Elem Indian Colony
Middletown Rancheria
Big Valley Rancheria
Robinson Rancheria
Scotts Valley Band of Pomo Indians
NRCS-USDA
State Water Board
County of Lake

United States Department of Agriculture, U.S. Forest Service (USFS)
Represented By: ____________________________________
Randy Moore, Regional Forester, Pacific Southwest Region
Date: _____________________________________________

California Department of Fish and Wildlife (CDFW)
Represented By: ____________________________________
Charlton H. Bonham, Director
Date: _____________________________________________

In addition to the decision making and regulatory signatories included above, the collaboration and partnership of other interested parties is important in furthering the conservation of the Clear Lake hitch. The following signatories are interested parties that have been working with the
critical decision making and regulatory entities listed above to develop the Strategy and Agreement, and their continued partnership will be essential in achieving the goals described in the Strategy. These entities include the Lake County Farm Bureau, Lake County Trust, the Chi Council for the Clear Lake Hitch, and USGS. If there are other stakeholders that would like to participate in working towards the goals outlined in the Strategy, we encourage your collaboration.

Partner Signatories to the Clear Lake Hitch Conservation Strategy

United States Department of the Interior, U.S. Fish and Wildlife Service (USFWS)
Represented By: ________________________
Paul Souza, Regional Director, California-Great Basin Region
Date: ________________________________

Lake County Farm Bureau
Lake County Trust
Chi Council for the Clear Lake Hitch
USGS
Appendix B – List of Known or Suspected Barriers

Kelsey Creek:
- Kelsey Creek –Main Street Bridge
- Detention structure, flash board style dam
- Low flow-Old Soda Bay Rd (DWR gauge)
- Off-road activity near the Merritt Road Bridge, ~500 yards downstream of Main Street Bridge

Cole Creek (low flow):
- Barrier downstream of the 29 crossing (private land)

Hill Creek (low flow):
- Potential barrier near confluence with McGaugh Slough (possibly at 29)

Adobe Creek:
- Bell Hill culverts

Manning Creek
- Low flow issue between Soda Bay Rd and 29 (currently being addressed)
- Low water crossing downstream of Matthews Rd Bridge
- Potential seasonal dam downstream of Akerly Road

Forbes Creek (channelized, concrete)
- Concrete barrier at the Fairgrounds
- Potential barrier at the box-culvert under the shopping center

Lyon’s Creek
- Sewer line at Lakeshore Blvd. (9 inch high at low flow)
- Box-culvert dam ~300 feet long (under Hwy 29)
- Return flow dam from the wastewater treatment plant (upstream of Hwy 29)
- Heavy debris

Robinson Creek (limited flow)

Scotts Creek
- Decker Bridge (similar to the Kelsey Creek bridge situation)
- Natural rocky outcropping at Green Ranch
- Gravel mining upstream of Green Ranch
- Drainage ditch that runs along Scotts Valley Road
- Issues at Tule Lake
Tributary to Hendricks Creek
  - Culvert at Hendricks Road (1/4 mile south of Scotts Valley Rd.)

Middle Creek
  - Rock weirs between Clover Diversion Channel and Rancheria Road
  - Rancheria Road Bridge footings, concrete wall
  - Rock outcroppings downstream of the Elk Mountain Rd Bridge may be a barrier (~1000 feet downstream of bridge)

Clover Creek
  - Blackberry vines at Arbor Bridge
  - Sediment accumulation before Elk Mountain Road Bridge, at the diversion
  - Trash
  - Sam Alley Ridge Road culvert, 2 or 3 miles east of Upper Lake

Schindler Creek
  - Fish Ladder at Hwy 20
  - Lots of sediment, vegetation growth
  - 10% slope

Seigler Canyon Creek (low flow)
  - Upstream culvert

Copsey Creek
  - Morgan Valley Road

Burns Valley Creek
  - A lot of privately maintained roads, culverted, potential barriers
  - Near the old “Bob’s Marine” there is a concrete barrier
  - Trash

Austin Creek
  - Houses have encroached into the lake

Molesworth Creek
  - Barrier at Ridgeview Dr. road crossing
  - Sewer crossing
  - Rerouted drainage (can still see the old channel)