Species Status Assessment for the Clear Lake Hitch (*Lavinia exilicauda chi*) Version 1.0

Clear Lake hitch displaying spawning behavior in a tributary to Clear Lake. Photo credit USGS, Fred Feyrer

January 2020
U.S. Fish and Wildlife Service
Region 8
Sacramento, California

Acknowledgements

This document was prepared by the U.S. Fish and Wildlife Service's Sacramento Field Office with assistance from the Pacific Southwest Regional Office and the….. Additionally, valuable peer reviews of a draft of this document were provided by XXX, CCC, WWW, and other partners, including members of YYY. We appreciate their comments, which resulted in a more robust status assessment and final report.

Suggested reference:
U.S. Fish and Wildlife Service. Year. Species Status Assessment for the Clear Lake Hitch (*Lavinia exilicauda chi*), Version 1.0. Month Year. Sacramento, California.

EXECUTIVE SUMMARY

On September 25, 2012, the U.S. Fish and Wildlife (Service) received a petition from the Center for Biological Diversity (CBD 2012, entire) to list the Clear Lake hitch (*Lavinia exilicauda chi*) as a threatened or endangered species under the Endangered Species Act of 1973, as amended (Act). On April 10, 2015, the Service published in the **Federal Register** a positive 90-day finding stating that the petition presented substantial scientific or commercial information indicating that listing the Clear Lake hitch may be warranted (80 FR 19259). As a result, we prepared this Species Status Assessment (SSA) Report to provide the scientific foundation for determining if the Clear lake hitch is warranted for listing under the Act.

The Clear Lake hitch 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 lake is surrounded by numerous tributaries, most of which are ephemeral and low gradient as they drain into the lake.

Historically, the Clear Lake hitch occurred in numerous lakes and ponds found throughout the Clear Lake watershed, including: Clear Lake, Thurston Lake, Upper Blue Lake, Lower Blue Lake, and Lampson Pond. During the spring, the Clear Lake hitch could also be found spawning in the numerous tributaries to these larger water bodies, including: Kelsey, Scott, Middle, Adobe, Seigler Canyon, Manning, Cole, Morrison, and Schindler Creeks. Currently, the subspecies is thought to be extirpated from the Blue Lakes, but still resides in Clear and Thurston Lakes throughout the year until the spring when reproductive adults migrate into tributary streams to spawn. The current status of the subspecies in Lampson Pond is unknown. Although all of the described waterbodies were hydrologically connected in the past, Thurston Lake and its tributary Thurston Creek are currently isolated from the other waterways. Although survey efforts have been conducted within the Clear Lake watershed, most were incidental to survey efforts that had a different purpose or were random documented observations; therefore, we do not have data on past or current population estimates for the subspecies.

Early accounts considered the hitch inhabiting Clear Lake to be identical to the hitch found in the Sacramento River (*Lavinia exilicauda*); however, in 1973 John D. Hopkirk described the Clear Lake hitch 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. Early genetic studies suggested the more wide spread species of hitch (*Lavinia exilicauda*) and the roach (*Hesperoleucus symmetricus*) are so genetically similar that they could be considered conspecifics, and further analysis found the two species showed such little genetic divergence that they could actually be considered congeners. A subsequent genetic analysis found the Clear Lake hitch shares mitochondrial DNA haplotypes with different forms of California roach outside of the Clear Lake watershed, and their status as a subspecies was not supported. However, a later analysis using nuclear and mitochondrial DNA had differing results. The nuclear DNA analysis supported the subspecies designation for the Clear Lake hitch, but the mitochondrial DNA analysis did not. A more recent genomic analysis suggests the three forms of hitch within California show strong population structuring but only weak subspecies structuring.

Adult Clear Lake hitch 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. Like other native juvenile cyprinids found in California, juvenile Clear Lake hitch 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.

The Clear Lake hitch grows much faster than other hitch subspecies found in lacustrine environments, most likely due to Clear Lake's high productivity and water temperatures. Females 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. Clear Lake hitch are thought to live 4 to 6 years, but it is possible some individuals can live longer. Because Clear Lake hitch females are much larger than the other subspecies of hitch within California, they are more fecund. A female Clear Lake hitch that is reproductive at age 3 and lives to age 6 could produce, on average, over 100,000 eggs over her lifetime.

For most of the year, Clear Lake hitch are only found within their lacustrine environment. However, between February and May, they begin to migrate into the surrounding tributaries to spawn. Spawning activities include one to five males pursuing a gravid female to fertilize her freshly extruded eggs, which are deposited on fine to medium sized gravel within the tributary stream. Fertilized eggs develop and hatch within 7 to 10 days, fry are free-swimming after another 7 to 10 days, and young migrate to the lake at about a month old before the streams dry up. Juvenile hitch are found within the nearshore habitat of the lake where they depend on submerged aquatic vegetation for cover and prey. Juvenile hitch move from the nearshore portion of the lake into open water in early to late fall. There is evidence that Clear Lake hitch do not require tributary streams with gravel to spawn, but can also spawn successfully in different portions of the lake (i.e., along the shore, the mouths of tributaries, and Rodman Slough) that lack a gravel substrate.

Clear Lake Hitch Viability Analysis

In order to assess the Clear Lake hitch's viability, we used the three conservation biology principles of resiliency, representation, and redundancy (together, the 3 Rs). These principles rely on assessing the subspecies at an individual, population, and subspecies level in order to help evaluate the likelihood that the Clear Lake hitch can sustain its persistence into the future. The Clear Lake hitch has two distinct, reproducing populations within the Clear Lake watershed: one in Clear Lake and its associated tributaries, and the other in Thurston Lake and its associated tributary, Thurston Creek. These two separate populations of Clear Lake hitch will be analyzed separately; however, the larger population within Clear Lake requires a more focused analysis of how different portions of Clear Lake contribute to the subspecies' overall viability. Therefore, in order to evaluate the 3 Rs and assess the subspecies' viability within Clear Lake we divided the Clear Lake watershed into Hydrologic Unit Code (HUC) 12 sub-watersheds and, because some of the sub-watersheds do not have all of the components that the subspecies requires to complete its life history and we have demographic data associated with more specific areas, we further grouped them into one of five SIG (strontium isotope groups) units. This further grouping was based on adult otolith strontium signatures that indicates natal origin, which provides information about reproduction and recruitment in those areas associated with the SIG.

A number of factors influence the resiliency of a Clear Lake hitch population, including reproduction, recruitment, and survival at all life stages. Influencing those factors is the quality and accessibility of

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Clear Lake hitch habitat, which determines how well the spawning areas allow for successful reproduction, or whether the nearshore nursery areas allow for young-of-year survival and subsequent recruitment. Within the tributary streams, water quality and quantity are important factors influencing survival at all life stages, reproductive success, and recruitment, and is important for connectivity between spawning habitat and the lake. The presence of spawning gravel may influence reproductive success by increasing egg survival; however, there are instances of the subspecies successfully reproducing in areas that lack gravel, so this need may not be absolutely required for successful reproduction. The presence of instream and streamside vegetation within the tributary streams may increase survival for early life stages by providing cover from predators, instream temperature regulation, and prey.

Within the lake environment, both juvenile and adult Clear Lake hitch require clean water for survival. To increase juvenile survival and the likelihood that juveniles will be able to contribute to recruitment, the Clear Lake hitch require tules and/or other submerged vegetation within nearshore habitats to provide cover from predators and for prey. Adults require prey items in the open waters of the lake, which contributes to adult survival and provides resources to produce eggs and milt for reproduction.

Our analysis of the current condition of the subspecies revealed there are two populations of Clear Lake hitch, one of which has a high level of resiliency and the other a moderate level of resiliency. Because both populations of Clear Lake hitch occur within the same watershed and occupy the same ecological niche, the subspecies has never had much environmental diversity and it is likely it does not have much genetic diversity. Therefore, the Clear Lake hitch has likely never shown a high level of representation and currently has a low level of representation. For the Clear Lake hitch, representation is best measured by assessing the different spawning strategies available to the subspecies. The Clear Lake hitch has redundancy by having two isolated distinct populations. It also shows within population redundancy in the number of different types of spawning habitats they can utilize for reproduction (i.e., tributary, lake, or interface between the two), and the number of available tributary streams within the watershed. However, because redundancy gauges the probability that a species has a margin of safety to withstand or bounce back from a catastrophic event, and the Clear Lake hitch has such a narrow range, the Clear Lake hitch currently expresses moderate redundancy,.

Our analysis of the past, current, and future factors influencing the Clear Lake hitch revealed that there are six factors influencing the future viability of the subspecies. These factors influencing viability are primarily related to habitat changes (both negative and positive), although the introduction of non-native species is also a major influence. These influencing factors include: the loss of spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams, which reduces early life stage survival, reproductive success, and the likelihood of recruitment; the loss of wetland/tule habitat that juveniles require for rearing, which also reduces early life stage survival and the likelihood of recruitment; the effects from poor lake water quality, which reduces adult and juvenile survival; the effects of increased competition from a combination of introduced fish species and habitat loss, which reduces survival of all life stages, reproduction, and the likelihood of recruitment; drought, which further reduces tributary flow; and the implementation of regulatory mechanisms (i.e., CESA, Lake County's Clear Lake Shoreline Ordinance, and SGMA) and management actions (i.e., Lake County's Aggregate Resources Management Plan, Middle Creek Flood Damage Reduction and Ecosystem Restoration Project, and other miscellaneous restoration actions occurring throughout the watershed), which improve conditions in the watershed and provide protection to individual hitch.

The influencing factors described above play a large role in the future viability of the Clear Lake hitch. Given our uncertainty regarding the rates at which future influencing factors may act on each of the populations and the uncertainty regarding funding or support for future beneficial actions (i.e., Middle Creek Flood Damage Reduction and Ecosystem Restoration Project), or the continuation of current beneficial actions to occur in the future (contaminant remediation, tributary function, barrier removal), we forecasted how possible future conditions could impact the resiliency, redundancy, representation, and overall condition of the Clear Lake hitch. In order to assess future condition, we developed three plausible future scenarios. The following is a description of the three future scenarios, the status of the Clear Lake hitch when analyzed under each scenario, and a summary of the assumptions we made under each scenario:

Scenario 1: Under Scenario 1, those factors that are currently having an influence on each of the Clear Lake hitch populations will either continue at current rates or may slightly increase, such as the incidence of drought and implementation of restoration actions. Under Scenario 1, we project the Thurston Lake population to decline to a moderate condition. The analysis units that make up the Clear Lake population will maintain a moderate condition except for SIG 5, which will maintain its low condition. The overall resiliency of the Clear Lake population will be maintained at a moderate level under Scenario 1.

Factors that are currently having an influence on the Clear Lake hitch continue at current rates for all of the influencing factors under this scenario. Projections under Scenario 1 include:

1. Climate change results in more arid conditions in some years throughout most of the range. Because the timing of precipitation is projected to change, some years the number of spawning tributaries available to the subspecies over the spawning season will be reduced. In addition, increased fire and flooding incidence due to climate change will increase the amount of erosion occurring in the tributary streams, further decreasing water quality within the lake.

2. Future drought conditions are projected to increase, both the number of years drought conditions persist and the intensity of drought. This will also impact the number of spawning tributaries available to the subspecies over the spawning season and will impact the water quality within the lake.

3. Direct take of Clear Lake hitch will be limited due to the subspecies listing under CESA.

4. The existing wetland/tule habitats surrounding the lake will continue to persist due to Lake County's shoreline ordinance.

5. Current restoration projects (contaminant remediation, tributary function, barrier removal) continue to be implemented at a small scale throughout the watershed. However, the Middle Creek Project has not yet been fully constructed.

6. Very little urban development occurs and the rate of agricultural production is similar to current rates.

Under Scenario 1, the Clear Lake hitch continues to have two populations within its range, although the resiliency of the Thurston Lake population declines from high to moderate. The level of

representation continues to be low under this scenario and although redundancy stays at a moderate level, it slightly declines within that level due to the loss of resiliency in the Thurston Lake population.

Scenario 2: Under Scenario 2, those influencing factors that are currently having a negative influence on each of the Clear Lake hitch populations continue at current rates, or slightly increase. Scenario 2 is the best case scenario for the Clear Lake hitch because all of the analysis units within the Clear Lake population either retain or improve their current condition due to restoration and enhancement activities being implemented throughout the watershed. Under Scenario 2, the overall level of resiliency for the Clear Lake and Thurston Lake populations will be moderate.

Similar to Scenario 1, those factors that are currently having an influence on both Clear Lake hitch populations continue at current rates for all of the influences. However, under this scenario, large-scale restoration and enhancement activities are implemented throughout the Clear Lake population watershed, benefiting the Clear Lake population. Projections under Scenario 2 include:

1. Climate change results in more arid conditions in some years throughout most of the range. Because the timing of precipitation is projected to change, some years the number of spawning tributaries available to the subspecies over the spawning season will be reduced. In addition, increased fire and flooding incidence due to climate change will increase the amount of erosion occurring in the tributary streams, further decreasing water quality within the lake.

2. Future drought conditions are projected to increase, both the number of years drought conditions persist and the intensity of drought. This will also impact the number of spawning tributaries available to the subspecies over the spawning season and will impact the water quality within the lake.

3. Direct take of Clear Lake hitch will be limited due to the subspecies listing under CESA.

4. The existing wetland/tule habitats surrounding the lake will continue to persist due to Lake County's shoreline ordinance.

5. Current restoration projects (contaminant remediation, tributary function, barrier removal) continue to be implemented throughout the watershed at an increased rate. In addition, the Middle Creek Project has been constructed, benefiting the Clear Lake population (the Thurston Lake population does not experience any additional benefit from the Middle Creek Project).

6. Very little urban development occurs and the rate of agricultural production is similar to current rates.

Under Scenario 2, the Clear Lake hitch continues to have two populations within its range, although, similar to Scenario 1, the resiliency of the Thurston Lake population declines from high to moderate. The level of representation continues to be low under this scenario and although redundancy stays at a moderate level, it slightly declines within that level due to the loss of resiliency in the Thurston Lake population.

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Scenario 3: Under Scenario 3, some of the factors would continue to occur at their current rates, and some that are predicted to stay constant may increase. In Scenario 3 we project the Clear Lake and Thurston Lake populations will decline to a low and moderate level of resiliency, respectively.

Similar to Scenarios 1 and 2, those factors that are currently having an influence on each of the Clear Lake populations continue at current rates for all of the influences. However, under this scenario, agricultural production slightly increases in areas not prioritized under the Sustainable Groundwater Management Act (SGMA) and restoration projects are not implemented (i.e., no or very few small scale restoration projects are implemented, the Middle Creek Project is not constructed, no passage barriers are removed). Projections under Scenario 3 include:

1. Climate change results in more arid conditions in some years throughout most of the range. Because the timing of precipitation is projected to change, some years the number of spawning tributaries available to the subspecies over the spawning season will be reduced. In addition, increased fire and flooding incidence due to climate change will increase the amount of erosion occurring in the tributary streams, further decreasing water quality within the lake.

2. Future drought conditions are projected to increase, both the number of years drought conditions persist and the intensity of drought. This will also impact the number of spawning tributaries available to the subspecies over the spawning season and will impact the water quality within the lake.

3. Agricultural production slightly increases in areas currently not prioritized by SGMA.

4. Direct take of Clear Lake hitch will be limited due to the subspecies listing under CESA.

5. The existing wetland/tule habitats surrounding the lake will continue to persist due to Lake County's shoreline ordinance.

6. Current restoration projects (contaminant remediation, tributary function, barrier removal) are no longer being implemented, or are greatly reduced, and the Middle Creek Project is not constructed.

7. Very little urban development occurs.

Under Scenario 3, the Clear Lake hitch continues to have two populations within its range, although, the resiliency of the Thurston Lake population declines from high to moderate and the resiliency of the Clear Lake population declines from moderate to low. The level of representation continues to be low under this scenario and because of the loss of population resiliency in both populations, the level of redundancy declines to low.

Over the next 50 years, we believe Scenario 1 is the most likely to occur and Scenario 2 is the least likely to occur. We believe Scenario 1 is the most likely since we expect that climate change is likely to continue (thereby increasing the likelihood of aridity, fire incidence, and flood incidence), future drought conditions are likely to increase, CESA will continue to limit direct take, the Lake County shoreline ordinance will continue to maintain the existing amount of available wetland/tule habitat

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surrounding the lake, and current small scale restoration projects will continue to be implemented into the future.

Scenario 2 is not the most likely to occur because large scale restoration projects like the Middle Creek Project and numerous small scale restoration projects spread throughout the watershed will require extensive funding and coordination. It is possible a small subset of restoration projects will occur over the next 50 years, potentially even the Middle Creek Project; however, the wide scale restoration of the entire watershed as described in this scenario is not likely to occur. Scenario 3 could occur, but is not the most likely when compared to Scenario 1. This is primarily because various restoration projects have been implemented throughout the Clear Lake watershed and the lack of restoration described under this scenario is not likely to occur.

There is also a lack of enforcement on those that commit streambed/lake alterations which makes it difficult for state wardens to do their job. What is the point of putting all this work on a case when the county does not enforce the regs.

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ACRONYMS AND DEFINITIONS

AB 32: Assembly Bill 32, also known as the Global Warming Solutions Act

Analysis unit: Units used to conduct an in-depth analysis of the Clear Lake population of Clear Lake hitch within its range. The analysis units include: Cole Creek (SIG1); Kelsey Creek (SIG2); Clear Lake and Adobe Creek (SIG3); Rodman Slough (SIG4); and Middle Creek, Clover Creek, and Seigler Canyon Creek (SIG5). Thurston Lake is its own analysis unit.

CalTrans: California Department of Transportation.

CAPP: Conceptual Area Protection Plans. A CAPP allows different organizations and agencies to apply for land acquisition funding through CDFW's Wildlife Conservation Board.

Caudal peduncle: Portion of the tail that holds the tail fin.

CDFW: California Department of Fish and Wildlife

CEQA: California Environmental Quality Act

CESA: California Endangered Species Act

CLIWMP: Clear Lake Integrated Watershed Management Plan

Cyprinids: Fish in the freshwater minnow family, Cyprinidae

DWR: California Department of Water Resources

EPA: Environmental Protection Agency

GIS: Geographic Information Systems

HUC-12: 12-digit Hydrologic Unit Code

Lacustrine: Associated or living within a lake.

Limnetic: Inhabiting the open water of a body of fresh water (i.e., lake).

Littoral: Inhabiting the near shore area of a body of water (i.e., lake).

Middle Creek Project: Middle Creek Flood Damage Reduction and Ecosystem Restoration Project. This project is both a flood risk reduction project for 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.

Milt: Semen of a male fish.

Mitochondrial DNA: DNA found exclusively in the mitochondria and is maternally inherited.

NEPA: National Environmental Policy Act

Nuclear DNA: DNA contained within each cell nucleus of most living organisms and is inherited from both parents.

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Pharyngeal teeth: Teeth found in the throat area, behind the mouth and nose.

PIT tag: Passive Integrated Transponder tag

RCP 4.5: Representative Concentration Pathway 4.5. A greenhouse gas concentration trajectory in which greenhouse gas emissions stabilize by mid-century and then decline to levels seen in the 1990's by the end of the century.

RCP 8.5: Representative Concentration Pathway 8.5. A greenhouse gas concentration trajectory in which greenhouse gas emissions continue to increase into the next century.

Recruitment: The process of adding new, reproducing individuals to a population or subpopulation.

Reproduction: The act or process of reproducing, or the process by which plants and animals give rise to offspring.

Reproductive success: An individual's successful production of offspring per breeding event or lifetime. The passing of genes onto the next generation.

SGMA: Sustainable Groundwater Management Act. A California state law which provides a framework for sustainable, groundwater management in California.

SIG: Strontium Isotope Grouping

SL: Standard Length. Length of a fish measured from the tip of their mouth/snout to the end of the tail, excluding the caudal (tail) fin.

SWRCB: California State Water Resources Control Board.

Terminal mouth: Location of a fish's mouth. Both jaws are the same length with the mouth located in the middle of the head pointing forward.

USFS: United States Forest Service

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CHAPTER 1: INTRODUCTION

1.1 Petition History and Previous Federal Actions

The Clear Lake hitch (*Lavinia exilicauda chi*) (Hopkirk 1973, pp. 55–56) is a large cyprinid (freshwater minnow) that is endemic to the Clear Lake watershed in Lake County, California. The subspecies resides in Clear and Thurston Lakes throughout the year until the spring when hitch migrate into tributary streams to spawn and then return to the lake. The U.S. Fish and Wildlife Service (Service) received a petition from the Center for Biological Diversity on September 25, 2012 (CBD 2012, entire), to list the Clear Lake hitch as threatened or endangered under the authority of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543) (Act). The Service issued a 90-day finding on April 10, 2015 (80 FR 19259), stating the petition presented substantial information that listing the Clear Lake hitch may be warranted. This conclusion was based on our review of the petition and sources cited in the petition, indicating that the petitioned action may be warranted due to: (1) the present or threatened destruction, modification, or curtailment of the species habitat or range from urban and agricultural development, dams, water diversions, migration barriers, mining activities, and grazing; (2) overutilization for commercial fishing, recreational fishing, and tribal harvest; (3) disease and predation; and (4) other natural or manmade factors affecting its continued existence, including effects from climate change, contaminants, and introduced fish. Therefore, a review of the status of the subspecies was initiated to provide the scientific information from which a determination will be made. Based on the information prepared for this SSA, the Service will issue a 12-month finding for the Clear Lake hitch.

1.2 Methodology

This assessment draws scientific information from resources such as primary peer-reviewed literature, reports submitted to the Service and other public agencies, species occurrence information in Geographic Information Systems (GIS) databases, habitat information in GIS databases, and expert experience and observations. It is preceded by and draws upon analyses presented in other Service documents, including the 90-day finding (80 FR 19259). Finally, we coordinated closely with our partners engaged in ongoing research and conservation efforts. This assures consideration of the most current scientific and conservation status information.

<u>Analytical Framework</u>

The Species Status Assessment (SSA) framework (Service 2016, entire) and the SSA Report developed from the framework are intended to support an in-depth review of the species' biology and influencing factors, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

This SSA Report for the Clear Lake hitch is intended to provide the biological support for the decision on whether to recommend listing the subspecies as threatened or endangered and, if so, where to recommend proposing to designate critical habitat. Importantly, the SSA Report does not result in a decision by the Service on whether the Clear Lake hitch should be proposed for listing as a threatened or endangered species under the Act. Instead, this SSA Report provides a review of the available information strictly related to the biological status of the Clear Lake hitch. The decision whether to list the subspecies will be made by the Service after reviewing this document and all

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relevant laws, regulations, and policies. The results of our review of the best available scientific information will be announced in the *Federal Register*. If listing is warranted, the proposed listing rule will be published with appropriate opportunities for public input.

For the purpose of this assessment, we generally define viability as the ability of the Clear Lake hitch to sustain itself within its natural ecosystem throughout the Clear Lake watershed up through and beyond a biologically meaningful timeframe, in this case, 50 years. We chose 50 years because the available climate models for the North Coast Region, where Clear Lake is located, show similar precipitation and temperature projections under the two different emissions scenarios (RCP 4.5 and RCP 8.5) into the mid-century (2040-2069). Beyond this time period (2070-2099), both temperature and precipitation projections begin to diverge under the two emissions scenarios. Since it is unknown what emissions scenario we will be tracking in the later part of the century, and that uncertainty increases with time, we will be conservative in using the shorter, 50-year timeframe. Using the SSA framework (Figure 1.1), we consider what the subspecies needs to maintain viability by characterizing the status of the subspecies in terms of its resiliency, representation, and redundancy (Wolf *et al.* 2015, entire).

- **Resiliency** describes the ability of populations to withstand stochastic events. Measured by the size and growth rate of each population, resiliency gauges the probability that the populations comprising a species are able to withstand or bounce back from environmental or demographic stochastic events. For the Clear Lake hitch, resiliency was evaluated by assessing the subspecies' demographic factors of reproduction and recruitment, and habitat elements of connectivity, water quality and quantity, and availability of wetland/tule habitat.

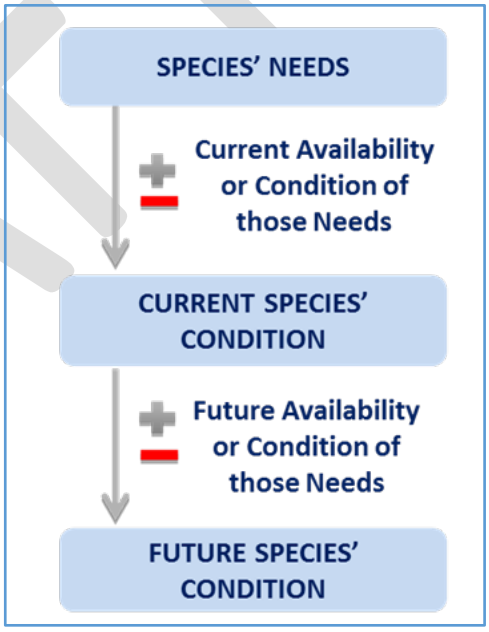

Figure 1.1 Species Status Assessment framework

- **Representation** describes the ability of a species to adapt to changing environmental conditions. Measured by the breadth of genetic or environmental diversity within and among populations, representation gauges the probability that a species is capable of adapting to environmental changes. Because the Clear Lake hitch has such a narrow range with similar habitat characteristics, the subspecies has never had much environmental diversity and likely does not have much genetic diversity. Therefore, it is likely the Clear Lake hitch has never had a high level of representation. For the Clear Lake hitch, representation was evaluated by assessing the different spawning strategies they can utilize under variable environmental conditions.

- **Redundancy** describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can

bounce back from catastrophic events. We evaluated redundancy of Clear Lake hitch in the context of its extant range that includes two populations, one that occupies Thurston Lake and its tributary (Thurston Creek), and one that occupies Clear Lake and its tributaries. In addition, we will also be describing how the subspecies expresses within population redundancy based on types of spawning habitats (tributary, lake, or interface between the two) and the number of available tributary streams within the watershed. Although this is not entirely consistent with the SSA framework's definition of redundancy, we believe this is important to describe since a plausible catastrophic event may be prolonged drought and having different spawning habitats available to the subspecies may increase the ability of the Clear Lake hitch to withstand a catastrophic drought event.

To evaluate the biological status of the Clear Lake hitch both currently and into the future, we assessed a range of conditions to allow us to consider the subspecies' resiliency, representation, and redundancy (together, the 3 Rs). This SSA Report provides a thorough assessment of the Clear Lake hitch's biology and natural history, and assesses demographic risks, influencing factors, and limiting factors in the context of determining the viability and risk of extinction for the subspecies.

The format for this SSA Report includes: (1) a description of the Clear Lake hitch, its life history, and habitat (Chapter 2); (2) the resource needs of individuals and populations, and a framework for determining population resiliency and how the distribution of populations across the subspecies' range can affect the hitch's viability (Chapter 3); (3) a review of the influencing factors that affect the subspecies' viability and to what degree (Chapter 4); (4) an analysis of the subspecies' current and future conditions (Chapters 5 and 6); and (6) a conclusion that describes the viability of the subspecies in terms of resiliency, representation, and redundancy (Chapter 7). This document is a compilation of the best available scientific and commercial information and a description of the past, present, and likely future risk factors to the Clear Lake hitch.

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CHAPTER 2: SUBSPECIES DESCRIPTION

In this chapter, we provide basic biological information about the Clear Lake hitch, including its taxonomic history and relationships; genetics; morphology; physical environment; known life history traits; and habitat requirements. Here, we report those aspects of the life history of the Clear Lake hitch that are important to our analysis. For further information about the Clear Lake watershed and the Clear Lake hitch, refer to Bairrington (2000), CDFW (2014), Moyle (2002), Suchanek et al. (2003), the Chi Council for the Clear Lake Hitch website (https://lakelive.info/chicouncil/), and the Clear Lake Environmental Research Center website (https://www.clerc.co).

2.1 Taxonomy and Genetics

The Clear Lake hitch is a fish subspecies classified in the Lavinia genus in the family Cyprinidae (freshwater minnows; see Table 2.1). 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, p. 139). However, after investigations of the geographic variation of another fish species, the tule perch, it was hypothesized that the Clear Lake watershed may be isolated and a center for speciation (Hopkirk 1973, p. 1). The type specimen of Clear Lake hitch was a reproductive female collected from Seigler Creek in 1964 by Paul R. Needham, John D. Hopkirk, and a group from the University of California, Berkeley (Hopkirk 1973, p. 55). The first biologist to describe the Clear Lake hitch as a distinct subspecies was John D. Hopkirk (Hopkirk 1973, p. 55). Hopkirk described the subspecies as "lake-adapted" and found it could be differentiated from the more wide-spread species by its deeper body form, larger scales and eyes, and its greater number of gill rakers (Hopkirk 1973, pp. 55–56; Moyle et al. 1995, p. 153). Similarly, the now extinct Clear Lake splittail (*Pogonichthys ciscoides*) and the extant Clear Lake tule perch (*Hysterocarpus traskii lagunae*), both have a greater number of gill rakers compared to the splittail and tule perch species found within the Sacramento River watershed (Hopkirk 1973, p. 56).

Table 2.1 Taxonomic Chart for the Clear Lake Hitch

Kingdom	Phylum	Class	Order	Family	Genus	Species	Subspecies
Animalia	Chordata	Actinopterygii	Cypriniformes	Cyprinidae	Lavinia	exilicauda	chi

Hitch are closely related to the California roach (*Hesperoleucus symmetricus*), which they are known to hybridize with and produce both fertile and infertile offspring outside of Clear Lake (Miller 1945, p. entire; Hubbs 1961, p. 11–12; Moyle et al. 1995, p. 153). Hitch have also been known to hybridize with other cyprinids, including the Sacramento blackfish (*Orthodon microlepidotus*), which produce sterile hybrids, and thicktail chub (*Gila crassicauda*), which is now extinct (Miller 1963, pp. 20, 24–27; Hopkirk 1973, p. 51; Moyle and Massingill 1981, entire; Moyle et al. 1995, pp. 5, 153). Hitch-roach hybrids are known to occur more frequently, whereas hitch-chub and hitch-blackfish hybrids have only been documented a few times (Moyle and Massingill 1981, p. 196).

The Clear Lake roach is now only found within the tributaries to Clear Lake and not within Clear Lake itself, likely due to the presence of numerous non-native predators within the lake (Moyle 2002, pp. 141, 142; Baumsteiger and Moyle 2019, p. 237). Although hitch outside of Clear Lake are known to hybridize with the various other cyprinid species described above, and those species currently or historically co-occurred with the hitch within the Clear Lake watershed, there are no verified records of Clear Lake hitch hybridizing with any of these species (Moyle et al. 2014, p. 1; CDFW 2014, p. 5). However, there is some disagreement in the literature about whether 12 specimens collected from Clear Lake in 1939 and 1940 were hitch-blackfish hybrids or another

species of *Lavinia* that subsequently went extinct before being formally described (Hopkirk 1973, pp. 56–59; Hubbs 1974, pp. 808–809; Jones 2001, p. 109). Therefore, although it is unlikely that Clear Lake hitch are currently hybridizing with other cyprinids within Clear Lake, it is possible.

Early genetic studies showed the hitch (*Lavinia exilicauda*) and the roach (*Hesperoleucus symmetricus*) are so genetically similar that they could be considered conspecifics; however, some minor genetic differences, differences in habitat use, and the extensive morphological differences between the two supported their separate species status (Avise et al. 1975. p. 417–421). Further genetic analysis completed by Avise and Ayala (1976, pp. 49–51) found hitch and roach showed very little genetic divergence despite their morphological differences, and they postulated that the two are congeners. Because of these findings, subsequent researchers considered the California roach to be in the same genus as hitch, *Lavinia*; however, more recent studies suggest the roach/hitch complex is actually comprised of two separate genera (Baumsteiger et al. 2017, entire; Baumsteiger and Moyle 2019, pp. 4–5; 223–224). Furthermore, changing the roach genera to *Lavinia* was not universally recognized and the American Fisheries Society still considers the species as *Hesperoleucus symmetricus* (Moyle 1980, p. 200; Moyle and Massingill 1981, p. 196; Page et al. 2013, p. 71).

Analyses of the taxonomic status of the different hitch and roach forms found throughout California were completed in both the early and late 2000's (decade between 2000 and 2009). A study done in the early 2000's found the Clear Lake hitch shares mitochondrial DNA haplotypes with different forms of the California roach outside of the Clear Lake watershed, and therefore, does not form a monophyletic group. However, due to differences in nuclear and mitochondrial DNA between the Clear Lake form of the California roach and the Clear Lake hitch, the author suggested treating the Clear Lake hitch as an Evolutionary Significant Unit instead of a subspecies because subspecies status was not supported by their analysis (Jones 2001, pp. 25–26). An analysis in the late 2000's using nuclear and mitochondrial DNA had differing results. The nuclear DNA analysis of ten microsatellite loci supported the subspecies designation for the Clear Lake hitch; however, the analysis of two mitochondrial DNA fragments did not find the Clear Lake form of hitch to be distinct from other hitch found throughout California (Aguilar and Jones 2009, p. 380). Despite the conflicting results, the authors conclude that the Clear Lake hitch should be considered a valid subspecies due to its geographic isolation from other hitch within California, their considerable morphological differences compared to other hitch forms, and the lack of known hitch-roach hybridization within the Clear Lake watershed (Aguilar and Jones 2009, p. 380).

More recent genomic analysis suggests the three forms of hitch within California show strong population structuring, but show only weak support for subspecies structuring. The authors further suggest their data reflects the three hitch forms found throughout California may actually be a single species that once had high gene flow occurring among the populations, but have recently become isolated from each other (Baumsteiger et al. 2019, p. 407). Since this analysis is still fairly recent and does not definitively conclude that the Clear Lake hitch is not a subspecies, and because the hitch is still currently considered a valid subspecies by the scientific community (ITIS 2019, Taxonomic Serial No.: 914028), we will continue to consider the Clear Lake hitch a subspecies for the purposes of this SSA Report.

2.2 Subspecies Description

Adult Clear Lake hitch 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 the adults have been described as round and the juveniles as oval.

The Clear Lake hitch 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, p. 197; Moyle et al. 1995, p. 153; Moyle 2002, p. 136–137; CDFW 2014, p. 5). As typical for other native juvenile cyprinid species found in California, 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, p. 55; Moyle et al. 1995, p. 153). As individuals age, their silvery coloring fades and their dorsal surface become a brownish-yellow (Moyle 1976, p. 177; Moyle et al. 1995, p. 153). As mentioned previously, compared to other subspecies of hitch the Clear Lake hitch has larger scales and eyes (Hopkirk 1973, pp. 55–56; Moyle et al. 1995, p. 153; CDFW 2014, p. 5).

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 water temperatures in Clear Lake (Murphy 1951, pp. 444–447; Moyle 1976, p. 178; Geary 1978, pp. 22–24; Moyle et al. 1995, p. 153; Moyle 2002, pp. 137–138). 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, pp. 7, 9). Males are sexually mature within their first or second year, whereas females are sexually mature in their second or third year (Murphy 1948b, pp. 103–104, 109; Moyle et al. 1995, p. 153). Hitch are thought to live 4 to 6 years based on scale analysis, but it is possible some individuals can live longer (Moyle 2002, p. 138; CDFW 2014, p. 8). The larger size of female hitch within Clear Lake compared to the other subspecies of hitch within California equates to greater fecundity. For female Clear Lake hitch 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, p. 387). 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, p. 55; Moyle et al. 1995, p. 153; Moyle 2002, p. 137). It is unknown why *Lavinia*, a feminine Latin name, was applied to the hitch (Moyle 2002, p. 137). The native Pomo referred to the Clear Lake hitch as *chy* or *chigh* and the eastern band used the name *hitch* or *hitc* for the Clear Lake splittail (Jordan and Gilbert 1895, p. 139; Barrett 1908, pp. 322, 327; Hopkirk 1988, pp. 185, 186).

2.3 Geographic Distribution

The Clear Lake hitch is restricted to the Clear Lake watershed in Lake County, California, in the central Coast Range. Most of the subspecies' range occurs on private land; however, some of the spawning tributaries and nearshore habitats are owned by county, state, or federal agencies (see Figure 2.1). In addition to Clear Lake itself, there are other small lakes found throughout the watershed that either currently or historically contained Clear Lake hitch. Historically, the species occurred in Clear Lake, Thurston Lake, the Blue Lakes, Lampson Pond, and numerous tributaries to Clear Lake, including Kelsey, Scott, Middle, Adobe, Seigler Canyon, Manning, Cole, Morrison, and Schindler Creeks (Moyle et al. 1995, p. 154; CDFW 2014, p. 6; see Figure 2.2). 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, p. 5). Although they are hydrologically connected to Clear Lake, the Clear Lake hitch is currently thought to be extirpated from the Blue Lakes (CDFW 2014, p. 6). Just to the west of the lower arm of Clear Lake is Thurston Lake, a small lake that is currently supporting a robust population of Clear Lake hitch (Ewing 2019, pers. comm.). Although Thurston Lake and its tributary Thurston Creek are currently isolated from Clear Lake and its associated tributaries, historically they may have been connected during flooding events (Ewing 2019, pers.

comm.). Because Thurston Lake is not currently hydrologically connected to Clear Lake during flood events, we do not anticipate it to be re-connected in the future. The status of the Clear Lake hitch in Lampson Pond is unknown.

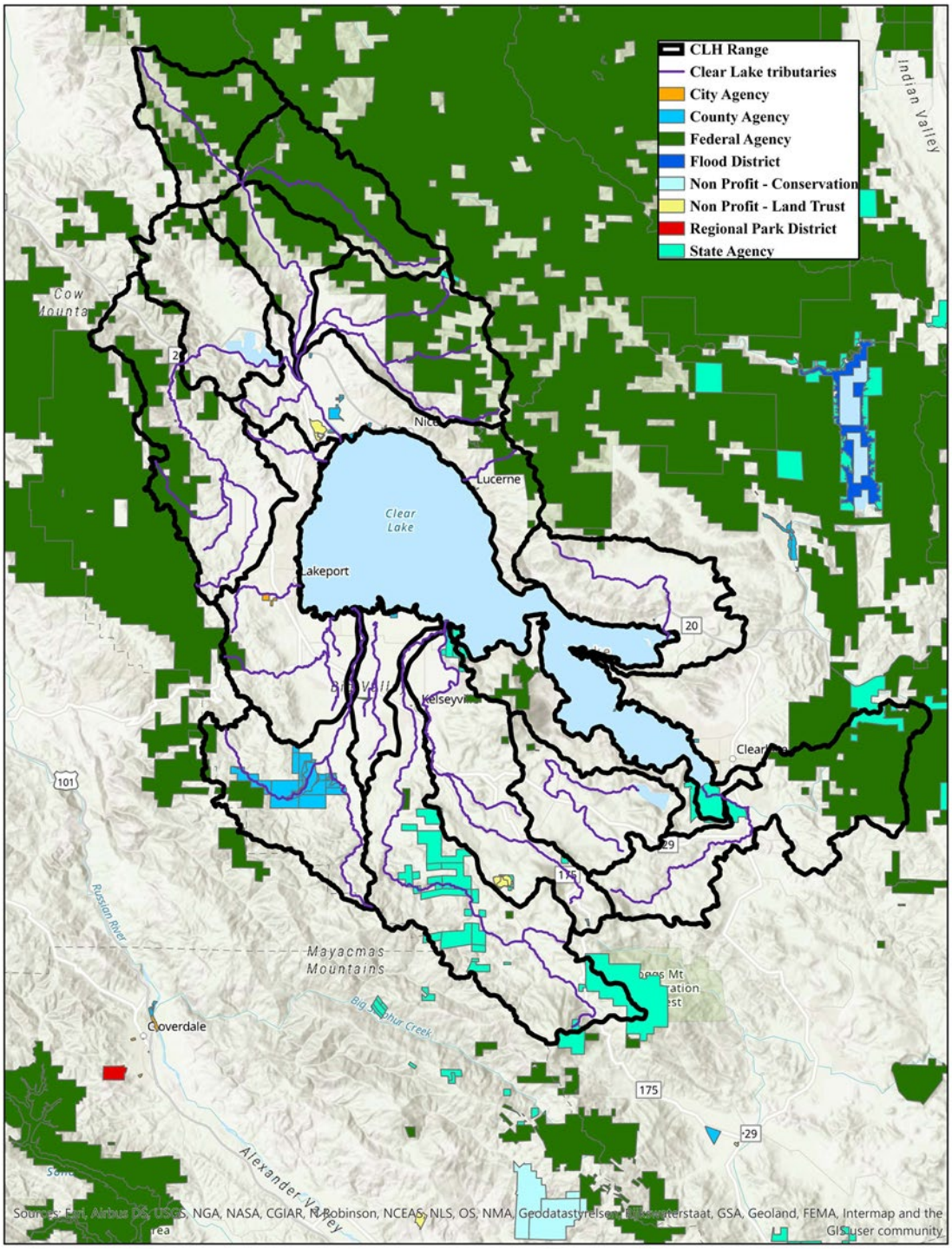

Figure 2.1 Land ownership within the range of the Clear Lake hitch

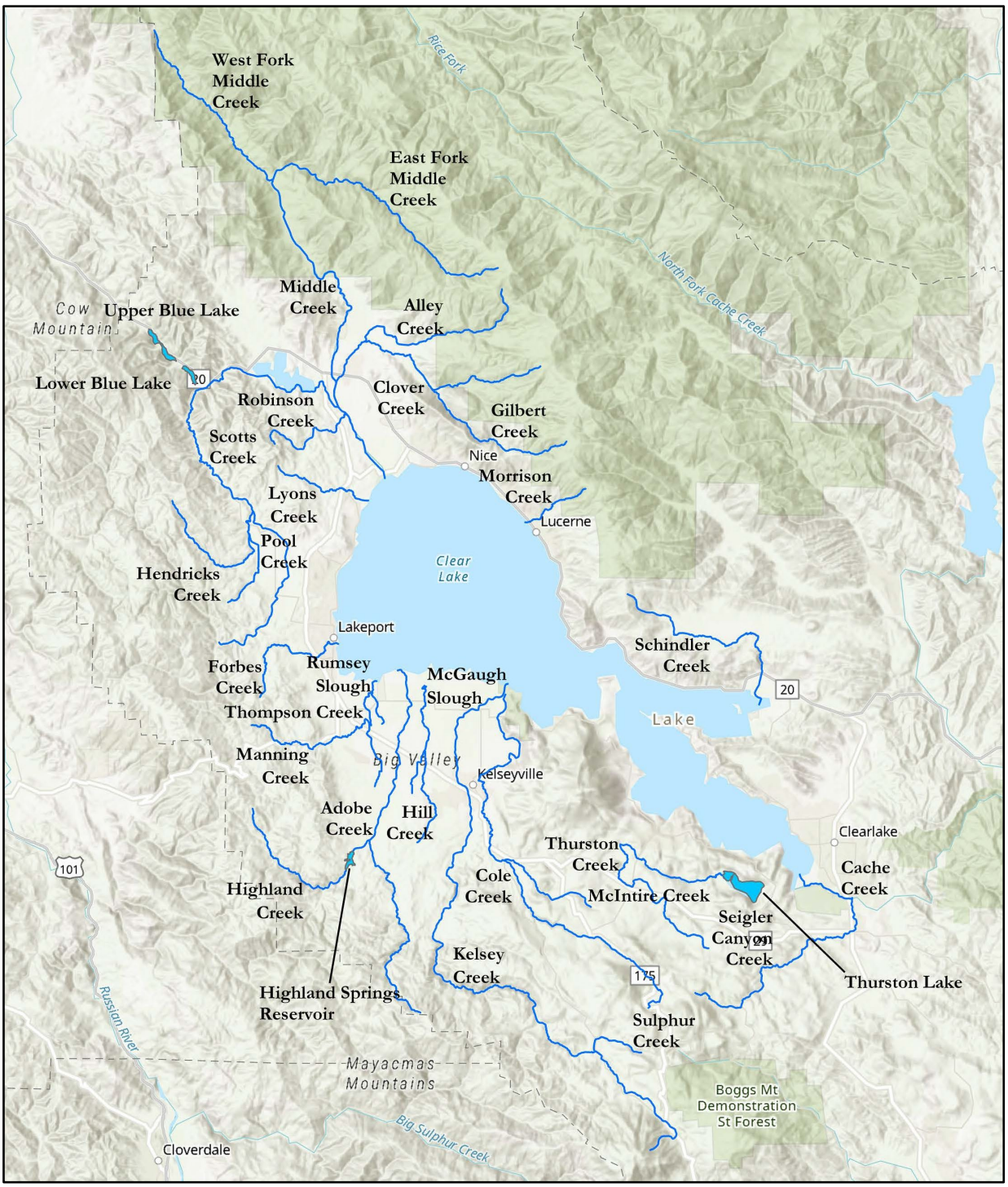

Figure 2.2 Clear Lake watershed

2.4 Habitat and Life History

Clear Lake Watershed

The Clear Lake watershed is located within the northern portion of the California Coast Ranges, approximately 100 miles north of the City of San Francisco (Bairrington 2000, pp. 1–2). The general

area is distinguished by mostly eastern-sloped mountains interspersed with several large valleys, and elevations vary from over 1,300 feet (surface of Clear Lake) to over 4,800 feet (High Grade Lookout) (Bairrington 2000, pp. 4–5). The Clear Lake area has a Mediterranean climate, characterized by hot, dry summers and cool, wet winters. The wet season is typically from October through April, although most precipitation occurs between the months of November and March (Bairrington 2000, p. 6).

Life History

Hitch 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, p. 2; CDFW 2014, p. 1). 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 Clear Lake hitch have not evolved a strong jumping ability (Murphy 1948b, p. 102; Macedo 1994, p. 4; CDFW 2014, p. 8). 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 1948b, p. 103; Kimsey 1960, p. 212; Moyle 1976, p. 179; Moyle et al. 1995, p. 154; CDFW 2014, pp. 8–9; Feyrer 2019b, p. 227). While some adults are actively engaged in spawning behaviors, schools of non-spawning hitch hold in pool habitat and feed on invertebrates (Feyrer 2019b, p. 228).

Eggs are deposited on fine to medium sized gravel that is along the margin or mid-channel of the stream (Shapovalov 1940 *in* Murphy 1948b, p. 102; Kimsey 1960, p. 211; CDFW 2014, p. 8). After the eggs are fertilized, they sink to the gravel covered stream bottom and become wedged between the gravel interstices (Moyle et al. 1995, p. 154; Feyrer 2019b, pp. 227, 229). Freshly extruded eggs that have not been fertilized are a light orange; however, once fertilized, eggs become a pale yellow (Swift 1965, p. 75). 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 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154). 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, p. 212).

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, p. 199; Geary and Moyle 1980, p. 388; Franson 2012, p. 15; CDFW 2014, pp. 8–9). 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, p. 199; Geary 1978, pp. 17, 25; Geary and Moyle 1980, p. 388; Moyle et al. 1995, p. 153; Moyle 2002, pg. 137–138; Moyle et al. 2014, p. 3). Clear Lake hitch feed primarily during the daylight hours (Geary 1978, p. 17; Moyle et al. 1995, p. 153). See Figure 2.3 for a basic life history model for the Clear Lake hitch.

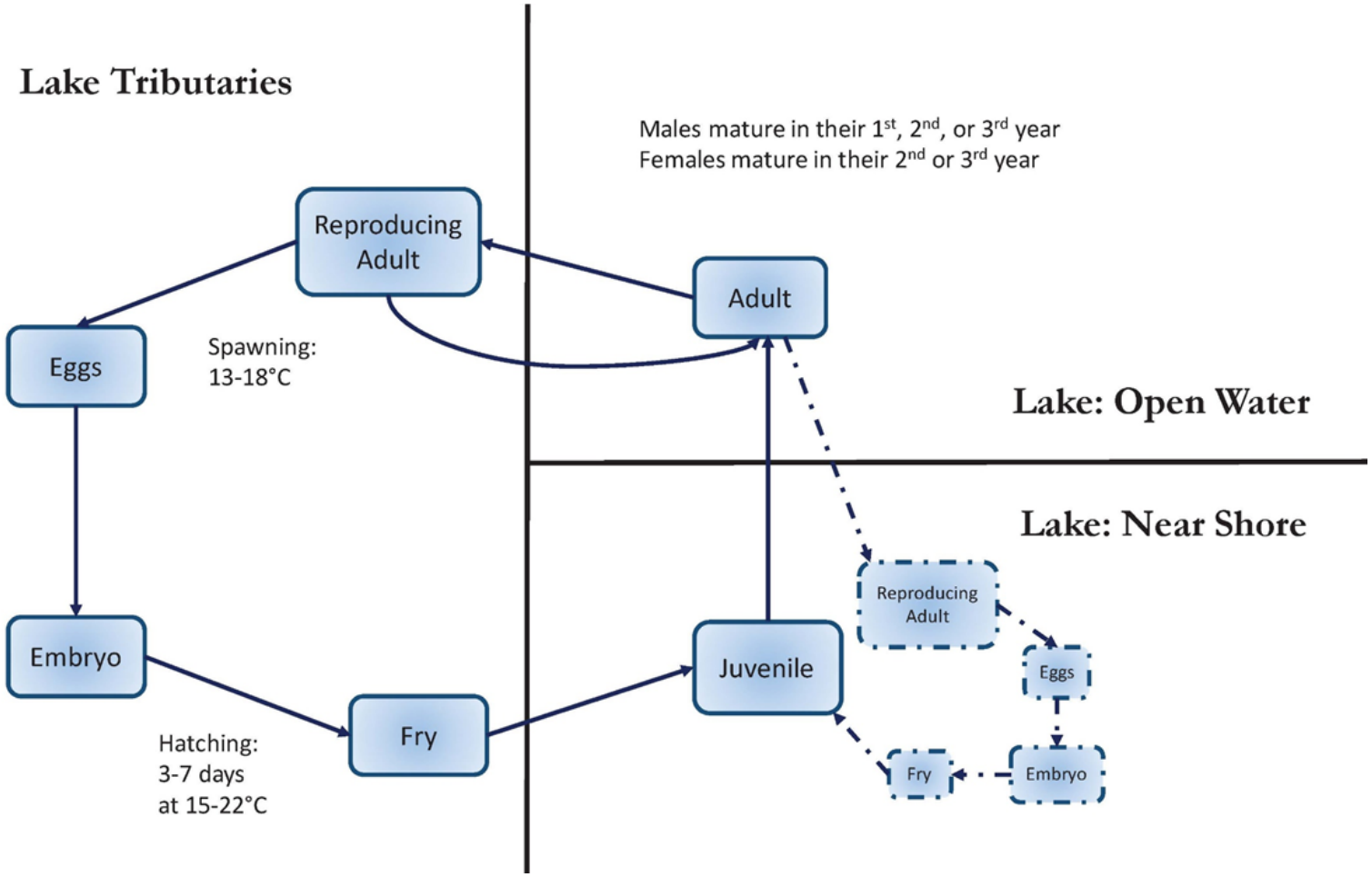

Figure 2.3 Clear Lake hitch basic life history model. Dashed lines represent individuals that spawn in the lake

Murphy (1948b, pp. 101–102) stated that Clear Lake hitch required gravel stream bottoms in order to spawn; however, Kimsey (1960, p. 211) detailed his personal observation of approximately 50 individuals exhibiting typical spawning behavior (chasing, swimming rapidly, 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 1960, p. 211). 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, pp. 211–212). 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, p. 212).

Kimsey (1960, p. 213) also documented a self-sustaining Clear Lake hitch 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, pp. 213–214). 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 stream habitat (Kimsey 1960, p. 214; Geary 1978, p. 22). More recent studies suggest the subspecies may be utilizing Clear Lake for spawning more frequently than first thought, especially during drought conditions. The areas of the lake that the subspecies is likely utilizing 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. 2019a, p. 1695).

CHAPTER 3: SUBSPECIES ECOLOGY

In this chapter we report what the subspecies needs at the individual and population level, which are best described when categorized by needs during each life stage (see Tables 3.1 and 3.4). We also define what a Clear Lake hitch population is and define an analysis unit, which is used to conduct a more in-depth analysis of the Clear Lake population. In addition, this chapter will also describe what each population, and the subspecies overall, needs for viability. Using the SSA framework, we describe the subspecies' viability by characterizing the status of the Clear Lake hitch in terms of its **resiliency**, **representation**, and **redundancy** (the 3 Rs).

3.1 Individual Needs

The following subsection, Individual Tributary Needs, will describe the subspecies' individual needs while within the tributaries to Clear Lake or Thurston Lake. In contrast, the next subsection, Individual Lacustrine Needs, will describe what an individual requires while residing within the lake. This separation is important as there are different subspecies needs within the different environments. A summary of individual needs by life stage is shown in Table 3.1.

Table 3.1 Clear Lake hitch individual needs by life stage. The last column categorizes the individual needs into whether they effect breeding (B), feeding (F), sheltering (S), or migration (M).

Life Stage	Needs	B/F/S/M
Egg/Embryo	Low gradient streams containing riffles with clean, fine to medium gravel	S
	Water temperatures of 15-22°C for multiple days for hatching	B
	Instream water depth that allows eggs to remain submerged	S
Larvae/Fry	Maintenance of water flow within tributary streams for downstream migration to the lake	M
	Instream and overhanging vegetation for cover and instream temperature regulation	S
	Food source (yolk sac/aquatic invertebrates)	F
Juveniles	Food source (insects, planktonic crustaceans, chironomid midges)	F
	Emergent vegetation (nearshore within the lake, wetland, marsh)	S
	Well oxygenated and uncontaminated lake water (nearshore and in wetlands/tule habitat)	S
	Water temperatures of 15°C or greater for survival	S
Adults	Food source (Daphnia, zooplankton, adult midges/insects)	F
	Maintenance of water flow within the tributary streams during the spawning season to allow adult access to spawning habitat	M/B
	Well oxygenated and uncontaminated lake water	S
	Water temperatures of 13-18°C in streams to initiate spawning	B
	Low gradient streams containing riffles with clean, fine to medium gravel	B

3.1.1 Individual Tributary Needs

The Clear Lake hitch is only found in the tributary streams during the spawning season. A reproductive adult that is attempting to spawn requires an adequate amount of flow within the tributaries to migrate upstream to appropriate spawning locations. In addition, spawning adults require unimpeded passage within those tributaries. Because the species is not a strong jumper like salmonids (Murphy 1948b, p. 102; Macedo 1994, p. 4; CDFW 2014, p. 8), small obstructions such as bridge footings, boulders, or a steep gradient can act as migration barriers. Reproductive females require at least one reproductive male, although several males typically spawn with one female. Once fertilized, the eggs require adequate stream flow to stay submerged and oxygenated, and require fine to medium sized clean gravel along the margin or within the mid-channel of the stream to hold

position during development (Shapovalov 1940 *in* Murphy 1948b, p. 102; Kimsey 1960, p. 211; Moyle et al. 1995, p. 154; CDFW 2014, p. 8).

The subspecies requires water temperatures between 13°C and 18°C to trigger spawning activity and presumably need water temperatures to be in a similar range for successful egg development (Swift 1965, pp. 75, 77; Moyle 2002, p. 138; Feyrer 2019b, p. 227). To initiate hatching, water temperatures must be maintained at 15-22°C for multiple days (Swift 1965, pp. 75, 77; Moyle 2002, p. 138). Laboratory studies show newly hatched hitch have a small yolk sac which they depend on for nourishment until they are able to swim freely (about 3 days). Once able to swim freely, young Clear Lake hitch require aquatic invertebrate prey (Kimsey 1960, p. 212). For cover and temperature regulation, downstream migrating fry likely require instream and/or overhanging streamside vegetation. The fry/juvenile life stage requires adequate stream flow to stay alive, and adequate flow needs to be maintained for at least a month to migrate downstream into the lake (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154). Recent otolith analysis shows the time until lake entry is associated with how long water is retained within the natal habitat. The time until lake entry ranged from 11 days to over 21 weeks (Feyrer et al. 2019a, p. 1693).

3.1.2 Lacustrine Needs

Outside of the spawning season, the Clear Lake hitch is primarily found in Clear or Thurston Lakes. They can be found in either the littoral zone (nearshore) as juveniles or the limnetic zone (sun-lit, offshore open water) as adults. During the spawning season, a majority of adults likely migrate into the lake tributaries; however, some reproductive adults may stay within the lake and spawn along the shore, the mouth of tributaries, or in back-water like areas of Clear Lake, like Rodman Slough. During extreme drought conditions, the only successful reproduction may be within the lakes.

Littoral Zone

Within a month of hatching, young Clear Lake hitch migrate into the lake before their natal stream dries (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154; Feyrer et al. 2019a, p. 1693). Once in the lake juveniles require stands of tules and/or other submerged aquatic vegetation to act as cover from aquatic and avian predators. Nearshore habitats containing vegetation also provide for invertebrate prey items, including insects, planktonic crustaceans, and chironomid midges. Juveniles also require the lake water to be of sufficient quality (i.e., well oxygenated and uncontaminated) and for water temperatures to be 15° or greater for survival (Franson 2012, p. 15; CDFW 2014, p. 9). During a recent year-long electro-fishing survey of the Clear Lake shoreline, hitch were the 7th most common species collected (Ewing et al. 2016, pp. 50–51). Over the course of the study, habitat parameters were recorded and there was a positive relationship found between weed cover and hitch presence, and amount of vegetated shoreline and hitch presence (Ewing et al. 2016, p. 54–55), which is reasonable as the subspecies uses the weeds and vegetation as cover from predators.

Some reproductive adults likely elect to spawn within the lake instead of migrating into the lake tributaries. Spawning observations along the Clear Lake shoreline have been noted in the past and self-sustaining populations of Clear Lake hitch have been documented in isolated ponds without a tributary access. Lake or pond spawning Clear Lake hitch have been documented spawning in areas with only a mud substrate that contains no gravel, so it is possible lake spawning individuals do not require gravel to successfully spawn (Kimsey 1960, p. 214; Geary 1978, p. 22). In addition, more recent studies suggest lake spawning occurs more frequently than first thought, especially during

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drought conditions. Lake spawning includes spawning along the shoreline, in the mouths of tributaries, and in Rodman Slough, which is a backwater-like area in Clear Lake (Feyrer et al. 2019a, p. 195).

Limnetic Zone

Juvenile hitch transition to adulthood when they reach about 50 mm and they move from the lake's nearshore habitat out into open water. At this stage of life the hitch require a diet almost exclusively composed of *Daphnia*, but also other zooplankton species and adult midges and insects (Lindquist et al. 1943, p. 199; Geary 1978, pp. 17, 25; Geary and Moyle 1980, p. 388; Moyle et al. 1995, p. 153; Moyle 2002, pg. 137–138; Moyle et al. 2014, p. 3). Adult Clear Lake hitch require adequate water quality (i.e., well oxygenated and uncontaminated) within Clear and Thurston Lakes to ensure they continue to survive (Franson 2012, p. 15; CDFW 2014, p. 9). A recent lake monitoring effort suggests adult hitch can be found throughout the lake where dissolved oxygen conditions are adequate (i.e., not hypoxic) and do not restrict themselves to open water (Feyrer et al. 2019b, pp. 5–7).

3.2 Population Needs

In this section, we define what a Clear Lake hitch population is and how we further divide the Clear Lake population into separate analysis units. The reason we further divide the Clear Lake hitch population into is to conduct a more focused analysis of how different portions of the lake contribute to the Clear Lake population's overall resiliency.

3.2.1 Definition of a Population and Population Analysis Unit

There are likely only two separate populations of Clear Lake hitch within the Clear Lake watershed: one is found in Clear Lake and its associated tributaries, and the other in Thurston Lake and its associated tributary. Although historically these two populations may have been hydrologically connected during wet years, they currently are isolated from each other and we do not anticipate them to be connected in the future. Because conditions can vary throughout Clear Lake and its associated tributaries, we did a more detailed analysis of the Clear Lake population. This was conducted by further dividing the Clear Lake watershed into Hydrologic Unit Code (HUC) 12 sub-watersheds, which better capture aquatic habitat features at a local, sub-watershed level. The HUC 12 sub-watershed units within the range of the Clear Lake hitch include (see Figure 3.1): West Fork Middle Creek, East Fork Middle Creek, Salt Flat Creek-Middle Creek, Lower Scotts Creek, Middle Scotts Creek, Clover Creek, Rodman Slough - Frontal Clear Lake, Manning Creek - Frontal Clear Lake, Adobe Creek, Kelsey Creek, McGaugh Slough - Frontal Clear Lake, Cole Creek, Thurston Lake, Clear Lake, Schindler Creek - Frontal Clear Lake, and Seigler Canyon - Cache Creek.

Because some of the sub-watersheds do not have all of the components that the subspecies requires to complete its life history, and because we have recent information about how different regions of the watershed have contributed to reproduction and recruitment, the two primary demographic factors limiting population growth, we further grouped some of the HUC 12 units into larger units (see Table 3.2). This further grouping was based on otolith strontium signatures that indicated natal origins can be assigned to one of five strontium isotope groups (SIG) throughout the watershed (Feyrer et al. 2019a, entire; see Section 5.2 for a detailed description of the strontium isotope analysis). The use of adult otoliths for the natal habitat strontium groupings indicates those areas associated with the SIG is contributing to reproduction and recruitment. The HUC 12 units in each SIG are shown in Figure 3.2.

Throughout the rest of this SSA Report, the analysis units used to analyze the overall condition of the Clear Lake population will be the five SIG's. Since the entire Thurston Lake watershed is completely within the Thurston Lake HUC 12, just that sub-watershed unit will be used to analyze the Thurston Lake population. It should be noted that just because the Clear Lake population is first analyzed at an analysis unit level before determining the overall condition of the population, the individuals that may occur within each analysis unit at any point in time are actually interbreeding with individuals from other analysis units and should not be considered separate, discrete populations in a genetic or population biology sense.

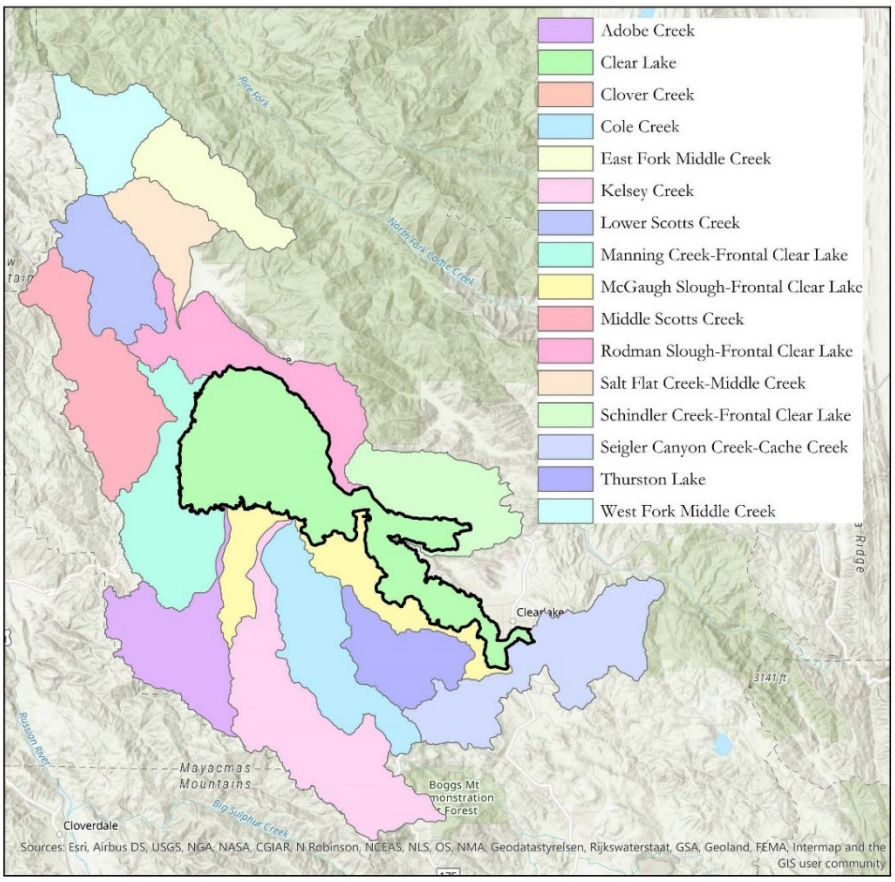

Figure 3.1 Clear Lake hitch HUC 12/analysis units. Clear Lake is outlined in bold

Table 3.2 Clear Lake hitch HUC 12 sub-watersheds within each SIG unit.

SIG #	HUC 12 UNIT
1	Cole Creek, Schindler Creek - Frontal Clear Lake, McGaugh Slough - Frontal Clear Lake
2	Kelsey Creek
3	Adobe Creek, Lower Scotts Creek, Middle Scotts Creek, Manning Creek - Frontal Clear Lake
4	Rodman Slough - Frontal Clear Lake
5	Clover Creek, West Fork Middle Creek, East Fork Middle Creek, Salt Flat Creek-Middle Creek, Seigler Canyon - Cache Creek

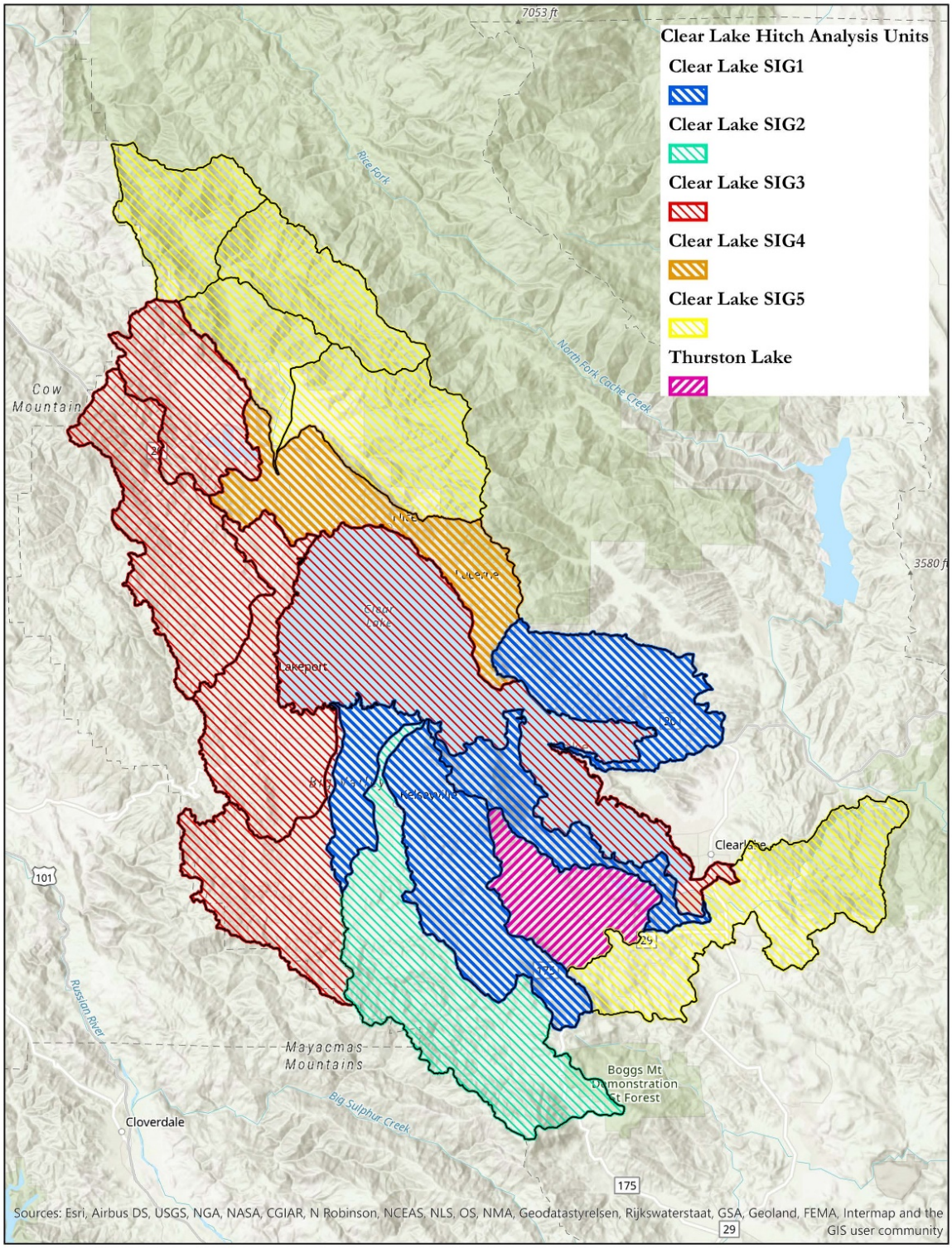

Figure 3.2 Clear Lake hitch analysis units: SIG1-SIG5 are associated with the Clear Lake population and the Thurston Lake HUC 12 sub-watershed is associated with the Thurston Lake

3.2.2 Population Resiliency

For the Clear Lake hitch to maintain viability, the habitat that supports each population, or some portion thereof, must be of sufficient quality to support resilient populations. Environmental stochastic events that have the potential to affect the Clear Lake hitch include severe storms, drought, contaminant exposure, and the modification of habitat via natural (i.e., fire, drought, etc.) and anthropogenic means (i.e., conversion to agriculture, vegetation management). A number of factors influence the resiliency of a population, including reproduction, recruitment, and survival at both the adult and juvenile life stages. Influencing those factors is the quality and connectivity of Clear Lake hitch habitat, which determines how well the spawning areas allow for successful reproduction, whether the nearshore nursery areas allow for young-of-year survival and subsequent recruitment or whether individuals can move between tributary spawning habitats and the lake. These demographic factors and habitat elements are discussed below and are shown in Figure 3.3. A summary of demographic factors and habitat elements that were ultimately eliminated from the analysis, and a reason for why they were eliminated, are shown in Table 3.3.

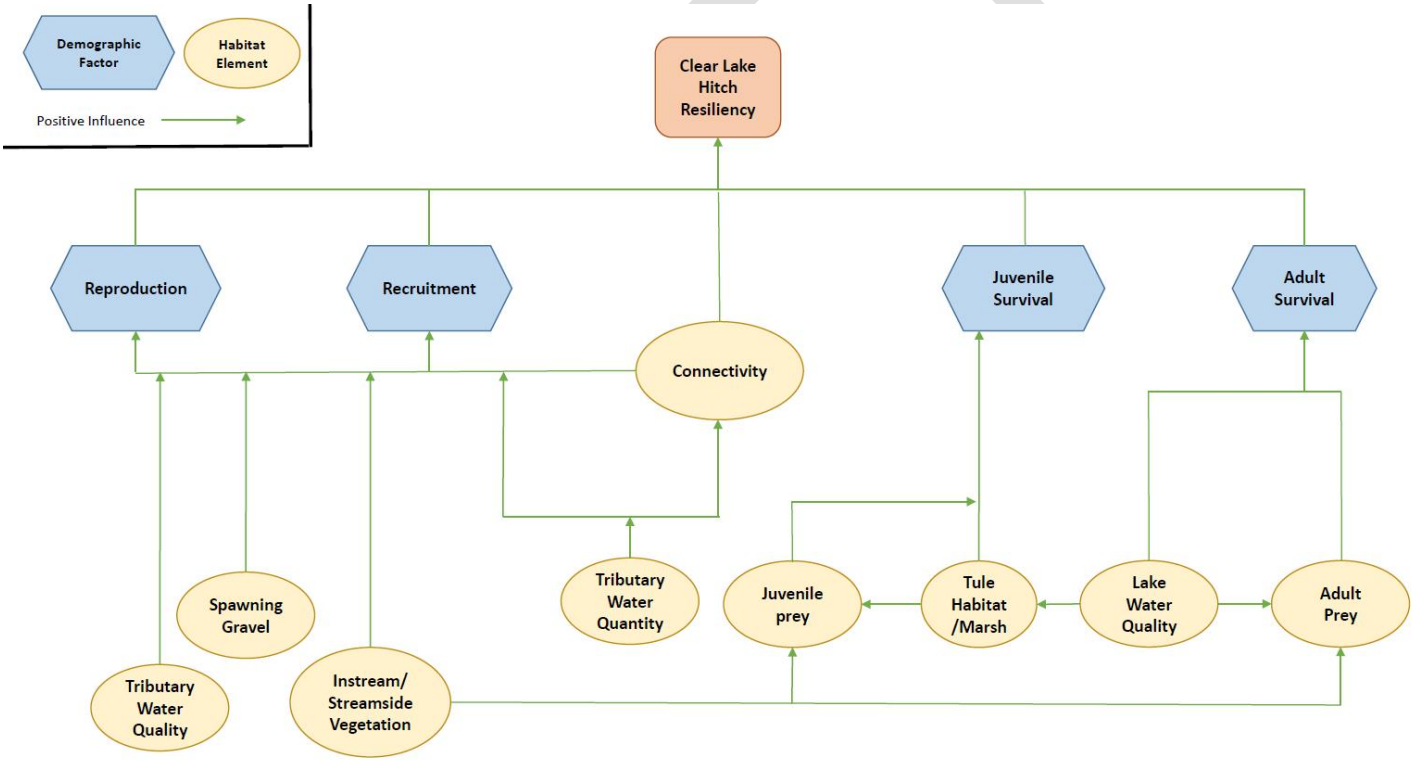

Figure 3.3 Clear Lake hitch resiliency conceptual model

Demographic Factors

<u>Reproduction and Recruitment</u>

Resilient Clear Lake hitch populations must have accessible spawning habitat and water flow must be maintained within tributary streams during the spawning season so any spawning efforts are successful and result in new reproducing individuals into the overall population (i.e., recruitment). The accessibility of spawning habitats available to a population may reflect the overall productivity

of that population. Accessibility to suitable spawning habitat and the ability to recruit is influenced by annual environmental conditions and anthropogenic pressures (i.e., water use, non-native introductions, wetland habitat loss, etc.), which then influence overall population trends that may be stable, increasing, or decreasing. For example, some spawning tributaries within the watershed that historically supported spawning hitch no longer do, or do so on a very limited basis. This loss of accessibility in certain spawning streams is likely a result of unfavorable environmental conditions, the construction of in-water infrastructure (e.g., bridge footings, culverts, poorly-constructed fish ladders, etc.), the modification of tributary habitat that decreases in-stream water retention, and an increased reliability on ground and in-stream water for urban and agricultural uses. The success of each spawning and rearing habitat influences overall survival and is collectively reflected in the subsequent season's population estimate because any new individuals produced the previous spawning season are now included in the overall population. However, until those new individuals are able to access appropriate spawning habitat to reproduce, they may not be actively recruiting new individuals into the overall population. The limiting factor for Clear Lake hitch reproduction is access to suitable spawning habitat. However, a portion of the population is spawning in habitats within the lake that should be accessible during the spring spawning season, even in years when streams are inaccessible.

Reproductive success has not been estimated for the Clear Lake hitch; however, in the current environment, reproductive success is likely low because the tributary streams do not always retain water flow long enough to complete early life stage development and/or migration to the lake. Because the Clear Lake hitch is larger than other subspecies of hitch found in California, it also has a higher average fecundity. The annual average fecundity for the Clear Lake hitch is about 36,000 eggs and fish measuring 312 mm SL range can range from having 9,000 to 63,000 eggs (Geary and Moyle 1980, p. 387). The length-fecundity relationship for the Clear Lake hitch is F = 504(SL mm) - 30,384, so as adults grow larger, they are able to produce more eggs (Moyle 2002, pg. 138). Although the Clear Lake hitch is able to produce a large number of eggs during the spawning season, a majority of those eggs will not then go on to develop into reproductive adults (see Survival below). Thus, much of an individual female's reproductive effort does not contribute to the overall population (i.e., recruitment). The primary factors influencing Clear Lake hitch recruitment are the loss of wetland habitats within the watershed and the presence of non-native fish species within those remaining wetland habitats (see Sections 4.1.2 and 4.5 for more information about wetland loss and the introduction of non-native fish species).

<u>Survival</u>

Clear Lake hitch need to maintain a fairly high adult survival rate in order to compensate for their potentially low average reproductive success. The subspecies needs to maintain a high adult survival rate so that they can spawn when environmental conditions allow, which could be once every several years during severe drought conditions. Some proportion of the population utilizes habitats within the lake to spawn and thus, may be able to spawn annually even during drought conditions.

The survival rate for Clear Lake hitch early life stages is likely low. The rapid decline of flow within the tributary streams during the spawning season can leave fertilized eggs, larvae, and juveniles exposed and at risk of desiccation or suffocation. Average annual survivorship has not been estimated for any Clear Lake hitch life stage and may be difficult to obtain as very few recaptures are recovered during surveys. Because survival rates are unknown for any of the life stages of hitch, we will not be carrying forward this factor in our analysis.

Tributary Habitat Elements

During the spawning season, a large proportion of adult Clear Lake hitch migrate into the surrounding tributary streams to reproduce. Their fertilized eggs develop in the interstitial spaces of the gravel-lined streams until the larvae ultimately hatch. Once the larvae become free swimming, they migrate down the rapidly drying tributary streams to suitable rearing habitat surrounding the lake.

Connectivity

In order for individuals to migrate up and down the tributary streams or to potential spawning habitat during the spring spawning season, hydrological connectivity within the watershed must be maintained. After spawning, adults leave the spawning habitats and move back into the open water of the lake, but the young remain within their natal habitat from as little as 11 days to as long as 152 days to develop (Feyrer et al. 2019a, p. 1693). Therefore, a hydrologic connection between spawning habitat and the main lake must be maintained until the young-of-year have finished their early development and are present in the lake. In addition to having enough water within the tributaries to allow for up- and down-stream passage during the spawning season, the streams must also be free of passage barriers that prevent hitch access. Because the species is not a very strong jumper, the spawning tributaries must be free of large obstacles that the subspecies is unable to clear (Murphy 1948b, p. 102; Macedo 1994, p. 4; CDFW 2014, p. 8).

Connectivity is considered a habitat element for this analysis because it analyzes the hydrological connectivity of two habitats (stream and lake) within a population, not the connectivity between separate populations. If we were to analyze the connectivity of two separate populations, then connectivity would be considered a demographic factor.

Tributary Water Quantity

As explained above, the Clear Lake hitch requires the maintenance of water flow within their tributary streams in order to successfully reproduce and recruit new individuals into the overall population. Adults need maintenance of water flow within the tributary streams during the spawning season to migrate upstream to areas with the appropriate spawning habitat. The eggs require an instream water depth that keeps the eggs submerged to avoid desiccation and larvae need water flow to be maintained within the tributary streams for downstream migration into the lake. The fry/juvenile life stage not only requires the maintenance of tributary flow to stay alive and avoid suffocation, but also requires the maintenance of flow within the tributary streams until they are able to migrate downstream into the lake (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154).

Tributary Water Quality

In addition to having enough water flow in the tributary creeks, the Clear Lake hitch also requires water temperatures to be within a specific range to trigger spawning and to initiate egg hatching. Reproductive adults require water temperatures of 13-18°C to initiate spawning and for egg hatching water temperatures must be maintained between 15°C and 22°C for multiple days (Swift 1965, pp. 75, 77; Moyle 2002, p. 138; Feyrer 2019b, p. 227). Currently, tributary water quality does not appear to be a factor limiting population growth for the Clear Lake hitch and therefore, will not be carried over through the analysis.

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Spawning Gravel

Clear Lake hitch eggs require fine to medium sized clean gravel so fertilized eggs can hold their place within the stream channel while developing (Shapovalov 1940 *in* Murphy 1948b, p. 102; Kimsey 1960, p. 211; Moyle et al. 1995, p. 154; CDFW 2014, p. 8). Individuals that spawn within the lake may also require gravel as a spawning substrate; however, a self-sustaining population of Clear Lake hitch occupied a farm pond that only had mud and vegetation as a bottom substrate, and did not have any tributary streams (Kimsey 1960, pp. 211, 213–214). Because the subspecies may not always require a gravel substrate to successfully spawn and due to the lack of evidence that spawning gravel is a factor limiting population growth, we will not be carrying forward this factor in our analysis.

Instream/Streamside Vegetation

While rearing within the tributary streams, Clear Lake hitch fry may require instream and/or overhanging streamside vegetation for cover from predators and for temperature regulation (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154). This cover likely increases early life stage survival, primarily by keeping portions of the stream cool and by providing shelter from predators. In addition, instream and streamside vegetation may also contribute to early life stage and adult prey base. Any young that survive through egg hatching and egg yolk absorption will require aquatic invertebrate prey and adults not actively involved in spawning activities have been documented holding in pool habitat while possibly feeding on invertebrates (Kimsey 1960, p. 212; Feyrer 2019b, p. 228). However, because the subspecies has been documented spawning in tributary streams without any vegetative cover, and because their prey items do not necessarily have to originate at that specific spawning site, this factor will not be carried forward in the analysis. In addition, there is no evidence this habitat element is limiting population growth.

Lacustrine Habitat Elements

The Clear Lake hitch spends most of its life in Clear Lake or Thurston Lake. As juveniles, the subspecies is found in littoral habitats, using tules and other aquatic vegetation for cover and preying on invertebrates found in the vegetation. As the juveniles develop into adults, they move out into the open water of the lake where they feed primarily on *Daphnia*. Some spawning does occur within the lake and past observations suggest the subspecies may not always require a gravel substrate for egg placement. Lake spawning is successful and can result in recruitment, but it is unknown how frequent lake spawning occurs and whether it results in a significant amount of recruitment (Kimsey 1960, p. 214; Geary 1978, p. 22; Feyrer et al. 2019a, pp. 1693, 1695).

Wetland/Tule Habitat

Young Clear Lake hitch that originate in the tributary streams have to migrate into the nearshore habitat of the lake before the tributaries dry up (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154). While in the littoral habitats, juvenile hitch require tules and/or other submerged vegetation to provide cover from the many avian and aquatic predators found in the lake (Franson 2012, p. 15; CDFW 2014, p. 9). Having vegetative cover in the littoral zone increases juvenile hitch survival and the likelihood that juveniles will transition to reproductive adults that will then recruit new individuals into the population. In addition to providing cover to juvenile hitch, the submerged aquatic vegetation found in the nearshore portions of the lake also provide for invertebrate prey items. Juvenile hitch prey on various invertebrate prey items, including insects, planktonic crustaceans, and chironomid midges (Franson 2012, p. 15; CDFW 2014, p. 9).

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Lake Water Quality

While in the lake, both juveniles and adults require well oxygenated and clean (i.e., uncontaminated) water. Some years Clear Lake develops a hypoxic layer that can then be mixed throughout the lake, resulting in fish kills. The high productivity of Clear Lake and the various nutrient inputs from throughout the watershed often result in toxic algae blooms that can also have detrimental effects on the hitch (see Chapter 4 for more information about lake mixing and toxic algae blooms). Water temperature within the lake is also important as juveniles in particular require water temperatures to be 15° or greater for survival (Franson 2012, p. 15; CDFW 2014, p. 9).

Adult Prey Items

Adult hitch live in the limnetic zone of the lake, where they primarily feed on *Daphnia*, but also rely on other prey items such as other zooplankton species, adult midges, and insects (Lindquist et al. 1943, p. 199; Geary 1978, pp. 17, 25; Geary and Moyle 1980, p. 388; Moyle et al. 1995, p. 153; Moyle 2002, pg. 137–138; Moyle et al. 2014, p. 3). Because there is nothing in the literature suggesting adult prey is currently limiting population growth, and we do not believe it will be a limiting factor in the future, this element will not be carried forward for the analysis.

Table 3.3 Summary of subspecies needs identified for the Clear Lake hitch and whether they were used in the analysis. For those demographic factors and habitat elements that were not carried through the analysis, the third column identifies why they were eliminated.

Demographic Factor/ Habitat Element	**Used in analysis? (Y/N)**	**Reason for eliminating the demographic factor or habitat element from the analysis**
Reproduction	Y	--
Recruitment	Y	--
Survival	N	We do not have enough information regarding survival at any life stage to analyze this need
Connectivity	Y	--
Tributary Water Quantity	Y	--
Tributary Water Quality	N	This habitat need is not likely a factor limiting population growth
Spawning Gravel	N	This habitat need is not likely a factor limiting population growth. In addition, there is evidence the subspecies may not require gravel for successful spawning
Instream/Streamside Vegetation	N	This habitat need is not likely a factor limiting population growth. In addition, the subspecies has been documented spawning in waterways without vegetative cover
Wetland/Tule Habitat	Y	--
Lake Water Quality	Y	--
Adult Prey Items	N	This habitat need is not likely a factor limiting population growth

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3.3 Representation

Maintaining representation in the form of genetic or ecological diversity is important to maintain the Clear Lake hitch's capacity to adapt to future environmental changes. Genetic studies within the subspecies have not been conducted; however, as discussed above, recent genetic analyses have indicated strong population structuring between the three forms of hitch that are currently referred to as subspecies (Baumsteiger et al. 2019, p. 407), and therefore, it is not likely there is strong population structuring within the Clear Lake entity. Even though there are two separate populations of Clear Lake hitch, they occur within the same watershed and occupy the same ecological niche. For the Clear Lake hitch, representation is best measured by assessing the different spawning strategies available to the subspecies under varying environmental conditions.

3.4 Redundancy

The Clear Lake hitch has redundancy by having two isolated populations, one that occupies Thurston Lake and its tributary, and one that occupies Clear Lake and its tributaries. Although redundancy gauges the probability that a species has a margin of safety to withstand or bounce back from a catastrophic event, due to the hitch's narrow range it may not actually express much redundancy. Depending on the scale of a catastrophic event happening within the watershed, it is possible a catastrophe could impact the entire watershed, and therefore, both populations and all tributary streams. Realistic catastrophic events that could potentially impact the Clear Lake hitch include earthquakes, volcanic activity, fires, drought, and flooding.

Because drought events are likely to occur in the future due to climate change (see Section 4.8), some of which will likely be considered catastrophic, we also describe within population redundancy that could potentially increase the ability of that population to withstand a prolonged, catastrophic drought event. The Clear Lake hitch expresses within population redundancy in the type of natal habitat used for reproduction (tributary, lake, or interface between the two) and the number of available tributary streams within the watershed. As the number of tributaries available increases and/or the types of habitat used for reproduction increases within a population, the more redundancy that population will exhibit.

3.5 Summary of Population Needs

This section provides a summary of Clear Lake hitch population needs at all life stages (see Table 3.4). Needs are described in terms of demographic factors and the habitat elements that are required to provide those factors.

The demographic factors required for Clear Lake hitch population resiliency include:

- **Reproduction/Recruitment:** Sustained water flow within the tributaries and accessibility to spawning habitats increase reproductive success and the possibility for future recruitment. Availability of wetland/tule habitat surrounding the lake increase early life stage survival, and therefore, recruitment. The accessibility and/or availability of spawning and rearing habitats reflect environmental conditions, anthropogenic uses (i.e., water use, development, etc.), and the presence of passage barriers, both natural and anthropogenic.

- **Survival:** To compensate for years when reproductive success and recruitment are low, adult Clear Lake hitch need to maintain a fairly high survival rate. A high survival rate allows the subspecies to maintain a viable population in an area where environmental conditions do not

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always allow for successful reproduction and recruitment. The most influential factors acting on the subspecies are influencing survival at the early life stages. The lack of consistent flow and presence of barriers within the tributaries, the loss of tule habitat along the shores of Clear Lake, and the effect of competition and predation while in the nearshore habitat all have a negative impact on juvenile survival. Due to the lack of information regarding survival at any life stage, this factor will not be carried forward for our analysis.

The habitat elements required to provide for the demographic factors described above include:

- **Connectivity:** Hydrological connectivity within the watershed is required for adult upstream spawning migrations and for the young to migrate downstream to the lake. In addition to having enough water within the tributaries to allow for up- and down-stream migrations, the streams must also be free of barriers that prevent hitch passage.

- **Tributary Water Quality:** Hitch require clean, uncontaminated tributary water. Water temperatures need to be within a specific range to initiate spawning activity (14-18°C) and egg hatching (15-22°C for multiple days). Tributaries with suitable water quality parameters allow for successful reproduction and early life stage survival. Because this habitat need is not likely a factor limiting population growth, it will not be carried forward for our analysis.

- **Tributary Water Quantity:** For successful reproduction and recruitment, the Clear Lake hitch requires tributary streams maintain consistent flow throughout the spawning season. Reproducing adults need adequate water flow to access suitable spawning habitat upstream, and their early life stages need consistent flow to avoid desiccation and to allow young to migrate downstream to the lake.

- **Spawning Gravel:** To maintain their position within their natal tributary stream while developing, fertilized Clear Lake hitch eggs require clean fine to medium sized gravel. When freshly extruded eggs are fertilized, they sink to the stream bottom and become wedged in the gravel interstices, increasing egg survival. Eggs that are fertilized during shoreline spawning may also require gravel to maintain position while developing; however, observations of successful spawning along shorelines only containing mud suggest gravel may not be required in some situations or areas. This factor will not be carried forward for our analysis because it is not likely a factor limiting population growth and there is evidence the subspecies may not require gravel for successful spawning

- **Instream/Streamside Vegetation:** Instream and streamside vegetation increase survival for early life stages of Clear Lake hitch by acting as cover from predators, providing instream temperature regulation, and by providing aquatic invertebrate prey. Because the subspecies can spawn without any vegetative cover, their prey items do not necessarily have to originate at that specific spawning site, and there is no evidence this habitat element is limiting population growth, this factor will not be carried forward for our analysis.

- **Wetland/Tule Habitat:** Juvenile Clear Lake hitch continue to develop and grow in the nearshore habitat of the lake until they transition to adults. The juveniles rely on tules and/or other submerged vegetation for cover from predators and that same vegetation provides

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invertebrate prey. Having adequate vegetative cover in the littoral zone increases juvenile hitch survival and the likelihood that juveniles will be able to contribute to recruitment.

- **Lake Water Quality:** Both juvenile and adult Clear Lake hitch require clean water. Hypoxic conditions, sediment and nutrient inputs, algae blooms, and contaminants all influence lake water quality and can negatively impact both juvenile and adult survival. Maintaining water temperatures above 15°C is also required for juvenile survival.

- **Adult Prey Items:** Adult hitch reside in the open water of the lake and feed on zooplankton, adult midges, and other invertebrates found in this habitat. Having an adequate adult prey base contributes to adult survival and provides resources for reproduction. This factor will not be carried forward for our analysis because adult prey is not likely a factor limiting population growth.

Table 3.4 Clear Lake hitch population needs by life stage. The last column categorizes what demographic need the habitat element fulfills: reproduction/recruitment (R) or survival (S)

Scale	Life Stage	Needs	R/S
Population	Eggs/Embryo/Larvae	Clean, uncontaminated tributary water	R/S
	All	Maintenance of water flow within tributary streams for survival and to migrate up and down tributaries	R/S
	Eggs/Embryo	Riffles with clean, fine to medium gravel substrate	R/S
	Larvae	Instream or streamside vegetation for cover and prey	R/S
	Juveniles	Emergent vegetation in littoral zone for cover and prey	R/S
	Juveniles/Adults	Well oxygenated and uncontaminated lake water for adult and juvenile survival	S
	Adults	Food supply to support adults in open water habitat	R/S

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CHAPTER 4: FACTORS INFLUENCING VIABILITY

In this chapter, we evaluate the past, current, and future factors that are affecting what the Clear Lake hitch needs for long term viability (see Figure 4.1). Current and potential future effects to the subspecies due to the influencing factors, along with current and expected distribution and abundance of the subspecies throughout its range, affect present viability and, therefore, vulnerability to extinction.

4.1 Habitat Loss, Degradation, and Modification

Beginning in the mid-1800's when Europeans 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, 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 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 (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 impact adult hitch survival, especially when poor lake conditions result in large fish kills.

4.1.1 Tributaries

The reduction in stream spawning fish, including the Clear Lake hitch, 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, p. 480). 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, p. 480). 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, possibly 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, p. 480).

<u>Loss of Consistent Tributary Flow</u>

Gravel mining activities in the Clear Lake watershed 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, pp. 1253-1254, Figure 10; Thompson et al. 2013, p. 19). Gravel mining originally occurred as scattered operations throughout the watershed until the early- to mid-20th century when operations became centralized within the creeks (County of Lake 1992, p. 48; Richerson et al. 1994, p. III-19). This time period coincides with improved automobile technology and increased pressure to build more reliable roads (County of Lake 1992, p.48). 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, p.

48; Richerson et al. 1994, p. VIII-150). 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, pp. III-19–III-20; CDFW 2014, p. 29). Although gravel mining no longer occurs within the Clear Lake tributaries, gravel accumulation within the stream channel can also act as a passage barrier; therefore, approximately 5,000 cubic yards of gravel is removed annually from Scotts Creek (Murphy 1948b, p. 106; Richerson et al. 2008, p. A260; CDFW 2014, p. 29).

Past gravel mining in tributary streams not only removed spawning substrate that the species uses for reproduction and egg development, but it also lowered streambeds and destabilized channels, causing increased erosion, incision, and channelization. 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 (see Section 4.1.2) (CDFG 1955, entire; Richerson et al. 1994, p. III-19, VIII-2; Suchanek et al. 2003, p. 1254; CDFW 2014, pp. 29, 45). 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, p. 29). There are almost 14 miles of levee structures that are maintained by the U.S. Army Corps of Engineers (Corps) on Scotts, Middle, Clover, and Alley Creeks (Corps 2012, p. 3).

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, pp. 1243–1245, 1246–1247). Numerous fires have occurred in the Clear Lake area in the recent past, with several large 10,000+ acre fires occurring directly in the watershed (Suchanek et al. 2003, pp. 1244, 1248, Figure 121.4 and Table 121.2). 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, entire). The 2018 Mendocino Fire Complex, a portion of which occurred in Lake County, was the largest fire on record in California (CalFire 2019b, entire). 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, p. 1247). Fire activity within the watershed results in increased erosion and bank incision, which channelizes the stream. This channelization can decrease the amount of time water is retained within the tributary channel (Murphy 1948b, p. 106; County of Lake 1992, p. 13).

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, pp. 1247–1248). Increased erosion and bank cutting further decrease the amount of time water is retained within the tributaries.

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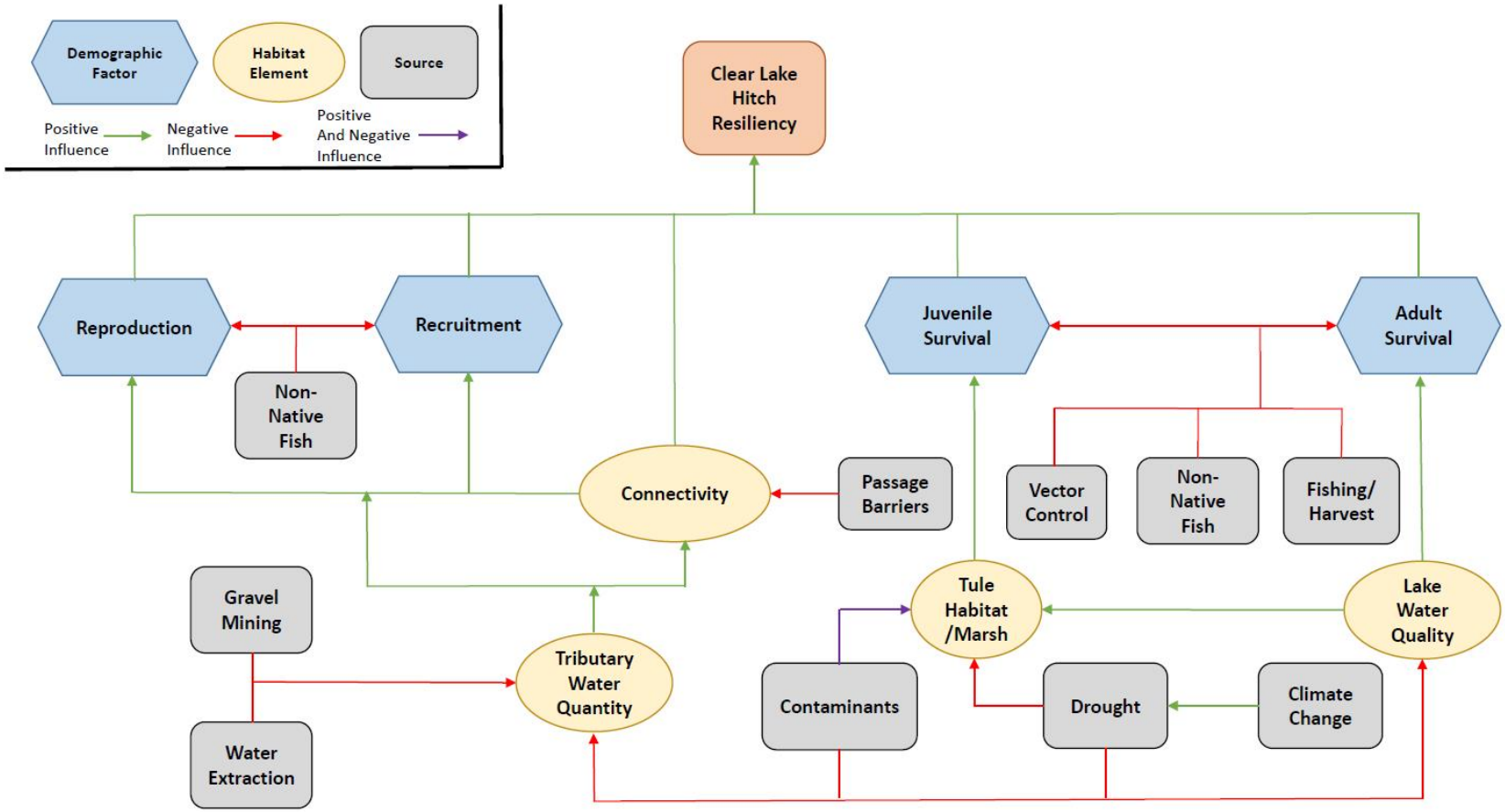

Figure 4.1 Clear Lake hitch resiliency influence diagram

Livestock grazing, primarily cattle and sheep, began in the Clear Lake watershed in the mid-1800's and still continues today. Although overgrazing no longer appears to be occurring in 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, p. 1257). 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 creeks, effectively reducing the amount of time water is retained within the channel (Murphy 1948b, p. 106; Suchanek et al. 2003, p. 1257). Although the amount of grazing pressure has decreased in the watershed, the impacts of past practices are still contributing to the issues seen in the watershed today.

Although a majority of instream gravel removal and all large-scale deforestation no longer occur in the watershed, the rate of runoff within the tributary streams is not likely to decrease into the future unless restoration actions are implemented. Likewise, fire activity will likely continue to increase within the Clear Lake watershed as the incidence of drought increases and intensifies due to climate change. In addition, some attribute 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, p. 1256).

Water extraction and the early drawdown of the tributary streams, in conjunction with habitat modifications throughout the watershed, likely led to the extinction of the Clear Lake splittail, another stream spawning native fish restricted to the Clear Lake watershed (Moyle 2002, pp. 138–139; CDFW 2014, p. 27). The Clear Lake splittail spawned later in the season than hitch and as the tributaries began to dry earlier in the season, their young were not able to migrate to the lake (Cook et al. 1966, p. 146; Moyle 2002, pp. 138–139; CDFW 2014, p. 27). Cook et al. (1966, p. 146) describes a "drastic reduction" in the number of splittail seen in Clear Lake during the 1940's and he attributed the reduction to increased water demand. The last time the Clear Lake splittail was recorded in Clear Lake was May 1972, when one individual was captured (Puckett 1972, pp. 1, 7; CDFW 2014, p. 27).

Water extraction continues throughout the watershed today. Both surface and ground water is being diverted from Clear Lake tributaries for agricultural purposes and domestic use (CDFW 2014, p. 27), with about 60% of supply coming 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, p. 27). 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 Clear Lake hitch (Big Valley 2015, p. 4). 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, entire).

Water extractions are 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 Clear Lake tributaries or the Clear Lake hitch. The California Department of Fish and Wildlife (CDFW) compared stream flow conditions at the USGS gauge on Kelsey Creek (USGS Station 11449500) and catch data from the early 1990's. 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, p. 27).

Agricultural production in the Clear Lake area 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, p. 1256; 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, p. 1257).

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, p. 3). 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, pp. 2–4). The acreage of fruit, nut, field, seed, and vegetable crops in Lake County only slightly increased from 2008 to 2017, with just over 107,100 acres in 2008 compared to 108,226 acres in 2017 (Lake County undated, pp. 3, 6, 7; Lake County 2018, pp. 4, 7, 8). 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 (see Figure 4.2; USDA 2019). The presence of agricultural production in the watershed not only has an impact on the amount water flowing in the tributaries to Clear Lake, but it likely also increases the amount of contaminants, in the form of pesticides and fertilizers, and sediment entering the lake. A description of pesticide and other contaminant use in the watershed is described in a later section (see Section 4.7).

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, entire). A few months later in June 2014, over 1,400 hitch were rescued 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, pp. 3, 6). 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, p. 7).

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 during the spring of 2018. 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, p. 1). It is unknown to what extent Clear Lake hitch were historically stranded within the tributary streams.

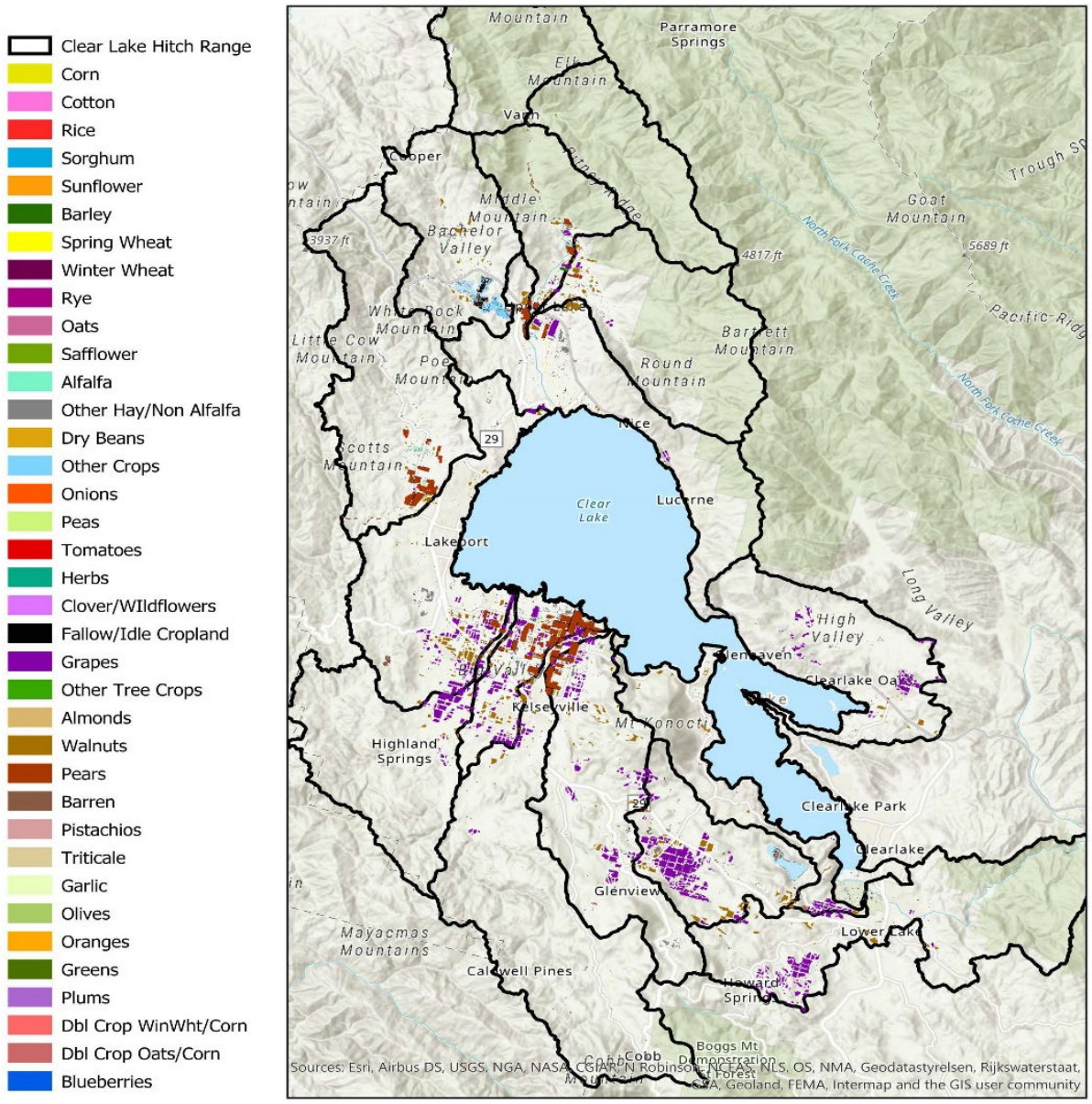

Figure 4.2 Agricultural production within the Clear Lake watershed during 2018

Regulatory mechanisms and management actions that are or could potentially provide some protection or benefit to tributary streams include: California Environmental Quality Act (CEQA) - any stream altering projects will be required to complete CEQA, which will direct all local and State agencies to avoid or minimize environmental damage, where feasible; US Forest Service (USFS) sensitive species designation – any USFS project within the Clear Lake hitch's range will avoid or minimize impacts to the subspecies. The USFS will also have to complete an analysis under the National Environmental Policy Act (NEPA); Lake County's Aggregate Resources Management Plan

– completely eliminated instream gravel mining in certain creeks and limits current mining activities to certain areas; Clear Lake Integrated Watershed Management Plan – has documented the historical and current conditions of the watershed (and specific tributary streams) and detail any specific implementation actions that will enhance and/or protect the watershed; and the Sustainable Groundwater Management Act (SGMA) – once implemented, will reduce or halt any overdraft from occurring and will bring groundwater basins into balance (i.e., water inputs are in balance with the amount of water extracted from the basin). Reducing overdraft from groundwater pumping in the Big Valley groundwater basin could improve flow conditions in Thompson Creek, Adobe Creek, Kelsey Creek, and Cole Creek. None of the regulatory mechanisms or management actions fully ameliorate habitat loss, degradation, and modification within the watershed, primarily because much of the degradation occurred in the past, although the effects are still occurring today. For a more thorough description of regulatory mechanisms and management actions, see Section 4.9 Regulatory Mechanisms and Management Actions below.

The loss of consistent tributary flow during the spawning season are seen throughout the Clear Lake hitch's range. This influence is affecting the subspecies at the individual, population, and subspecies level and is likely to continue into the future. The loss of consistent tributary flow has and will continue to reduce population resiliency by reducing reproductive success, early life stage survival, and the likelihood of recruitment. This reduction in resiliency results in a reduction to the subspecies' overall representation and redundancy.

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, p. 1254; CDFW 2014, pp. 45, 69–70; see Figure 4.3). 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, pp. 24-25). 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. Fertilized eggs have been known to accumulate just below a barrier to the point that they will die due to oxygen deprivation (Robinson Rancheria 2015, p. 1).

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, p. 1248). In addition, during the spring of 2016 CDFW identified potential barriers on Lyon's Creek, Scott's Creek, Seigler Canyon Creek, Clover Creek, and Kelsey Creek (Ewing 2016a, entire). 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, p. 69).

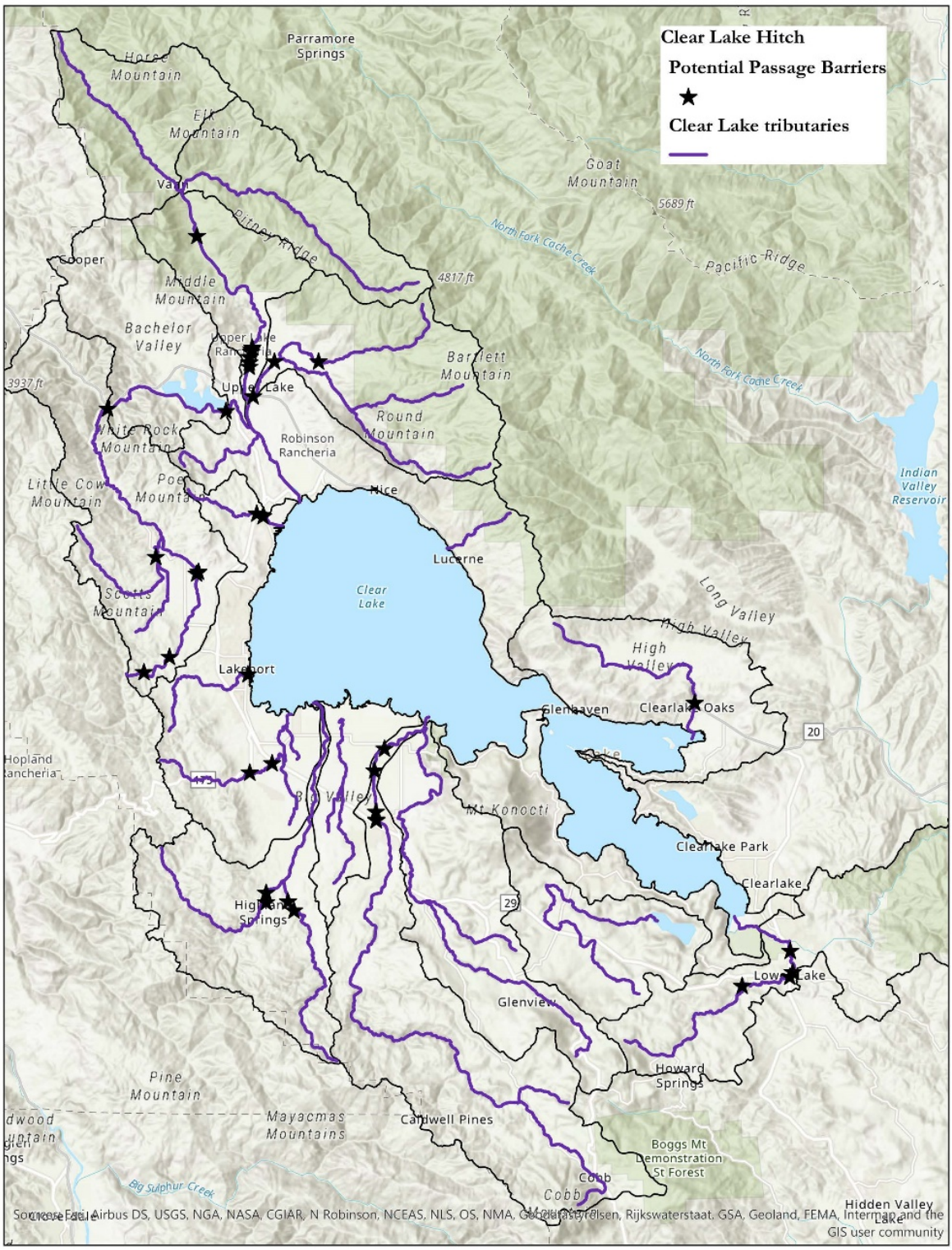

Figure 4.3 Potential passage barriers within the Clear Lake watershed. Data from: McGinnis and Associates 2006; County of Lake et al. 2010b, 2010c, and 2010d; CDFW 2014; and Windrem 2019.

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. 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, entire). 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, entire).

The presence of passage barriers are seen throughout the Clear Lake hitch's range; however, most physical barriers are concentrated to the west and northwest portions of the watershed (see Figure 4.3 above). This influence is affecting the subspecies at the individual, population, and subspecies level and is likely to continue into the future. The presence of barriers has and will continue to reduce population resiliency by reducing reproduction and early life stage survival. This reduction in resiliency results in a reduction to the subspecies overall representation and redundancy. There are currently no regulatory mechanisms or management actions that fully ameliorate the presence passage barriers.

4.1.2 Lakes

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, pp. 1256, 1257; CDFW 2014, p. 21). However, 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 historical mercury mining 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, which will be discussed in a future section (see Section 4.7).

<u>Wetland/Tule Habitat Loss</u>

Prior to early European settlement, large wetland/marsh complexes surrounded Clear Lake (CDFW 2014, p. 21). The conversion of these large wetland complexes was largely driven by the desire for agricultural production and urban development (Suchanek et al. 2003, pp. 1256, 1257; CDFW 2014, p. 21). 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, p. 1255). 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, p. 31). It has been estimated that there were at least 9,000 acres of marsh habitat 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 85% of Clear Lake's nearshore, wetland/tule habitat (Week 1982, p. 16; Suchanek et al. 2003, p. 1241). Figure 4.4

shows the concentration of development within the Clear Lake hitch's range and Figure 4.5 shows the remaining wetland habitats surrounding the lake.

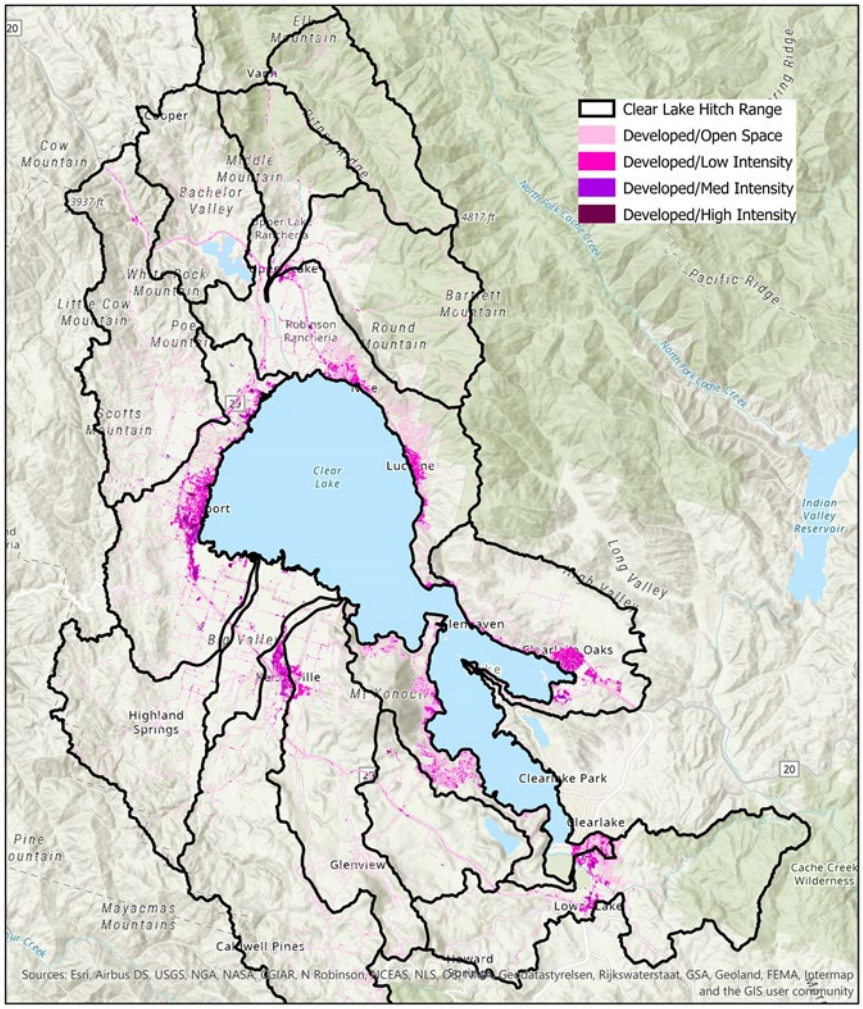

Figure 4.4 Urban development in the Clear Lake watershed

As seen in Figures 4.2 and 4.4, 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, p. 1239; Thompson et al. 2013, p.18). 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/PST045218). 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, p. 20; CDFW 2014, p. 37). 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, p. 37).

Guidance for future development within Lake County can be found in the Lake County General Plan, which was developed in 2008 and provides guidance through 2028. The county plans to implement "smart growth" by aiming to direct growth within existing developed areas and by discouraging urban sprawl (Lake County 2008, pp. 3-15–3-18, 3-51–3-55). 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, which will have different negative effects to the watershed (i.e., decreased tributary flow, decreased lake water quality).

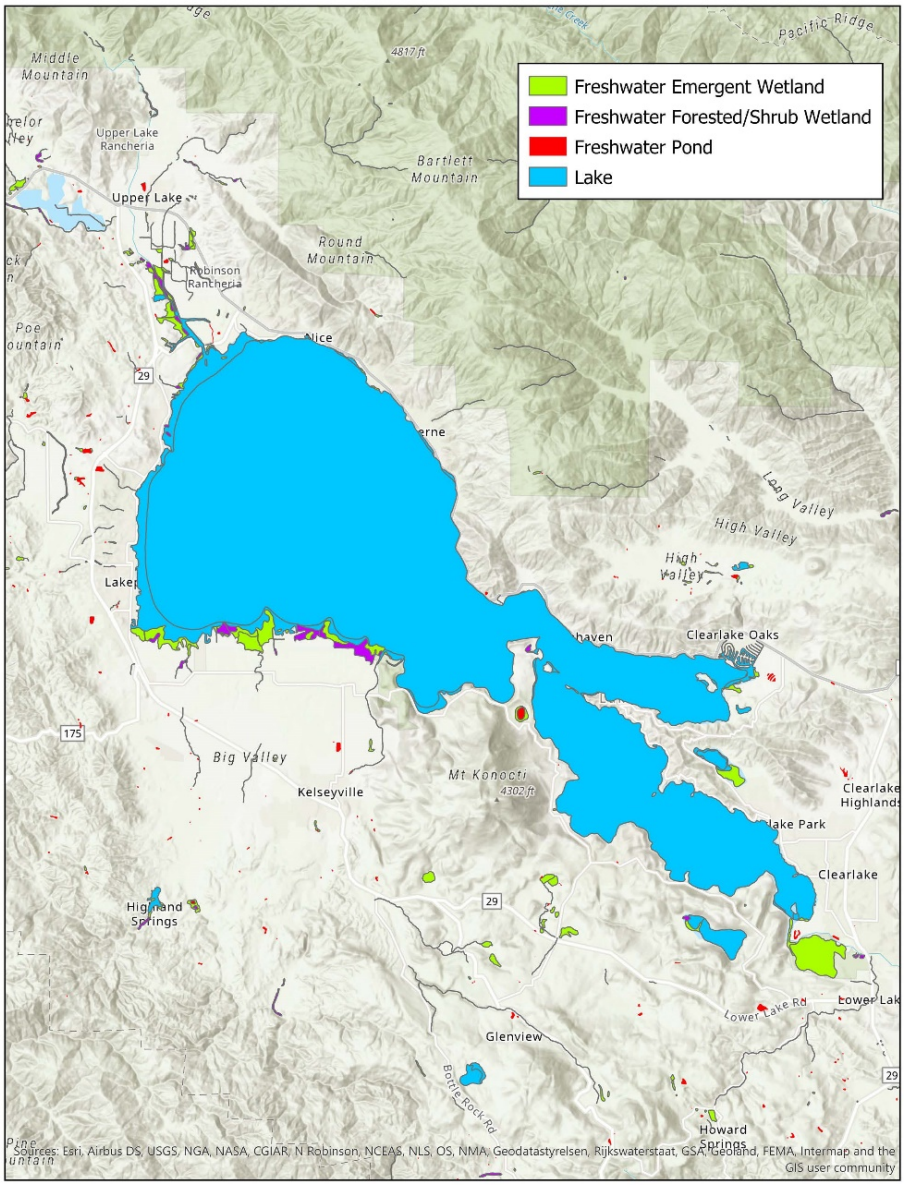

Figure 4.5 Remaining wetland habitat in the Clear Lake watershed

Regulatory mechanisms and management actions that are or could potentially provide some protection or benefit to wetland/tule habitats surrounding Clear Lake include: the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project – if this project is constructed in the future, it could potentially increase the amount of wetland/tule habitat surrounding the lake and improve the condition of currently degraded wetland habitat. Construction of this project would greatly benefit juvenile hitch by providing increased cover from predators and competitors, and increased prey abundance; and the Clear Lake Shoreline Ordinance – this county ordinance has prohibited the destruction of tules on residential properties along the shoreline around Clear Lake and requires full mitigation for any tule habitat that is destroyed. This ordinance benefits the Clear Lake hitch by providing a consistent amount of tule habitat for juveniles. None of the regulatory mechanisms or management actions fully ameliorate wetland habitat loss, primarily because the loss occurred in the past and the county ordinance only maintains the amount of existing tule habitat. For a more thorough description of regulatory mechanisms and management actions, see Section 4.9 Regulatory Mechanisms and Management Actions below.

The existing loss of wetland/tule habitat is affecting the subspecies at the individual, population, and subspecies level, and is likely to continue into the future. The loss of wetland/tule habitat has reduced the amount of habitat available to juvenile hitch, increasing intra-species competition for available cover and prey items. In addition, the introduction of non-native fish species that also utilize this habitat type further increases competition for the limited available resources (see Section 4.5). The loss of wetland/tule habitat has and will continue to reduce population resiliency by reducing juvenile survival and the likelihood of recruitment. This reduction in resiliency results in a reduction to the subspecies overall representation and redundancy.

<u>Cyanobacteria "Blue-Green Algae" Blooms</u>
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, p. 21). 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, pp. III-1, V-1, VIII-1; Suchanek et al. 2003, p. 1255). 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 increased incidence of these blooms currently are likely indirectly caused by this wetland loss (Stone 1876, p. 381; Suchanek et al. 2003, p. 1255; 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, p. III-9). 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, pp. III-9, III-11). Phosphorus is found naturally in underlying sediments within the Clear Lake watershed (Richerson et al. 1994, p. V-99) 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, pp. 37–38). Blue-green

algae blooms can be toxic to fish (Gorham 1960, p. 242; Prine et al. 1975, p. 23; Richerson et al. 1994, p. III-9); however, it is unknown what impact they have on the Clear Lake hitch. There are currently no regulatory mechanisms or management actions addressing blue-green algae blooms.

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, p. 381). 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, p. 453). The most recent large fish kill was documented in 2017 (USGS 2018, p. 9). 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, p. 84; Murphy 1951, p. 448; Cook et al. 1966, p. 152). Whatever the ultimate cause, a hypoxic zone frequently develops in the summer at the bottom of the lake (Cook et al. 1966, p. 152; Hopkirk 1973, p. 4; Feyrer et al. 2019b, p. 6). Lake monitoring during the summer of 2017 and 2018 found both juvenile and adult hitch were abundant in areas where dissolved oxygen levels are suitable (Feyrer et al. 2019b, p. 6), so it is likely the hitch actively avoid hypoxic areas. Fish kills have been observed in the absence of algae blooms and these have been attributed to surface water temperature changes (Macedo 1991, p. 5). Due to the wind action that frequently occurs at Clear Lake and the lake's relatively shallow depth, the lake is mixed numerous times throughout the year (Thompson et al. 2013, p. 9).

Regulatory mechanisms and management actions that are or could potentially prevent fish kills due to decreased lake water quality include: the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project – if this project is constructed in the future, it will improve degraded water quality by reducing the amount of sediment and nutrients entering Clear Lake, potentially reducing the incidence of large fish kills; and the Aggregate Resources Management Plan – this plan has reduced, and will continue to limit, the amount of instream gravel mining activities being conducted throughout the watershed. Limiting gravel mining has reduced the rate of erosion in the tributary streams and the amount of sediment entering Clear Lake. In addition, Lake County, the California Department of Transportation, USFS, and the Bureau of Land Management have undertaken various actions to prevent or reduce nutrients and contaminants from entering Clear Lake. There are no regulatory mechanisms or management actions that are fully ameliorating lake water quality degradation. For a more thorough description of regulatory mechanisms and management actions, see Section 4.9 Regulatory Mechanisms and Management Actions below.

Declines in Clear Lake water quality are affecting the subspecies at the individual level, and depending on the extent of the fish kill, it could be affecting the Clear Lake hitch at the population level as well (Clear Lake population). This influence is likely to continue into the future. The impacts of reduced lake water quality and the occurrence of periodic fish kills reduce both juvenile and adult survival, reducing overall resiliency, representation, and redundancy.

4.2 Overutilization for Commercial, Recreational, or Educational Purposes

Commercial fishing in Clear Lake began in the early 1900's and has been shut down and reinstated several times for different fish species (Murphy 1951, pp. 451, 452; Moyle and Holzhauser 1978, p. 574; Thompson et al. 2013, p. 18). 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 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, pp. 16–18; CDFW 2014, p. 11). There is one record from 1976 that documented the catch and sale of over 1,500 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 subspecies (CDFG 1961-2001; CDFW 2014, p. 33). Although there is a documented instance of the Clear Lake hitch 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, p. 33).

Clear Lake is known for its recreational fishery, with largemouth bass 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, pp. 1, 8, Figure 3). Hitch comprised 2% of the reported catch and all of the hitch caught were in the southern portion of the lake (Macedo 1991, pp. 8, 10, 11, Figures 3–5). 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, p. 8, Figure 3). 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 for the period between August 14, 2019, and December 5, 2020, there are currently 66 fishing contests that have been approved and 2 are 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, pp. 37-38).

Commercial and recreational fishing affect the subspecies at the individual level and it is likely only a negligible amount of hitch are actually caught. In addition, because the subspecies is listed as threated under the California Endangered Species Act (CESA), anglers are prohibited from taking the subspecies unless authorized by a permit. Although CESA may not completely ameliorate the loss of individuals due to overutilization for commercial or recreational purposes, the loss is already negligible since any fishing efforts are not targeting the subspecies. For a more thorough description of CESA, see Section 4.9 Regulatory Mechanisms and Management Actions below.

4.3 Tribal Harvest/Cultural Use

The Clear Lake area is one of the earliest known sites to be occupied by Native Americans, approximately 10,000 years ago (Richerson et al. 2008, p. A259). The local Pomo tribes historically relied on the large spawning runs of hitch during the spring for subsistence, drying and storing them to eat throughout the year. The hitch was such an important diet staple that the local tribes went to war over access to the abundant resource (Barrett 1908, p. 14; Kniffen 1939, p. 362, 370; Scotts Valley 2013 *in* CDFW 2014, p. 34). The local tribes collected hitch in the tributary streams by constructing a series of willow-made dams in the creek after the adults completed their upstream migration to spawn. Hitch would collect above the dams as they made their migration back to the lake and the Pomo would capture the hitch using woven baskets (Kniffen 1939, p. 363).

It is unknown how many hitch were historically collected for tribal harvest; however, early tribal accounts suggest the subspecies spawned in large numbers (Scotts Valley 2013 *in* CDFW 2014, p.

34). Tribes continued to harvest hitch until the mid-1980's when the spawning runs began to decline (Big Valley Environmental Protection Agency 2013 *in* CDFW 2014, p. 26). State regulations allowed capture of hitch on tributary streams by hand or dip-net until the species was designated a candidate for state listing under CESA (CDFW 2014, p. 26). Prior to the state listing of the subspecies and while it was still considered a candidate for listing, CDFW issued a Memoranda of Understanding to three tribes for collection of hitch for scientific and educational purposes (Kratville, D. pers. comm., October 7, 2013, unreferenced *in* CDFW 2014, p. 26). Because large spawning runs continued to be maintained annually, historical harvest for tribal subsistence did not appear to have a substantial population-level effect on the species. Because tribes no longer harvest large quantities of hitch from their limited spawning runs, tribal harvest only affects the hitch at an individual level. There are currently no regulatory mechanisms or management actions that fully ameliorate individual loss due to tribal harvest; however, any current or future tribal harvest of hitch will require authorization from CDFW since the subspecies is listed as threated under CESA.

4.4 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 Clear Lake hitch. Parasites, such as anchor worms (*Lernaea* spp.), do infect the Clear Lake hitch 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, p. 3). Anchor worms are a parasitic crustacean (copepod) that infect freshwater fish (Steckler and Yanong 2012, p. 1). 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, p. 2). Heavy anchor worm infections have not been reported for Clear Lake hitch (CDFW 2014, p. 36).

In addition to anchor worm infections, there have been three instances of Clear Lake hitch having facial deformities. 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, slide 16; Clear Lake Hitch Conservation Strategy Meeting Notes 2019, p. 2). 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, entire; Schmitt and Orth 2015, entire). 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.

The effects of parasites and deformities will continue to act on the subspecies into the future. There are no accounts of disease, parasites, or deformities causing mass mortality or extreme detrimental effects to the subspecies, and therefore, this influence only affects the hitch at an individual level. There are no regulatory mechanisms or management actions that address parasites and/or deformities.

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4.5 Predation and Competition

Twenty-five different species of non-native fish have been introduced into Clear Lake for recreational or biological control purposes, and although not all of them have become established, about 20 are still found in the lake today (Thompson et al. 2013, pp. 12–17, Table 1). Even early accounts in the late 1800's document the presence of non-native fish in Clear Lake. The first recorded introduction is from 1873 when Livingston Stone introduced lake whitefish (*Coregonus clupeaformis*) into Clear Lake; however, this attempt proved to be unsuccessful (Stone 1876, p. 377–378; Murphy 1951, p. 450). The introduction of carp is believed to be accidental when a resident of the Clear Lake area installed a carp pond in 1880 on the north shore of the lake. When the pond flooded the next winter, some of the carp were able to reach Clear Lake and become established (Murphy 1951, p. 449). White catfish (*Ameiurus catus*) and brown bullhead (*Ameiurus nebulosus*) were also introduced around 1880, although the specifics regarding their introduction are unknown (Murphy 1951, p. 450). Largemouth bass were first stocked in Clear Lake for a recreational fishing in 1888 and by 1910, the lake was known for its excellent bass fishing (Murphy 1951, p. 450, 451, 452, Table 6). By 1894, the brown bullhead, white catfish, carp, and largemouth bass were documented as inhabiting Clear Lake (Jordan and Gilbert 1895, p. 140). Smallmouth bass were introduced in 1895 and although considered unsuccessful, they have been documented in the lake since (Murphy 1951, p. 451; Thompson et al. 2013, p. 16). The California Fish Commission introduced golden shiners (*Notemigonus crysoleucas*) into Clear Lake in 1896 as forage for planted sport fish, and the bluegill, black crappie, and possibly the green sunfish were all introduced between 1909 and 1910, likely for recreational fishing (Murphy 1951, p. 450; Dill and Cordone 1997, p. 53; Thompson et al. 2013, p. 17). The initial introduction of golden shiners proved to be unsuccessful; however, subsequent plantings were successful (Thompson et al. 2013, p. 15, Table 1).

Western mosquitofish were introduced to the lake in 1925 to help control the gnat and mosquito populations (Murphy 1951, p. 451; Thompson et al. 2013, p. 17). The fathead minnow and redear sunfish were introduced in the 1950's as a forage fish and sport fish, respectively (Cook et al. 1966, p. 156; Dill and Cordone 1997, p. 56; Thompson et al. 2013, p. 16, Table 1). The local vector control district introduced the Mississippi silverside (*Menidia audens*) to Clear Lake and the Blue Lakes in 1967 to help control outbreaks of the Clear Lake gnat population (Geary 1978, pp. 1; Cook and Moore 1970, p. 70; Prine et al. 1975, p. 26, 28). By 1969, the Mississippi silverside was considered established within Clear Lake and Lower Blue Lake, but not within Upper Blue Lake (Cook and Moore 1970, p. 72). Threadfin shad were illegally introduced into Clear Lake in the 1980's to provide forage for sport fish (Bairrington 2000, p. 23). During the 2017 lake monitoring surveys conducted by USGS, threadfin shad comprised the largest proportion of catch (USGS 2018, p. 12). It is unknown when pumpkinseed were introduced and white crappie were likely introduced during the early 1900's (Bairrington 2000, p. 12; Thompson et al. 2013, p. 16, Table 1).

The introduction of the many non-native fish to Clear Lake have had effects on the native fish fauna and the habitat found in Clear Lake. All of the native fish populations within Clear Lake have undergone declines and four species that historically occurred in the lake (Pacific lamprey, hardhead, thicktail chub, and Clear Lake splittail) are now considered extirpated (Thompson et al. 2013, p. 12). Although the loss of these species can most likely be attributed to habitat modifications throughout the watershed or a combination of different factors, the introduction of non-native fish species led to the decline, and the possible extirpation, of the Sacramento perch population within Clear Lake (Murphy 1948a, pp. 99, 100; Murphy 1951, p. 475; Cook et al. 1966, pp. 155, 157–158; Thompson et al. 2013, p. 38; CDFW 2014, p. 34).

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All of the piscivorous fish species in Clear Lake are potential predators of Clear Lake hitch and there have been accounts of hitch in the stomach contents of both largemouth bass and channel catfish (Moyle et al. 2014, p. 10). In conjunction with a recent assessment of the Clear Lake fishery, a proportion of the black bass and catfish species that were captured had their gut contents analyzed to determine what fish species they were consuming in the lake (Ewing et al. 2016, p. 4). Surveys were conducted by electro-fishing the shoreline of the lake and the largemouth bass was the most common species collected (Ewing et al. 2016, pp. 50–51). Gut analysis revealed inland silversides were the most commonly identified fish species eaten by largemouth bass; however, the largest proportion of items removed from the gut were unidentifiable fish or fish parts (Ewing et al. 2016, p. 52). The main gut contents in the channel catfish stomachs analyzed were aquatic invertebrates and the most common fish species were inland silversides (Ewing et al. 2016, p. 53). No hitch were identified in any of the gut contents analyzed; however, it is possible the unidentifiable fish parts were from hitch (Ewing et al. 2016, pp. 52–53).

In addition to preying on hitch when they grow to larger sizes, smaller largemouth bass are also known to feed on insects and zooplankton, directly competing with both juvenile and adult hitch for food resources (Moyle and Holzhauser 1978, pp. 577–578, 581). Threadfin shad and silversides are also known to compete with the hitch since they also depend on the same aquatic prey base (Anderson et al. 1986, entire; Bairrington 2000, p. 33; CDFW 2014, p. 35). During years when silverside or shad abundance is especially high, they could deplete prey resources that the hitch depends on. A comparison of hitch trend data and abundances of silversides and threadfin shad suggests there may be a correlation between their abundances (CDFW 2014, p. 35); however, more detailed studies need to be completed. Silversides are also known to prey on larval fish, so it is possible some predation of hitch larvae by silversides is occurring in Clear Lake (Bennett and Moyle 1996, pp. 526, 529; Moyle et al. 2014, p. 9-10).

Besides the numerous piscivorous fish species that occur within Clear Lake, the Clear Lake hitch is also susceptible to predation from various bird and mammal species, especially during spawning migrations when they are more exposed. These species may include, but are not limited to, common merganser (*Mergus merganser*), hooded merganser (*Lophodytes cucullatus*), red-breasted merganser (*Mergus serrator*), pied-billed grebe (*Podilymbus podiceps*), horned grebe (*Podiceps auritus*), eared grebe (*Podiceps nigricollis*), western grebe (*Aechmophorus occidentalis*), Clark's grebe (*Aechmophorus clarkii*), white pelican (*Pelecanus erythrorhynchos*), double-crested cormorant (*Phalacrocorax auritus*), great blue heron (*Ardea herodias*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), green heron (*Butorides virescens*), black-crowned night-heron (*Nycticorax*), osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), river otter (*Lontra canadensis*), raccoon (*Procyon lotor*), striped skunk (*Mephitis*) and possibly black bear (*Ursus americanus*) (R. Macedo and S. Hill, pers. comm. 2009 *in* Moyle et al. 2014, p. 3; CDFW 2014, p. 9; Big Valley 2015, p. 6; eBird 2019).

Predation and competition will continue to affect the Clear Lake hitch at the individual, population, and species level into the future throughout its range. Predation and competition pressure within Clear Lake impacts the subspecies by reducing survival and recruitment, which reduces resiliency by decreasing the size of the overall population. Predation pressure within the tributaries to Clear Lake impacts the subspecies by reducing survival, reproduction, and recruitment, which further reduces resiliency by decreasing the size of the spawning population in any given year and by reducing the overall population altogether. This loss of resiliency reduces the subspecies' overall representation and redundancy since it results in fewer individuals spawning in each of the tributary streams and

natal habitat types. There are currently no regulatory mechanisms that address predation or competition.

4.6 Drought

Drought conditions within the Clear Lake watershed can have detrimental effects on the Clear Lake hitch by reducing the amount of flow within the tributary streams over the spawning season, reducing water quality in the lake, and possibly reducing emergent vegetation growth in the lake. Murphy (1948b) describes the almost complete lack of spawning runs in 1946 and 1947 due to the lack of water flow in the tributaries (Murphy 1948b, p. 105). However, the subspecies' ability to spawn along the lake shore provides an alternative to tributary spawning for at least a small proportion of the population. In addition, the subspecies' long lifespan is likely an adaptation to natural drought conditions in California, which can last for years.

Annual average air temperatures in California have increased by 1.5°F since the beginning of the 20th century (Bales 2013, p. 2). This coincides with increased aridity or drought conditions recorded within California since the early 1900s (Cook et al. 2004, p. 1016). This increase in aridity can impact the Clear Lake hitch by reducing the amount of time water is retained within the tributary streams and wetland habitats, which the hitch requires for spawning and rearing. Increases in aridity also reduce wetland/emergent vegetation growth, which the subspecies requires for rearing and for cover from predators. All of these factors can impact the reproductive success and recruitment of the subspecies and could potentially reduce survival if flows drop too drastically in the tributary streams and/or within their wetland habitats, or if they are subject to increased predation due to a reduction in cover.

The reduction of flow in the tributary streams during the spawning season can completely eliminate or greatly reduce the likelihood for successful reproduction and/or recruitment, and due to the Clear Lake hitch's very narrow range, the effects of drought will impact the entire subspecies. The ability to spawn along the shore provides for some redundancy within each population, but it is unknown whether shore spawning would be able to support a viable population over the long-term. Having a longer life-span is likely an adaptation to variable environmental conditions; however, prolonged droughts can have devastating effects on the overall population, especially in conjunction with other factors that are currently acting on the subspecies. There are currently no regulatory mechanisms that address drought.

4.7 Pesticides and Other Contaminants

A variety of pesticides have been applied to the lake in order to control insect or plant outbreaks and numerous contaminants have entered the watershed, primarily due to mining activity, but also from other anthropogenic uses. Clear Lake has been listed as an impaired water waterbody by the California State Water Resources Control Board (SWRCB) under Section 303(d) of the California Clean Water Act, due to both mercury contamination and increased nutrient input from sedimentation (SWRCB 2012; SWRCB 2019).

<u>Pesticides</u>

Clear Lake gnat outbreaks occur regularly in Clear Lake and have been 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, pp. 284–285; Cairns and Parfitt 1980, p. 504; Suchanek et al. 2003, pp. 1249–1250). Although the highest levels of DDD concentrations were seen in piscivorous fish species, fish species at lower trophic levels like the Clear Lake hitch also had concentrations of the larvicide in their tissues (Cook 1965, pp. 44, 46). 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, pp. 504, 509). 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, pp. 505–506). 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, p. 44; Cairns and Parfitt 1980, p. 504).

The application of DDD not only had a direct impact on the hitch through contamination, but it also likely impacted the subspecies 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, pp. 5, 10, 13; Hunt and Bischoff 1960 *in* Suchanek et al. 2003, p. 1249). The application of DDD not only eliminated or greatly reduced gnat populations, it was also known to reduce another prey item of juvenile Clear Lake hitch, chironomid larvae. However, chironomid larvae populations were able to recover faster than gnat populations post-DDD treatment (Lindquist and Roth 1949, p. 13).

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, p. 44; Suchanek et al. 2003, p. 1250). 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, p. 1250). The Clear Lake gnat still occurs in Clear Lake and their population in 2010 and 2012 were at a high level not seen for some time. The gnat population is thought to fluctuate in response to the silverside population in the lake, which was specifically introduced to help control the gnat outbreaks (Cook and Moore 1970, p. 70; Prine et al. 1975, p. 26, 28; Geary 1978, pp. 1; CDFW 2014, p. 32).

In addition to the insecticides used to control the Clear Lake gnat population, the aquatic herbicides Komeen™ (copper sulfate) and SONAR™ (fluridone) have also been applied in the lake to control *Hydrilla verticillata*, a highly invasive submerged aquatic weed (Suchanek et al. 2003, p. 1250, 31; CDFW 2014, p. 32). Two herbicides were used to target different parts of the plant, Komeen targets *Hydrilla* vegetative growth while SONAR treats the tubers (Suchanek et al. 2003, p. 1250). Komeen is not known to directly kill fish; however, it is known to affect various aquatic invertebrates within the treatment areas and, therefore, may indirectly impact fish, including the hitch through a reduction in prey base (Bairrington 2000, p. 63). SONAR is considered less toxic than Komeen, but because it is a systemic herbicide that is slowly absorbed in the vascular system, it also impacts

similar non-target vegetation such as tules and other submerged vegetation (Bairrington 2000, pp. 64–65; CDFW 2014, p. 32). Because juvenile Clear Lake hitch require tule habitat for cover, the use of Komeen can indirectly impact the subspecies (CDFW 2014, p. 32).

Other pesticides are also used throughout the watershed on private homeowner and agricultural lands. Pesticide use on private 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, pp. 1250–1251). 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 poundage increased to almost 759,000 lbs. (CALPIP 2019). However, it is unknown what effect terrestrial pesticides are having on the aquatic environment or if they are being transported through tributary streams into the lake (Suchanek et al. 2003, p. 1252). Furthermore, it is unknown what effect they could be having on the Clear Lake hitch.

Mercury

In addition to the gravel mining operations throughout the watershed, 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, p. 1253). 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, p. A259). The company continued to mine sporadically throughout the 1950's until the Sulphur Bank Mercury Mine was officially closed in 1957, although waste continued to contaminate the lake well into the 1990's (Suchanek et al. 2008, p. A153).

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, p. A257). 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, pp. A267–269). 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 (^{15}N) 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, pp. A257, A268–270). 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, p. A271). 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, p. A260).

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, p. A275). 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, pp. A265, A275; EPA 2019).

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, p. 1; Suchanek et al. 2003, p. 1253; Thompson et al. 2013, p. 19). 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 Clear Lake hitch (Crump and Trudeau 2008, pp. 902, 904; CDFW 2014, p. 32–33). Mercury concentrations found in hitch caught in Clear Lake from the 1980's and 1990's averaged 0.19 mg/kg, while the larger piscivorous fish such as adult largemouth bass averaged .54 mg/kg (CEPA 2002, pp. *ii*, 9; CDFW 2014, p. 33). 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 Clear Lake hitch (CEPA 2002, p. *ii*). Consumption advisories for fish removed from Clear Lake were first issued in the 1980's and the California Office of Environmental Health Hazard Assessment continues to provide advisories for Clear Lake fish and invertebrates (Thompson et al. 2013, p. 19; OEHHA 2018).

Regulatory mechanisms and management actions that are or could potentially prevent effects to the Clear Lake hitch due to pesticide and mercury contamination in Clear Lake include the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project, which if constructed in the future will improve degraded water quality by filtering some of the contaminants that enter Clear Lake from the tributary streams. In addition, Lake County, the California Department of Transportation, USFS, and the Bureau of Land Management have undertaken various actions to prevent or reduce contaminants from entering Clear Lake. There are currently no regulatory mechanisms or management actions that are fully ameliorating habitat degradation due to contamination from pesticides or other sources. For a more thorough description of regulatory mechanisms and management actions, see Section 4.9 Regulatory Mechanisms and Management Actions below.

The effects of mercury contamination, and possibly pesticide use, will continue to act on the subspecies into the future; however, it is unknown what effects pesticide and mercury contamination are having on the Clear Lake hitch and there are no accounts of either causing mass mortality or extreme detrimental effects to the subspecies.

4.8 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 2013a, p. 1450). 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, p. 1450).

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, pp. 35–54, 82–85; IPCC 2013b, pp. 3–29; IPCC 2014, pp. 1–32). 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, pp. 21–35; IPCC 2013b, pp. 11–12 and Figures SPM.4 and SPM.5).

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, entire; Ganguly et al. 2009, pp. 11555, 15558; Prinn et al. 2011, pp. 527, 529). 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, pp. 760–764 and 797–811; Ganguly et al. 2009, pp. 15555–15558; Prinn et al. 2011, pp. 527, 529; IPCC 2013b, pp. 19–23). See IPCC 2013b (entire), 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, pp. 15–16). Therefore, we use "down-scaled" projections 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, pp. 58–61, 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, pp. 12423–12424, Figure 1). 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, pp. 12424–12425, Supplemental Figure 11).

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 Clear Lake hitch 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, pp. 841, 842, 844, Figure 1). 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, pp. 848–850). 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 Clear Lake hitch. 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, p. 855).

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, entire). 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 1990's by the end of the century (RCP 4.5) (Grantham 2018, p. 15). 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, pp. 17–18, Figure 2.4).

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, p. 20; Grantham 2018, p. 19). There is also less difference between the two different emissions scenarios than was seen for the temperature predictions (Pierce et al. 2018, p. 20). 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, p. 19, Figure 2.7).

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, pp. 23–24, Figures 13 and 14). 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, pp. 22-24). 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, pp. 6, 19–20). 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, p. 23). 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, pp. 27–28).

Because the Clear Lake hitch 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 subspecies. Moyle et al. (2013) conducted an assessment to determine the Clear Lake hitch's vulnerability to the effects of climate change. They determined that the subspecies was "critically vulnerable" to the effects of climate change (specifically, the change in spring hydrograph) and that the subspecies "…is extremely likely to be driven to extinction by year 2100 without conservation measures (Moyle et al. 2013, pp. 3, 7, Table S1)."

Regulatory mechanisms and management actions that are or could potentially provide some protection from the effects of climate change include the Clean Air Act and the California Global Warming Solutions Act. Both address climate change by reducing greenhouse gas emissions within the United States and California, respectively. There are no regulatory mechanisms or management actions that fully address the effects of the climate change. For more information on the Clean Air Act and the California Global Warming Solutions Act, see Section 4.9 Regulatory Mechanisms and Management Actions below.

The effects of climate change will impact the Clear Lake hitch at the individual, population, and subspecies level into the future. The loss and/or reduction of suitable spawning streams throughout the subspecies' range and the declining quality of riparian and rearing habitat will likely reduce reproductive success, recruitment, and survival. The reduction in tributary streams available to the hitch for spawning will further decrease the subspecies' overall representation and redundancy.

4.9 Regulatory Mechanisms and Management Actions

<u>California Endangered Species Act (CESA)</u>
On August 6, 2014, the California Fish and Game Commission determined the Clear Lake hitch 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. It should be noted that the state's definition of take is not the same as the Service's definition of take under the Federal ESA.

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.

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 Clear Lake hitch 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.

Clean Air Act

The Clean Air Act of 1970 (42 U.S.C. 7401 et seq.) provides the platform for the Environmental Protection Agency (EPA) to develop and enforce regulations to protect the general public from exposure to airborne contaminants known to be hazardous to human health. In 2007, the Supreme Court held that gases such as carbon dioxide fit within the Clean Air Act's definition of "air pollutant," and thus that EPA has the authority to regulate the emissions of such gases from new motor vehicles (Massachusetts et al. v. EPA, 549 U.S. 497, 532 (2007)).

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.

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, entire). 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, entire; County of Lake et al. 2010c, entire; County of Lake et al. 2010d, entire).

Aggregate Resources Management Plan

Lake County developed an Aggregate Resources Management Plan (County of Lake 1992, entire) 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, pp. 83–86). 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. In-stream sources of gravel are no longer the primary source of aggregate in Lake County, gravel is now acquired from other sources (CEPA 2008, pp. 8, 89).

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 was once approximately 1,400 acres of wetland habitat that was lost in the early 1900's 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. Final 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

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appropriated to start project design; however, funding for land acquisition has been acquired (Corps 2012, pp. 1–2).

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. It will also increase the existing amount of wetland habitat within the Clear Lake watershed by approximately 79 percent (Corps 2012, p. 3). 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.

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 (County of Lake et al. 2010a, pp. ES-16, 3-10; CDFW 2014, p. 42). These ordinances benefit the Clear Lake hitch by providing a consistent amount of tule habitat for juveniles.

Clear Lake Hitch Conservation Strategy

A group including local tribes, local government, state agencies, and federal agencies have been working on the development of a conservation strategy for the hitch. The strategy will document the past and current status of the subspecies, will describe the negative influences that have resulted in the subspecies' current status, and will identify the actions that will address those negative influences in order to maintain a viable population of Clear Lake hitch throughout its range. This strategy will benefit the hitch by helping to inform the public on how they can help the hitch and to direct funds to implement actions or projects that will specifically benefit the hitch.

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, pp. 2, A-1). 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. Groundwater Sustainability Agencies have been formed for the Big Valley and Scotts Valley basins; however, a Groundwater Sustainability Plan has not yet been developed for the Big Valley basin (DWR 2019b; DWR 2019c;

DWR 2019d). Reducing overdraft from groundwater pumping in the Big Valley basin could improve flow conditions in Thompson Creek, Adobe Creek, Kelsey Creek, and Cole Creek.

Miscellaneous

Lake County, the California Department of Transportation, US Forest Service, and the Bureau of Land Management have undertaken various actions to prevent or reduce nutrients and contaminants from entering Clear Lake (West Lake Resource Conservation District, undated; CDFW 2014, p. 41). These actions include the Eightmile Valley Sediment Reduction and Habitat Enhancement Project, which the Bureau of Land Management and Scotts Valley Band of Pomo Indians have recently received a grant for (CDFW 2014, p. 41). 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 Clear Lake hitch during early life stages (CDFW 2014, p. 42).

4.10 Cumulative Effect of Combined Factors Influencing Viability

Multiple influencing factors can act on a species or its habitat at the same time, which can result in impacts that are not accounted for when factors are analyzed separately. Factors that appear minor when considered alone may have greater impacts on individuals, populations, or habitat when analyzed in combination with other factors.

The Clear Lake hitch evolved in Lake County, California, which has always had a highly variable climate with natural periodic droughts. However, the degradation and loss of water retention within their spawning streams and the loss of large stretches of suitable spawning habitat due to various instream barriers has likely reduced reproductive success and recruitment. During drought conditions this can completely or almost completely eliminate all stream based spawning in a given year. If drought conditions persist over multiple years, stream based reproduction can also be reduced or eliminated for multiple years. Furthermore, climate change projections suggest the Clear Lake area will see more varied precipitation and higher temperatures during the spring, which could result in even less water flow being retained within the tributary streams during the subspecies spawning season (Pierce et al. 2013, pp. 842, 844, 848–850, Figure 1). Although the subspecies has the ability to spawn within the lake, it is unknown whether that method of reproduction would be able to sustain a viable population of hitch in Clear Lake.

The combination of wetland habitat loss and drought can result in increased predation pressure and competition. Past habitat loss have left only a small proportion of wetland habitat surrounding Clear Lake and drought conditions can reduce the amount of emergent vegetation growth within those remaining wetland habitats. This reduction in emergent vegetative growth reduces the amount of cover the hitch uses to hide from predators, increasing predation pressure. It can also increase competition as more fish concentrate into this limited habitat type.

4.11 Summary

Our analysis of the past, current, and future factors influencing viability revealed there are six primary factors affecting the current and future viability of the Clear Lake hitch. These risks to viability are primarily related to habitat changes, both negative and positive:

1. The loss of spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams;
2. The loss of wetland/tule habitat that juveniles require for rearing;
3. The effects from poor lake water quality;
4. The effects of increased competition and predation from a combination of introduced fish species and habitat loss;
5. Drought, which further reduces tributary flow; and
6. The implementation of regulatory mechanisms (i.e., CESA, Lake County's Clear Lake Shoreline Ordinance, and SGMA) and management actions (i.e., Lake County's Aggregate Resources Management Plan, Middle Creek Flood Damage Reduction and Ecosystem Restoration Project, and other miscellaneous restoration actions occurring throughout the watershed).

Furthermore, most of these influences will all be exacerbated by the effects of future climate change. Although we did assess the use or take of Clear Lake hitch for tribal harvest, we will not be carrying this factor forward into the future analysis because these risks do not appear to be occurring at a level that affects the entire population. The six influences listed above, will be carried forward in our assessment of the current condition of the Clear Lake hitch, which is described in the next chapter (Chapter 5). To assess the possible future condition of the Clear lake hitch, we use those same six influences for our analysis but we also include the effects of climate change. The future condition analysis is described in Chapter 6.

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CHAPTER 5: CURRENT CONDITION

In this chapter we report the historical population estimates and observations of the subspecies, and the current survey efforts that are occurring throughout the watershed. We also analyze the current condition of the subspecies by determining the condition of each of the demographic factors and habitat elements carried forward from Section 3.2.2, in light of the past and current influences to Clear Lake hitch viability that were defined in Chapter 4. The past and current influencing factors that have resulted in the current condition of the subspecies include the loss of spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams, the loss of wetland/tule habitat that juveniles require for rearing, the effects of poor lake water quality, the effects of increased competition from a combination of introduced fish species and habitat loss, drought reducing tributary flow, and the implementation of regulatory mechanisms and restoration actions. We describe the subspecies' current condition by characterizing its status in terms of **resiliency**, **representation**, and **redundancy** (3 Rs).

5.1 Historical Population Estimates/Observations

There are not any robust, statistically valid population estimates for the historical population of Clear Lake hitch. 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 Clear Lake hitch 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, entire; Thompson et al. 2013, p. 12). 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, p. 226)." Cook et al. (1966, p. 143–144) 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 (e.g., Clear Lake splittail and Sacramento pikeminnow).

Incidental catch records for commercial fishing operators operating between 1961 and 2001 included information about catch of Clear Lake hitch. 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, pp. 16–18; CDFW 2014, p. 11). 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 caught within the lake can vary widely, with some reported hauls catching no hitch at all and others recording over 10,000 individuals (CDFG 1961-2001; CDFW 2014, pp. 11–13, 17–18). The high variability of hitch incidentally caught could suggest high population variability. This variability would likely be in response to variable environmental conditions in the Clear Lake area, with prolonged dry periods reducing overall abundance. Documented observations from 1961-1963 described great numbers of hitch ascending the flooding tributaries and spilling out into drainage ditches and farm ponds; however, during the dry spring of 1964, very few hitch were seen in the spawning tributaries (Cook et al. 1966, p. 145; CDFW 2014, pp. 11–13, 17–18).

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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, p. 8). However, new research suggest adults can be found in any portion of the lake where conditions are suitable, specifically, where dissolved oxygen levels are normal (Feyrer et al. 2019b, pp. 5–7). 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, pp. 11, 16).

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.

5.2 Current Population Estimates and Distribution

There is not a current population estimate for the Clear Lake hitch; however, more recent survey efforts conducted by CDFW, local tribes, and USGS are accruing more data to aid in providing a more accurate estimate. Current 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 also been conducting visual surveys during the spawning season. The purposes 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 or other large waterbody surveys conducted by CDFW include electrofishing efforts to identify hitch spawning in the lake, assess the population residing in the Soda Bay area 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, pp. 7, 9–10). 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, and 118 hitch were collected from Kelsey Creek (Ewing 2014b, pp. 8–10). There were two recaptures on Adobe Creek, one that contained a PIT (Passive Integrated Transponder) 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, pp. 4–5, 8–10).

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, p. 2). 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, pp. 8–10). 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, pp. 2, 9–10). All of the hitch captured during the 2016 spawning survey were in the 225 mm or greater size class (Ewing 2016c, p. 11). The 2017 mark recapture survey resulted in many more fish captured 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, p. 2). 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, pp. 9–11). Out of all the years of sampling, only one individual that CDFW tagged had truly been recaptured (Ewing 2017b, p. 12).

Beginning in 2005 and continuing until today, members of the Chi Council for the Clear Lake Hitch 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, accessibility to spawning habitat, and surveyor miscalculation due to a lack of in-stream visibility. 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; CDFW 2014, p. 14). Table 5.1 is a summary of tributaries with documented hitch from the Chi Council for the Clear Lake Hitch observational surveys, by year.

Table 5.1 Summary of Chi Council for the Clear Lake Hitch observational surveys by year.

Tributary/HUC12	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Adobe Creek	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Kelsey Creek	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cole Creek	X	X	X	X	X	X	X					X			X
Scotts Creek	X	X	X	X	X	X				X	X	X	X	X	X
Clover Creek	X		X	X	X	X	X				X	X	X	X	X
Middle Creek	X		X	X	X	X		X		X	X	X	X	X	X
Seigler Canyon Creek								X	X	X	X		X	X	X
Rodman Slough	X										X	X			X
Manning Creek	X	X				X	X					X	X	X	X
McGaugh Slough	X	X											X		
Schindler Creek							X	X							

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, p. 2). Surveys were repeated again in 2016, 2017, and 2018, and like the observational surveys conducted by the Chi Council for the Clear Lake Hitch, the results of CDFW's visual spawning surveys varied from year to year. The number of tributaries documented as 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 CCCLH surveys, Adobe Creek had spawning observations every year (Ewing 2014c, p. 5; Ewing 2016b, pp. 2, 5–6; Ewing 2017a, pp. 7, 8; Ewing 2018b, pp. 2, 7). A summary of the CDFW visual spawning surveys are seen in Table 5.2

In addition to the tributary surveys, CDFW conducted electrofishing surveys along the lake's shoreline in 2014 in an attempt to identify any hitch spawning along the lake shore. The survey occurred during the night of May 7, 2014, and resulted in the capture of 36 hitch, all of which were subsequently tagged with either a PIT tag (larger than 275 mm or greater) or a fin clip (individuals between 200 mm and 275 mm). During the electrofishing survey, there was only one male hitch that was in spawning condition (e.g. expressing milt) (Ewing 2014d, pp. 2–3, 5). CDFW also implemented three electrofishing studies in 2015. The first 2015 effort focused on Soda Bay where a total of 75 hitch were captured and many more were seen. All of the fish ranged from 143-194 mm in length, indicating they were 1 to 2 year old fish (Ewing undated, entire). The other two efforts were to determine whether Clear Lake hitch were present within Thurston Lake and Highland Springs Reservoir, which is just south and southwest of Clear Lake, respectively (Ewing 2015b, p. 1; Ewing 2015c, p. 1, see Figure 2.2 above). During the surveys, seven hitch were captured in Thurston Lake and one was captured in Highland Springs Reservoir (Ewing 2015b, p. 2; Ewing 2015c, p. 1). Highland Springs Reservoir is located on Highland Springs Creek, a tributary to Adobe Creek.

Table 5.2 Summary of CDFW visual spawning surveys by year.

Site ID	Tributary	2014	2016	2017	2018
1	McGaugh Slough	--	--	--	--
2	McGaugh Slough	--	--	--	--
3	McGaugh Slough	--	68	5	--
4	Hill Creek	--	--	--	--
5	Hill Creek	--	--	--	--
6	Adobe Creek	140	605	50	200
7	Adobe Creek	371	--	50	200
8	Adobe Creek	48	--	39	318
10	Thompson Creek	--	--	--	--
11	Thompson Creek	--	--	27	--
12	Thompson Creek	--	--	50	--
13	Cole Creek	--	20	--	--
14	Cole Creek	--	--	--	--
15	Cole Creek	--	--	--	--
16	Kelsey Creek	495	--	--	150
17	Kelsey Creek	--	--	3	--
18	Kelsey Creek	55	--	--	150
19	Kelsey Creek	10	--	--	133
21	Manning Creek	--	--	293	2
22	Manning Creek	--	--	--	--
23	Manning Creek	--	--	--	--
TOTAL		1119	693	517	1153

From 2017-2019, USGS surveyed Clear Lake to determine the status, distribution, and habitat preferences of the Clear Lake hitch throughout the lake (USGS 2018, p. 4; Feyrer 2019a). 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, p. 4). 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, p. 8; Feyrer 2019a). In 2017 and 2018, 280 and 297 hitch were captured, respectively. The Clear Lake hitch 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, p. 8). 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 2019a), which may have resulted in hitch avoiding being captured because the gill nets were visible.

Over the course of the lake monitoring effort it become apparent there was a large difference in size distribution of hitch captured over the three survey years (see Figure 5.1). 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 during that year. 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, pp. 9–10; Feyrer 2019a). During the 2017 and 2018 efforts, the younger cohorts were most often encountered in shore habitats while adults were more equally 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, pp. 8–10). Lake surveys may continue into 2020 and 2021.

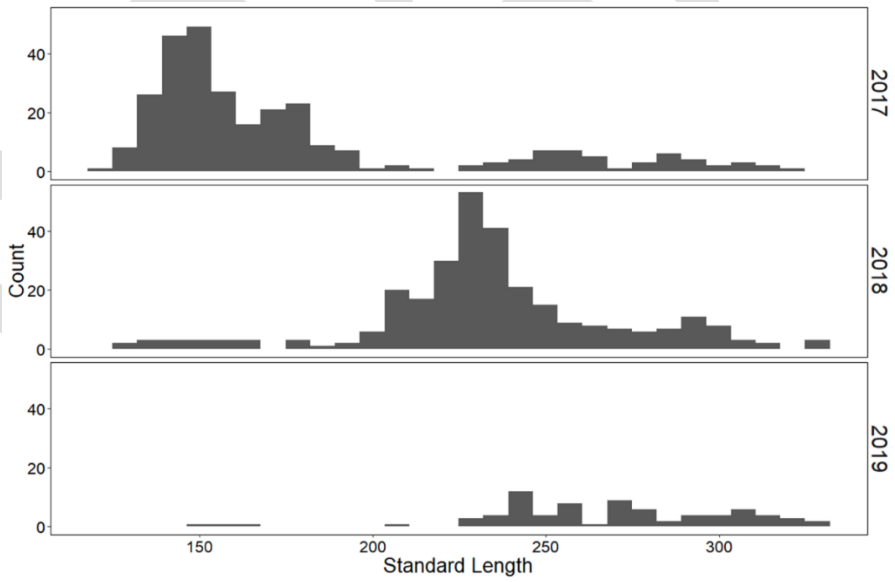

Figure 5.1 Summary of hitch caught during the 2017-2019 lake monitoring effort conducted by USGS. Credit: USGS, Fred Feyrer

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. 2019a, pp. 1690, 1692). Strontium signatures from water samples taken throughout the watershed indicated the

watershed could be assigned to one of five unique strontium isotope groups (SIG) (see Figure 3.2 above). 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 (SIG 1); Kelsey Creek, Burns Valley Creek (SIG 2); Clear Lake, Adobe Creek, Scotts Creek (SIG 3); Rodman Slough (SIG 4); Middle Creek, Clover Creek, Seigler Canyon Creek (SIG 5). 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. 2019a, pp. 1693, 1695).

Each of the five SIG's were represented in the otolith signatures, with most (58%) of the adults being assigned to SIG 3. It is likely the natal habitat associated with a majority of individuals representing SIG 3 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 (SIG 4), 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 SIG 1 and Kelsey Creek is the most likely source for individuals from SIG 2. Middle, Clover, and Seigler Canyon Creeks all likely contribute to SIG5 since they all are well known spawning tributaries. 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 Clear Lake hitch is able to utilize the mouths of streams with little to no flow movement and areas within Clear Lake itself (Feyrer et al. 2019a, pp. 1693–1695).

5.3 Introduction for Current Condition Analysis

We have considered what the Clear Lake hitch needs for viability (Chapter 3) and we have evaluated the past, current, and future influencing factors impacting the Clear Lake hitch (Chapter 4). We now will analyze the subspecies' current condition by considering how those past and current influences described in Chapter 4 have impacted the condition of those demographic factors and habitat elements identified in Chapter 3. We apply the concepts of resiliency, representation, and redundancy to describe the current condition of the Clear Lake hitch.

The various past and current negative influencing factors discussed in Chapter 4 have significantly reduced the current abundance of hitch compared to historical accounts. This decline in abundance is primarily due to reductions in reproductive success, recruitment, and survival, caused by the loss of consistent tributary flow, the loss of wetland/tule habitat surrounding the lake, reductions in lake water quality, effects due to introduced fish species, and the effects of drought conditions. Table 5.3 describes those influencing factors we carried forward for the current condition analysis. These will be used, in addition to implemented management actions, to assess the current condition of each Clear Lake population and the viability of the subspecies overall. The current resiliency of each population will help describe the level of redundancy and representation the subspecies currently expresses. However, neither redundancy nor representation could ever be considered at a high level due to the hitch's narrow range and low variability of habitat characteristics across the subspecies' geographical range.

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Table 5.3 Influences used to determine the current and future condition of the Clear Lake hitch

Negative Factor Influencing Viability	Cause(s)	Past, Current, and/or Future Factor	Effect(s) to the Clear Lake Hitch	Potential Regulatory Mechanism or Management Action
The loss of spawning habitat - altered tributary flow regime	Instream gravel mining	Past activity, currently having effects on the watershed and will continue in the future	Reduced reproduction, early life stage survival, and likelihood of recruitment	CEQA; Lake County's Aggregate Resources Management Plan
	Deforestation	Past activity, currently having effects on the watershed and will continue in the future	Reduced reproduction, early life stage survival, and likelihood of recruitment	CEQA; NEPA; US Forest Service (USFS) sensitive species designation
	Grazing practices	Past activity, currently having effects on the watershed and will continue in the future	Reduced reproduction, early life stage survival, and likelihood of recruitment	There are currently no regulatory mechanisms that address grazing practices
	Existing flood control project infrastructure	Past installation, currently having effects on the watershed and will continue in the future	Reduced reproduction, early life stage survival, and likelihood of recruitment	CEQA; NEPA
	Fire activity; increased incidence due to climate change	Past, Current, and Future	Reduced reproduction, early life stage survival, and likelihood of recruitment	Clean Air Act; California Global Warming Solutions Act
	Water utilization for agricultural and urban uses	Past, Current, and Future	Reduced reproduction, early life stage survival, and likelihood of recruitment	SGMA
The loss of spawning habitat - blocked access	Lack of adequate tributary flow	Past, Current, and Future	Reduced reproduction and early life stage survival	SGMA; Misc. restoration actions
	Physical barriers (dams, diversions, roadways, and crossings)	Past, Current, and Future	Reduced reproduction	Barrier removal and/or fish ladder installation by CDFW and CalTrans

Negative Factor Influencing Viability	Cause(s)	Past, Current, and/or Future Factor	Effect(s) to the Clear Lake Hitch	Potential Regulatory Mechanism or Management Action
The loss of wetland/tule habitat	Conversion to agricultural production and urban development	Past activity, currently having effects on the watershed and will continue in the future	Reduced early life stage survival and likelihood of recruitment	Clear Lake Shoreline Ordinance; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project
Reductions in lake water quality	Loss of wetland/tule habitat surrounding the lake	Past activity, currently having effects on the watershed and will continue in the future	Reduced survival	Clear Lake Shoreline Ordinance; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project
	Mercury contamination	Past activity (mercury mining), currently having effects on the watershed and will continue in the future	Reduced survival	Aggregate Resources Management Plan; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project; Misc. restoration actions
	Increased sediment and nutrient input	Past, Current, and Future	Reduced survival	Aggregate Resources Management Plan; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project; Misc. restoration actions
	Cyanobacteria blooms	Past, Current, and Future	Reduced survival	Aggregate Resources Management Plan; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project; Misc. restoration actions
Increased predation and competition pressure due to the establishment of non-native fish species	Introduction of non-native fish species	Past activity (introduction), currently having effects on the subspecies and will continue in the future	Reduced survival, reproduction, and likelihood of recruitment	There are currently no regulatory mechanisms that address predation and competition.
Drought conditions	Environmental setting; increased incidence due to climate change	Past, Current, and Future	Reduced reproduction and recruitment	There are currently no regulatory mechanisms that address drought.

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5.3.1 Summary of Methods for Current Condition Analysis

We are considering two populations of Clear Lake hitch, one occupying Clear Lake and its tributaries, and the other Thurston Lake and its tributary. In order to analyze the Clear Lake population in more detail, we broke the populations down into HUC 12 sub-watersheds. There are 16 HUC 12 sub-watersheds found throughout the range of the subspecies, each of which occupy different areas within the watershed that contribute to the various hitch needs during their different life history stages. We further grouped some of the HUC 12 units based off of an analysis of strontium signatures throughout the watershed, which indicate the contribution of different natal habitats to the population in Clear Lake. Because the entire Thurston Lake population occurs entirely within the Thurston Lake HUC 12 unit, it will be not be lumped into a SIG and resiliency of that HUC 12 will be used as the analysis unit for that entire population. Since Thurston Lake is a closed system and contains an apparently robust population, we are assuming the current resiliency of the Thurston Lake population is high. The Clear Lake population occupies numerous HUC 12 units, each of which are associated with one of the five SIG's (see Figure 3.2 and Table 3.2 above). Each of the demographic factors and habitat elements carried forward from Section 3.2.2 will be analyzed using the methods/assumptions described below and shown in Tables 5.4a and 5.4b.

<u>Reproduction:</u> Observational data collected by CCCLH and CDFW will be used to analyze reproduction. Specifically, the consistency of spawning observations in those primary natal habitat associated with each SIG, except for SIG 4, will be used to categorize condition. The following are the primary natal habitats for each SIG, minus SIG 4: Cole Creek (SIG 1); Kelsey Creek (SIG 2); Clear Lake and Adobe Creek (SIG 3); Middle Creek, Clover Creek, and Seigler Canyon Creek (SIG 5). SIG 4, Rodman Slough is not typically included in observational surveys, and therefore, the recruitment category level assigned to SIG 4 will also be used for reproduction (moderate, see below).

<u>Recruitment:</u> The recruitment analysis for the Clear Lake hitch will have two components: the presence of wetland habitat and the results from the otolith analysis. Since the otolith analysis confirmed some level of recruitment for each of the SIG's, this component of the analysis will be weighted double. Overall scores are determined by adding the two components. Because we know the remaining amount of wetland habitat surrounding the lake has declined compared to the historical condition, we are assuming for this analysis that this component cannot be in a high condition. Therefore, we will be defining a moderate condition for the wetland habitat component as having remnant habitat within the SIG and a low condition as having very little remnant habitat within the SIG (see Table 5.4b). Figure 5.2 shows the existing wetland habitat within each SIG.

Although only one year of the otolith analysis was conducted, we will be using the proportion of individuals assigned to each SIG to categorize the otolith component of recruitment. We recognize that if all portions of the lake were equally contributing to recruitment, which may have been the case historically, the proportion of individuals representing each SIG would be equal (20%). However, because of the loss of wetland habitat surrounding the lake, we are assuming that each SIG can no longer support an equal amount of recruitment. Therefore, this component of the analysis is really just a comparison of what portion of the lake is currently contributing to recruitment. For the otolith component, we define a high condition as those SIG's that are contributing 20% or more to recruitment, moderate as less than 20% but more that 10%, and low condition as less than 10%. Of the hitch analyzed for the otolith analysis, 57% came from SIG 3, 18% came from both SIG's 2 and 4, and 2% and 5% from SIG's 1 and 5, respectively.

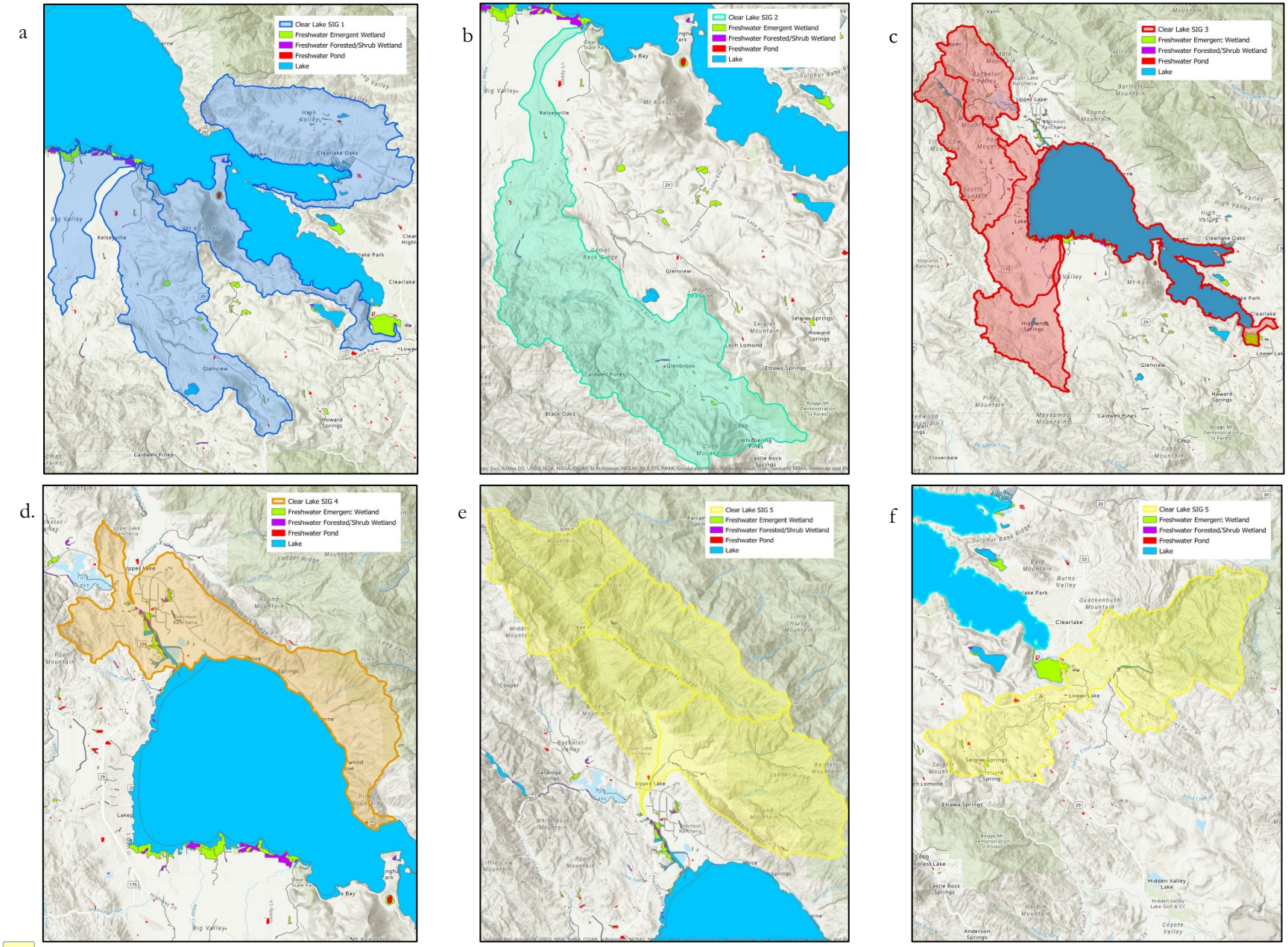

Figure 5.2 Remnant wetland habitat within each SIG. a. SIG 1; b. SIG 2; c. SIG 3; d. SIG 4; e. upper portion SIG 5; f. lower portion SIG 5

Connectivity: Connectivity will be analyzed by considering the presence and concentrations of passage barriers within a SIG (see Figure 5.3). Larger concentrations of potential passage barriers will be considered a low condition (SIG's 2, 3, and 5), whereas SIG's with no or few barriers are considered high condition (SIG's 1 and 4). There will not be an initial moderate category for this factor; however, depending on future projections, passage barriers within a SIG could improve or deteriorate from a high or low current condition to a future moderate condition.

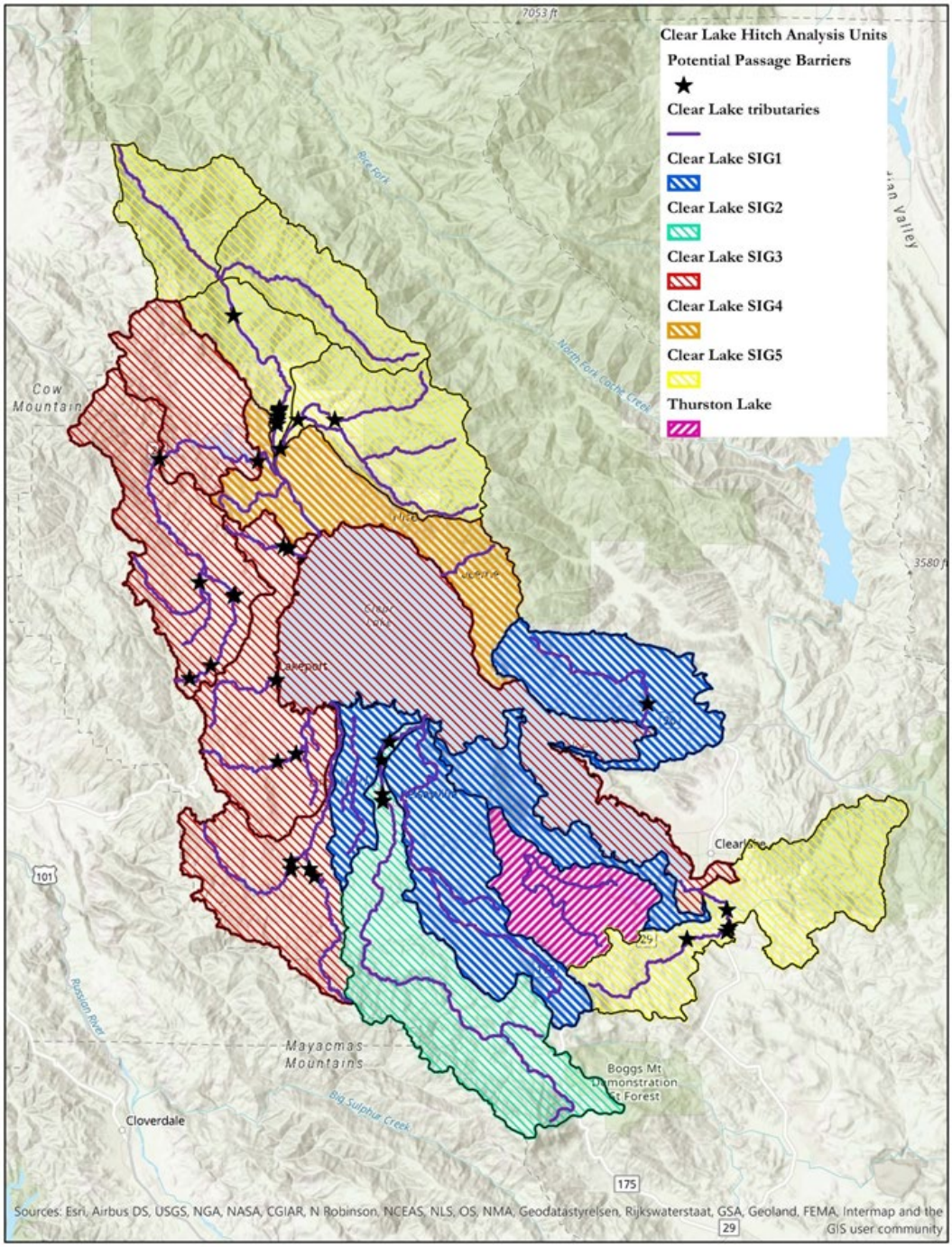

Figure 5.3 Passage barriers within each analysis unit

Tributary Water Quantity: The amount of water within a primary natal habitat stream is likely influenced by the presence of surrounding urban development and agricultural production (see Figures 4.2 and 4.4 above). The greatest concentration of agricultural production is within SIG 1, with lower levels of production in each of the other analysis units. The greatest concentration of urban development is within SIG's 2 and 3, and there is an intermediate amount in SIG's 1, 4, and 5. Therefore, for the purposes of this analysis, SIG's 1, 2, and 3 are considered a low condition due to the high concentration of water users, and SIG's 4 and 5 are a moderate condition since water reliance is not as intense. Coincidentally, SIG's 1, 2, and 3 happen to fall within the Big Valley groundwater basin, which has been given a medium priority under SGMA due to overdraft.

Wetland/Tule Habitat: Remaining wetland/tule habitat is found either within each SIG or, as in the case for SIG 5, is found in the SIG between SIG 5 and the lake. Because the amount of wetland/tule habitat has been greatly reduced from past conditions and the presence of non-native fish within this habitat type has increased both predation pressure and competition, we consider wetland/tule habitat to be at a low condition for all analysis units. It is assumed that the loss of rearing habitat (both physical loss and the introduction of non-native fish that exclude the hitch via predation or competition) is one of the primary factors limiting population growth.

Lake Water Quality: The current water quality condition for Clear Lake is considered moderate. Although the lake has been degraded and in some years conditions should be considered low, it is not thought to have a population level effect on the subspecies every year and therefore, is typically at a moderate condition.

Table 5.4a Demographic factors and habitat elements used to create condition categories in Table 5.5a below

	Demographic Factors		**Tributary Habitat Elements**		**Lake Habitat Elements**	
Condition Category	**Reproduction**	**Recruitment (see Table 5.4b)**	**Connectivity**	**Tributary Water Quantity**	**Wetland/ Tule Habitat**	**Lake Water Quality**
High	Reproduction documented each year	Overall recruitment total from recruitment analysis is high	Free passage under all flow conditions; no/few barriers	Water is retained within the tributaries throughout the spawning season	Extensive wetland habitat is available for rearing	Lake water is well oxygenated and uncontaminated
Moderate	Reproduction documented frequently, but not each year	Overall recruitment total from recruitment analysis is moderate	--	Water is retained within the tributaries throughout a large portion of the spawning season	Some wetland habitat is available for rearing	Lake water is oxygenated most of the time, hypoxic conditions do occur periodically. Some contaminants are present, but not at lethal levels
Low	Reproduction documented infrequently	Overall recruitment total from recruitment analysis is low	Free passage only under specific flow conditions; many or large concentration of barriers	Water is retained within the tributaries throughout just a small portion of the spawning season	Limited wetland habitat is available for rearing	Lake water is not well oxygenated and hypoxic conditions occur frequently. Contaminants are present, sometimes at lethal levels
Ø	No reproduction	No recruitment	No passage under any flow conditions	Water is not retained within the tributaries during any portion of the spawning season	No wetland habitat is available for rearing	Lake water quality is uninhabitable

Table 5.4b Recruitment analysis used to create recruitment condition category in Table 5.4a above. The otolith analysis is weighted double when calculating the overall condition

Condition Category	Recruitment – Wetland Habitat	Recruitment – Otolith Analysis (2X)
High	--	Otolith analysis shows SIG is a primary contributor to population recruitment (>20%).
Moderate	Remnant wetland habitat occurs within the SIG	Otolith analysis shows SIG contributes to population recruitment, but is not the primary source (<20% and >10%).
Low	Very little remnant habitat occurs within the SIG	Otolith analysis shows SIG has very little contribution to population recruitment (<10%)
Ø	No wetland habitat within the SIG	No recruitment, no individuals assigned to SIG

Determining Overall Analysis Unit Condition

The overall condition for each analysis unit is calculated by summing the condition of each of the demographic factors and habitat elements within that unit. A high condition for any demographic factor or habitat element (factor/element) is worth a score of 3, moderate is worth 2, and a low condition is worth 1. Because there are six factors/elements to analyze, an analysis unit that has all factors/elements in a high condition would have a total score of 18. Likewise, an analysis unit with all six factors/elements in moderate condition would have a total of 12 and one with all factors/elements in low condition would have a total of 6. We took the difference between the lowest and highest possible overall condition scores (6 and 18) and divided this into three equal intervals representing the breadth of possible scores. A score of 9 or less means the analysis unit is in overall low condition, a score of 15 or greater means the unit is in overall high condition, and scores between 10 and 14 mean the unit is in overall moderate condition.

Determining Population Condition

The overall condition of a particular factor/element for the entire Clear Lake population is calculated by summing the condition of that particular factor for each analysis unit, which was determined using the evaluation described above. Similar to the analysis unit evaluation, conditions of high, moderate, and low are scored as 3, 2, and 1, respectively. However, unlike the analysis unit evaluation, there are only five SIG's that are being evaluated, therefore, a factor/element in high condition for each of the analysis units would have a total score of 15. Likewise, a factor/element with all five SIG's in moderate condition would have a total of 10 and one with all SIG's in low condition would have a total of 5. We took the difference between the lowest and highest possible overall condition scores (5 and 15) and divided this into three intervals representing the breadth of possible scores. A score of 8 or less means the factor/element is in overall low condition, a score of 13 or greater means the factor/element is in overall high condition, and scores between 9 and 12 mean the factor/element is in overall moderate condition.

The overall condition of the Clear Lake population is determined by using the same scoring process that was used to determine the condition of each analysis unit, which is described above. All six factors/elements have a score ranging from 1 to 3 based on the condition of that factor/element (high condition = 3, moderate condition = 2, and low condition = 1). The condition of all

factors/elements are summed to give an overall population score between 6 and 18. A score of 9 or less means the population is in overall low condition, a score of 15 or greater means the population is in overall high condition, and scores between 10 and 14 mean the population is in overall moderate condition.

5.4 Current Population Resiliency

The Clear Lake hitch currently has two populations throughout its range, one occupying Clear Lake and its tributaries, and the other Thurston Lake and its tributary. Thurston Lake and Thurston Creek are both within the same HUC 12 unit, which is its own analysis unit and is considered to be at a high level of resiliency due to the robust population that currently resides there. The Clear Lake population occupies numerous HUC 12 units, which have been further grouped into one of five SIG's based on natal origin strontium signatures.

Using the methods summarized in Section 5.3 and Tables 5.4a and 5.4b, and as seen in Table 5.5a, the current condition of wetland/tule habitat within the Clear Lake population is at a low condition in each of the five units. Similarly, the current condition of lake water quality is at a moderate condition for all five SIG units. For reproduction, SIG's 2 and 3 are currently at a high condition because they have had consistent spawning observations each survey year. Reproduction for SIG's 1 and 5 are currently at a moderate condition due to somewhat frequent, but still inconsistent, annual spawning observations (see Tables 5.1 and 5.2 above). The portion of the watershed associated with SIG 4 is not typically included in observational surveys, so the current condition of recruitment for SIG 4, moderate, is also being used for reproduction. As explained above, the current recruitment condition for SIG 3 is high, moderate for SIG's 2 and 4, and low for SIG's 1 and 5. For connectivity, SIG's 1 and 4 are currently at a high condition, and SIG's 2, 3, and 5 are at a low condition. The current condition for tributary water quantity is low for SIG's 1, 2, and 3, and moderate for SIG's 4 and 5. Currently, the Clear Lake population has four analysis units at a moderate resiliency (SIG's 1–4), and one unit at a low resiliency (SIG 5), for an overall Clear Lake population resiliency of moderate. The Thurston Lake population is currently in high condition (see Table 5.6).

Table 5.5a Current condition for each of the Clear Lake population analysis units and the overall current condition of the Clear Lake population. See Table 5.4a for a description of condition categories. See Table 5.5b for the detailed current recruitment condition analysis.

Clear Lake Population Analysis Unit (AU)	Demographic Factors		Habitat Elements				Current Condition
	Reproduction	Recruitment (see Table 5.5b)	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Cole Creek (SIG1)	Moderate	Low	High	Low	Low	Moderate	Moderate
Kelsey Creek (SIG2)	High	Moderate	Low	Low	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	High	High	Low	Low	Low	Moderate	Moderate
Rodman Slough (SIG4)	Moderate	Moderate	High	Moderate	Low	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Moderate	Low	Low	Moderate	Low	Moderate	Low
Overall Condition	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate

Table 5.5b Current recruitment condition analysis for the Clear Lake population of Clear Lake hitch. See Table 5.4b for a description of the recruitment condition categories.

Clear Lake Population Analysis Unit (AU)	Demographic Factor - Recruitment		Overall Current Recruitment Condition
	Wetland Habitat	Otolith Analysis	
Cole Creek (SIG1)	Moderate	Low	Low
Kelsey Creek (SIG2)	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	Moderate	High	High
Rodman Slough (SIG4)	Moderate	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Low

Table 5.6 Current resiliency for each of the Clear Lake hitch populations.

Population	Demographic Factors		Habitat Elements				Current Condition
	Reproduction	Recruitment	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Thurston Lake	--	--	--	--	--	--	High
Clear Lake	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate

5.5 Current Species Representation

The Clear Lake hitch currently has a low level of representation. Although the subspecies currently has different spawning strategies they can utilize under variable environmental conditions, the subspecies occupies a very narrow range with similar habitat characteristics.

5.6 Current Species Redundancy

The Clear Lake hitch currently has a moderate level of redundancy. Although the subspecies currently has two separate populations (Thurston Lake and Clear Lake) it is possible a catastrophic event could still impact the entire range of the species. The hitch also expresses some within population redundancy by being able to utilize different habitats for reproduction and through the number of available tributary streams within the Clear Lake population.

5.7 Summary of Current Condition

We used the best available information to determine the current condition of the Clear Lake hitch. Our goal was to describe the viability of the subspecies in a manner that will address the needs of the hitch in terms of resiliency, representation, and redundancy. When considering the current condition of the Clear Lake hitch, we considered the following factors influencing the subspecies:

1. The loss of spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams. The lack of consistent tributary flow seen in the Clear Lake watershed is due to the effects of past instream gravel mining, deforestation, and grazing practices, existing flood control project infrastructure, fire activity, and water utilization for agricultural and urban uses. Passage barriers in the watershed

include the lack of adequate tributary flow and physical barriers such as dams, diversions, roadways, and crossings;

2. The conversion and loss of wetland/tule habitat for agricultural production and urban development;

3. Reductions in lake water quality due to the loss of wetland/tule habitat surrounding the lake, contamination from past mercury mining along the lake's shore and pesticide use for agricultural and urban uses, the input of sediment and nutrients from degraded tributary streams, and nutrient inputs from surrounding urban and agricultural development. Increased nutrient and sediment inputs have contributed to periodic cyanobacteria blooms, which further reduce water quality;

4. The past introduction and establishment of non-native fish species;

5. Drought conditions within the Clear Lake watershed further reducing tributary flow during the spawning season; and

6. The implementation of current regulatory mechanisms (i.e., CESA, Lake County's Clear Lake Shoreline Ordinance) and management actions (i.e., Lake County's Aggregate Resources Management Plan, other miscellaneous restoration actions occurring throughout the watershed).

The various past and current negative influencing factors detailed above have significantly reduced the current abundance of hitch, primarily due to reductions in reproductive success, recruitment, and survival. These influences were used, in addition to implemented management actions, to assess the current condition of the Clear Lake hitch in terms of the 3 Rs. Currently, the Clear Lake hitch has one population at a high resiliency (Thurston Lake) and one at a moderate resiliency (Clear Lake). The Clear Lake hitch currently has a low level of representation; however, the subspecies has never had a high level of representation due to its very narrow range with similar habitat characteristics. The Clear Lake hitch is currently at a moderate level of redundancy. Both the Thurston and Clear Lake populations are currently extant, and each likely expresses within population redundancy in spawning habitat types and/or the number of available tributary streams.

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CHAPTER 6: FUTURE CONDITION

6.1 Introduction

We have considered what the Clear Lake hitch needs for long term viability (Chapter 3), evaluated the past, current, and future factors that are influencing those needs (Chapter 4), and we determined the current condition of those needs (Chapter 5). We now will analyze the subspecies' future condition by considering how those past and current influencing factors described in Chapter 4 will continue to act on the subspecies into the future, and how those influencing factors will impact the future condition of the Clear Lake hitch's needs (i.e., demographic factors and habitat elements). We apply our future projections to the concepts of resiliency, representation, and redundancy to describe the future viability of the Clear Lake hitch.

Although the Clear Lake hitch population has declined significantly in overall observed abundance (see Sections 5.1 and 5.2), it currently occupies most of its historical range. There are currently two separate populations of hitch, one that resides in Clear Lake and its tributaries, and one that occupies Thurston Lake and its tributary. Historically, the hitch spawning run would fill the surrounding tributary streams, producing an abundance of hitch that the local tribes relied on for sustenance. However, as the watershed underwent European settlement and the various activities described in Chapter 4 modified the watershed, the number of tributary streams available to the subspecies for reproduction during the spawning season decreased. In addition, the amount of available wetland habitat decreased from the reclamation and conversion of large wetland tracts surrounding the lake. These impacts to the watershed reduced reproductive and recruitment success for the subspecies, and caused an overall population decline.

The different combinations of influencing factors, both negative and positive (i.e., regulatory mechanisms and management actions), discussed in Chapter 4 that will continue to act on the subspecies into the future could result in varying changes to each of the Clear Lake hitch populations throughout its range. A reduction or increase in the number of available natal habitat types and tributary streams or impacts to lake water quality can reduce or increase that population's resiliency. Any reduction or increase in resiliency will further reduce or increase the level of redundancy and representation the subspecies expresses. However, neither redundancy nor representation should ever be considered at a high level because of the hitch's narrow range and low variability of habitat characteristics across the species' geographical range. As a consequence of those influencing factors acting on the subspecies and the subspecies' current condition (see Chapter 5), the future viability of the Clear Lake hitch now primarily depends on ensuring successful reproduction and recruitment to maintain or increase overall population abundance. This can be accomplished by preventing further destruction of natal and rearing habitats, maintaining or improving the water quality within Clear Lake, and potentially, the restoration of tributary streams so they can retain water throughout the spawning season.

Table 5.3 above describes those influencing factors we carried forward for the future condition analysis. These influencing factors will be used, in addition to implemented management actions, to assess the possible future condition of each Clear Lake hitch under three different scenarios. The future resiliency of each population will help describe the level of redundancy and representation the subspecies will express in the future, under that specific scenario. However, neither redundancy nor representation could ever be considered at a high level under any scenario due to the hitch's narrow range and low variability of habitat characteristics across the subspecies' geographical range.

6.1.1 Summary of Methods

Because we have significant uncertainty regarding if, when, where, and/or to what extent agricultural production, urban development, restoration actions, or climate effects may occur, we have forecast the possible viability of the Clear Lake hitch in terms of resiliency, representation, and redundancy under three plausible future scenarios. We chose to forecast the future scenarios for Clear Lake hitch viability over the next 50 years because it is within the range of the available climate change model projections for the North Coast Region, where Clear Lake is located (Grantham 2018; Pierce *et al.* 2018). These projections are given over two different time periods, one out 50 years (2040-2069) and one out to the end of the century (2070-2099). We chose the shorter timeframe because the two emissions scenarios used in the climate models, RCP 4.5 and RCP 8.5, have similar precipitation and temperature projections into the mid-century (2040-2069). Beyond this time period, both temperature and precipitation projections begin to diverge. Because we are uncertain what emissions trajectory we will follow into the future, and that uncertainty increases with time, we are being conservative and are using the shorter time period for this analysis. Because the rate of urban development has slowed in the last decade, we do not anticipate a significant amount of urban growth into the future. The timeframe for the current Lake County General Plan is 20 years and only projects growth out to 2028; however, we still do not expect growth to increase much after 2028. Although the amount of agricultural development increased substantially leading up to the 21st century, over the last 10 years or so the acreage of fruit, nut, field, seed, and vegetable crops in Lake County only slightly increased. Therefore, we do not anticipate a substantial increase in the amount of agricultural production into the future and do not have a specific timeframe to project the rate agricultural production into the future. It should be noted that the presence of agricultural production in the watershed will continue to result in sediment and nutrients entering the lake into the future.

Scenario 1 evaluates the condition of the Clear Lake hitch if there is a similar or slight increase in the amount of being water extracted from the watershed and the number of restoration actions being performed throughout the watershed from what exists today. It also takes into account climate change and what effects it may have on those influencing factors already acting on the subspecies. The other scenarios will evaluate the response of the subspecies to different changes in each of those influencing factors. For each scenario we describe the factors influencing viability that would occur in each analysis unit and population, and the subspecies' response. Since the entire Thurston Lake population is completely within the Thurston Lake HUC 12, we will continue to evaluate that population using just the one analysis unit when analyzing future scenarios.

We examine the resiliency, representation, and redundancy of the Clear Lake hitch under each of these three plausible scenarios. The resiliency of a Clear Lake hitch population depends on future environmental conditions and the availability of spawning and rearing habitat within that population. We expect each population to experience changes to these aspects of their habitat in different ways under the different scenarios. We projected the expected future resiliency of each population based on the events that may occur under each scenario and then projected an overall condition for the subspecies. For these projections, populations in high condition are expected to have high resiliency at that time period; i.e., there are multiple tributaries available throughout the spawning season and the different natal habitats are present and can be used for reproduction, individuals within a population are reproducing successfully and actively recruiting, and the amount and quality of spawning and rearing habitat is sufficient to allow for varying population densities.

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Populations in high condition are expected to persist into the future, beyond 50 years, and have the ability to withstand stochastic events that may occur. Populations in moderate condition are less resilient than those in high condition, but are expected to persist beyond 50 years. Populations in moderate condition may contain fewer natal and spawning habitats, and therefore, will contribute less to reproduction and recruitment than those populations in high condition. Finally, those populations in low condition have low resiliency and may not be able to withstand stochastic events. As a result, populations in low condition are less likely to persist for 50 years; however, a population in a low condition does not automatically mean the population cannot support any reproduction or recruitment, it just means those demographic factors are greatly reduced.

6.2 Scenario 1

Under Scenario 1, those factors that are having an influence on each of the Clear Lake hitch populations continue at current rates, or slightly increase. The effects of climate change, specifically increased aridity, are already occurring throughout the watershed, although the effects of increased aridity are not apparent every year. Future drought conditions are projected to increase in both the number of years drought conditions persist and the intensity of drought. Due to the increased incidence of aridity, and because future climate projections show the timing of precipitation will change, some years the number of spawning tributaries available to the subspecies over the spawning season will decrease. Increased fire and flooding incidence will increase the amount of erosion occurring in the tributary streams, decreasing lake water quality. As conditions worsen in the tributary streams, the subspecies will have to increasingly rely on spawning in the lake or the mouths of streams. Because the Clear Lake hitch is a state listed species, direct take will continue to be limited. Due to Lake County's shoreline ordinance, existing wetland/tule habitats surrounding the lake will continue to persist. Under Scenario 1, restoration projects (contaminant remediation, tributary function, barrier removal) continue to be implemented at a small scale throughout the watershed. Scenario 1 assumes the benefits of the Middle Creek Project have not been fully met (i.e., has not yet been fully constructed; see Section 4.9 Regulatory Mechanisms and Management Actions for a full description of benefits associated with the Middle Creek Project). A detailed analysis of each Clear Lake population analysis unit is shown in Tables 6.1a and 6.1b. The future condition of each Clear Lake hitch population under Scenario 1 is shown in Table 6.2.

6.2.1 Resiliency

<u>Thurston Lake Population</u>

Thurston Lake – Under Scenario 1, the resiliency of the Thurston Lake population will decline from high to a moderate level due to effects from climate change. Climate change will impact this population by reducing the availability of spawning habitats in some years and by reducing lake water quality. The one tributary stream to the lake, Thurston Creek, may not have continual flow to accommodate spawning every year.

<u>Clear Lake Population</u>

SIG 1 (Cole Creek) – In Scenario 1, SIG 1 experiences an increase in aridity during some years due to climate change. The increase in aridity would result in reduced spawning tributary availability during that year and a slight potential reduction in natal habitat variety. Since this analysis unit is within the Big Valley groundwater basin, the implementation of sustainable groundwater use through SGMA may increase the amount of water retained within the tributary creeks, reducing the effects of arid conditions during some years due to climate change. Under this scenario, SIG 1 would maintain a moderate resiliency.

SIG 2 (Kelsey Creek) – This analysis unit will also experience an increase in aridity during some years due to climate change. Similar to SIG 1, the increase in aridity would result in a potential reduction in natal habitat variety and reduced spawning tributary availability during those years. Because SIG 2 is in the Big Valley groundwater basin, implementation of SGMA may increase the amount of water retained within the tributary creeks, reducing the effects of climate change. Under Scenario 1, this analysis unit would maintain a moderate resiliency.

SIG 3 (Adobe Creek and Clear Lake) – SIG 3, which includes both Adobe Creek and Clear Lake, will also experience an increase in aridity during some years due to climate change under Scenario 1. Similar to SIG's 1 and 2, the increase in aridity would reduce spawning tributary availability, especially since this SIG will likely continue to have a high concentration of passage barriers. During drought years, there will likely be a reduction in the number of natal habitats the subspecies can utilize since the tributary streams may not be fully available. Because Adobe Creek is in the Big Valley groundwater basin, implementation of SGMA may increase the amount of water retained within the tributary creeks, reducing the effects of climate change. This analysis unit would maintain a moderate resiliency under Scenario 1.

SIG 4 (Rodman Slough) – This analysis unit will also experience an increase in aridity during some years due to climate change, which would reduce spawning tributary availability during those years. However, because a large portion of spawning habitat within this unit is contained within the lake, impacts due to climate change will be less than the other SIG's. Under Scenario 1, SIG 4 would maintain a moderate resiliency.

SIG 5 (Middle, Clover, and Seigler Canyon Creeks) – Similar to SIG's 1 and 2, SIG 5 will experience increased aridity during some years due to climate change under Scenario 1. Also comparable to those SIG's, the effects of climate change will reduce tributary availability over the spawning season and natal habitat variety. Unlike SIG's 1 and 2, SIG 5 is not included in the Big Valley groundwater basin and any benefits from SGMA will not apply to this analysis unit; however, overdraft is not projected to be as much of an issue in this unit. Therefore, SIG 5 would maintain a low resiliency under Scenario 1.

Table 6.1a Future condition for each of the Clear Lake population analysis units and the overall future condition of the Clear Lake hitch under Scenario 1. See Table 6.1b for the detailed future recruitment analysis under Scenario 1.

Clear Lake Population Analysis Unit (AU)	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment (see Table 6.1b)	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Cole Creek (SIG1)	Moderate	Low	High	Low	Low	Moderate	Moderate
Kelsey Creek (SIG2)	High	Moderate	Low	Low	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	High	High	Low	Low	Low	Moderate	Moderate
Rodman Slough (SIG4)	Moderate	Moderate	High	Moderate	Low	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Moderate	Low	Low	Moderate	Low	Moderate	Low
Overall Condition	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate

Table 6.1b Future recruitment condition analysis for the Clear Lake population of Clear Lake hitch under Scenario 1.

Clear Lake Population Analysis Unit (AU)	Demographic Factor - Recruitment		Overall Future Recruitment Condition
	Wetland Habitat	Otolith Analysis	
Cole Creek (SIG1)	Moderate	Low	Low
Kelsey Creek (SIG2)	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	Moderate	High	High
Rodman Slough (SIG4)	Moderate	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Low

Overall Clear Lake Population – Under Scenario 1, the Clear Lake population maintains a moderate level of resiliency. The effects of climate change, specifically increased aridity, may reduce or eliminate stream based spawning in some years; however, future climate change projections do not predict increased aridity every year and the subspecies will still have the ability to spawn in other lake based habitats when drought conditions do occur. In addition, small-scale restoration projects throughout the watershed will increase the amount of available spawning habitat available to the hitch when conditions do allow for stream based spawning.

Table 6.2 Future resiliency for each of the Clear Lake hitch populations under Scenario 1

Population	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Thurston Lake	--	--	--	--	--	--	Moderate
Clear Lake	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate

Scenario 1 projects the condition of each Clear Lake hitch analysis unit if the current risks continue on the same, or a very similar, trajectory they are on now. Overall, four of the five Clear Lake population analysis units would be at a moderate condition and one would be at a low condition. The Thurston Lake analysis unit, and population overall, would be at a moderate condition

Over the next 50 years, this scenario is most likely to occur since we expect climate change to continue (thereby increasing the likelihood of aridity) and the amount of water use within the watershed will only slightly increase due to urban development and agricultural production. We also expect groundwater resources will slightly improve in the Big Valley groundwater basin due to the implementation of SGMA, and we expect small scale restoration projects to continue throughout the watershed.

6.2.2 Representation

The Clear Lake hitch currently has a low level of representation and that is unlikely to change under Scenario 1. Under this scenario, the subspecies will continue to have different spawning strategies to utilize under different environmental conditions.

6.2.3 Redundancy

Under Scenario 1, the Clear Lake hitch will likely continue to maintain its current moderate level of redundancy, as both populations are expected to be maintained and the variety of habitats that can currently be utilized for reproduction will continue to be available to each hitch population. However, because the resiliency of the Thurston Lake population is expected to decrease due to an increased incidence of drought, redundancy will decrease slightly.

6.3 Scenario 2

Scenario 2 is a best case scenario for the Clear Lake hitch, where all of the analysis units within the Clear Lake population either retain or improve their current condition due to restoration and enhancement activities throughout the watershed. Similar to Scenario 1, those factors that are currently having a negative influence on each of the Clear Lake hitch populations continue at current rates, or slightly increase. Under this scenario, the effects of climate change affect the entire watershed, although they may not occur annually. Drought conditions are projected to increase and some years the number of spawning tributaries available to the subspecies over the spawning season will decrease. Erosion within the tributary streams will continue to be an issue due to increased incidence of fire and flooding, and as a consequence the water quality in the lake will decrease. However, restoration actions will also increase throughout the watershed, including the construction of the Middle Creek Project. The restoration of tributary streams will improve water retention throughout the spawning season, the removal of passage barriers will increase the amount of tributary habitat the subspecies can use for spawning, and construction of the Middle Creek Project will increase the amount of available rearing habitat, improving that habitat element for the Clear Lake population from low to moderate condition. These activities will all increase reproductive success and increase the likelihood of recruitment within Clear Lake. The restoration of tributary streams and the creation of wetland habitats surrounding the lake from the Middle Creek Project will improve the water quality of Clear Lake, but not enough to increase it from a moderate to a high condition because mercury contamination and nutrient input are not likely to cease. Like Scenario 1, the direct take of hitch will continue to be limited by CESA, and the existing wetland/tule habitats surrounding the lake will continue to persist due to county ordinances. A detailed analysis of each Clear Lake population analysis unit is shown in Tables 6.3a and 6.3b. The future condition of each Clear Lake hitch population under Scenario 2 is shown in Table 6.4.

6.3.1 Resiliency

<u>Thurston Lake Population</u>

Thurston Lake – Like Scenario 1, the resiliency of the Thurston Lake population will decline to a moderate level due to effects from climate change under Scenario 2. Climate change will impact this population by reducing the availability of spawning habitats in some years. The one tributary stream to the lake, Thurston Creek, may not have continual flow to accommodate spawning every year and the water quality within the lake will likely decrease. Even though restoration projects are occurring throughout the watershed under this scenario, those efforts are not directed to the Thurston Lake sub-watershed.

<u>Clear Lake Population</u>

SIG 1 (Cole Creek) – In Scenario 2, SIG 1 experiences an increase in aridity during some years due to climate change. The increase in aridity could reduce tributary availability and natal habitat variety; however, due to restoration actions within the watershed, the tributary creeks will be able to retain water until later in the season, and miles of additional tributary habitat will become available with the

removal of passage barriers. Those factors, along with the increase of wetland habitat for rearing, will increase reproductive success and recruitment within SIG 1 under Scenario 2. Although the condition of most demographic factors and habitat elements increase under this scenario, resiliency would be maintained at a moderate level.

SIG 2 (Kelsey Creek) – Analysis unit SIG 2 experiences an increase in aridity during some years due to climate change. Similar to SIG 1, the increase in aridity would reduce natal habitat variety and tributary availability, but restoration actions throughout the watershed would help in countering those negative effects and would improve stream function. The removal of passage barriers within this unit increases the amount of tributary habitat available to the subspecies for spawning. Under Scenario 2, the resiliency of SIG 2 will be maintained at moderate.

SIG 3 (Adobe Creek and Clear Lake) – The resiliency of the SIG 3 analysis unit will be maintained at a moderate level under Scenario 2. Even though the effects of climate change are still projected to occur, the restoration of spawning and rearing habitat will improve the tributary water quantity and wetland/tule habitat elements, and the removal of passage barriers will increase connectivity.

SIG 4 (Rodman Slough) – Conditions in SIG 4 under Scenario 2 will primarily stay the same, except for an increase of wetland/tule habitat due to restoration projects, which will increase recruitment. Although tributary restoration improved water quantity conditions in SIG's 1–3 under this scenario, this unit is already currently at a moderate condition and effects from climate change make it unlikely for any high condition to occur within the watershed. Under Scenario 2, SIG 4 would maintain a moderate resiliency.

SIG 5 (Middle, Clover, and Seigler Canyon Creeks) – Under Scenario 1 the Middle Creek Project is constructed and this analysis unit will receive the bulk of the benefit from it, primarily through an increase in habitat that supports successful reproduction and population recruitment. Like all of the analysis units in this scenario, climate change will effect SIG 5 through increased incidence of drought, but restoration actions will help counter those effects. The resiliency of SIG 5 will increase to a moderate condition under Scenario 2.

Table 6.3a Future condition for each of the Clear Lake population analysis units and the overall future condition of the Clear Lake hitch under Scenario 2. See Table 6.3b for the detailed future recruitment analysis under Scenario 2.

Clear Lake Population Analysis Unit (AU)	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment (see Table 6.3b)	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Cole Creek (SIG1)	High	Moderate	High	Moderate	Moderate	Moderate	Moderate
Kelsey Creek (SIG2)	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	High	High	Moderate	Moderate	Moderate	Moderate	Moderate
Rodman Slough (SIG4)	Moderate	High	High	Moderate	Moderate	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Overall Condition	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Table 6.3b Future recruitment condition analysis for the Clear Lake population of Clear Lake hitch under Scenario 2.

Clear Lake Population Analysis Unit (AU)	Demographic Factor - Recruitment		Overall Future Recruitment Condition
	Wetland Habitat	Otolith Analysis	
Cole Creek (SIG1)	High	Moderate	Moderate
Kelsey Creek (SIG2)	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	High	High	High
Rodman Slough (SIG4)	High	High	High
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	High	Moderate	Moderate

Overall Clear Lake Population – Under Scenario 2, the Clear Lake population maintains a moderate level of resiliency, although a majority of factors/elements increase in condition due to the implementation of restoration efforts throughout the watershed. The effects of climate change, specifically increased aridity, may reduce or eliminate stream based spawning in some years; however, future climate change projections do not predict increased aridity every year and the subspecies will still have the ability to spawn in other lake based habitats when drought conditions do occur.

Table 6.4 Future resiliency for each of the Clear Lake hitch populations under Scenario 2

Population	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Thurston Lake	--	--	--	--	--	--	Moderate
Clear Lake	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Scenario 2 provides an idea of the Clear Lake hitch's best possible condition over the next 50 years. This scenario presumes all of the analysis units within the Clear Lake population are able to maintain or improve their current condition. Because most restoration activities are likely to be concentrated on tributaries to Clear Lake and the lake itself, and climate change impacts will be felt throughout the watershed, the resiliency of Thurston Lake will decrease from high to moderate. Under Scenario 2, all five analysis units within the Clear Lake population would be at a moderate condition.

Over the next 50 years, this scenario is not the most likely to occur because large scale restoration projects like the Middle Creek Project and numerous small scale restoration projects spread throughout the watershed will require a lot of money and coordination. It is possible a small subset of restoration projects could occur over the next 50 years, potentially even the Middle Creek Project; however, the wide scale restoration of the entire watershed as described in this scenario is not likely to be completed within the 50 year timeframe.

6.3.2 Representation

Under Scenario 2, the Clear Lake hitch will continue to have a low level of representation. Although conditions will improve throughout portions of the watershed, the subspecies will still be restricted to the same watershed, will continue to occupy the same ecological niche, and will continue to have the current spawning strategies available in the future. Therefore, the level of representation will not change under this scenario.

6.3.3 Redundancy

The Clear Lake hitch will likely continue to maintain its current moderate level of redundancy under Scenario 2, even with improved conditions throughout most of the watershed. Because the subspecies occurs within a narrow range, and the entire subspecies could be susceptible to a potential catastrophic event, the hitch will never be at a high level of redundancy. Under this scenario, both populations and the different natal habitat types within each population will continue to be maintained.

6.4 Scenario 3

Under Scenario 3, some of the risks we forecasted would continue to occur, and some that are predicted to stay constant may increase. In this scenario, climate change results in more arid conditions throughout the subspecies' range and impacts from increased fire and flooding will increase erosion occurring in the tributary streams, further decreasing water quality within the lake to a low condition. As conditions worsen in the tributary streams, the subspecies will have to increasingly rely on spawning in the lake or in the mouths of streams. In addition, under this scenario agricultural production slightly increases in areas currently not prioritized by SGMA, no or very few small scale restoration projects have been implemented, the Middle Creek Project has not been constructed, and no passage barriers have been removed. Under Scenario 3, Lake County's shoreline ordinance will continue to limit tule habitat loss and take of individuals will be limited by CESA. A detailed analysis of each Clear Lake population analysis unit is shown in Tables 6.5a and 6.5b. The future condition of each Clear Lake hitch population under Scenario 3 is shown in Table 6.6.

6.4.1 Resiliency

<u>Thurston Lake Population</u>

Thurston Lake – Similar to Scenarios 1 and 2, the resiliency of the Thurston Lake population in Scenario 3 will decline to a moderate level due to effects from climate change. Climate change will impact this population by reducing the availability of spawning habitats in some years. The one tributary stream to the lake, Thurston Creek, may not have continual flow to accommodate spawning every year and the water quality within the lake will likely decrease.

<u>Clear Lake Population</u>

SIG 1 (Cole Creek) – In Scenario 3, SIG 1 experiences an increase in aridity during some years due to climate change. The increase in aridity will reduce tributary availability and natal habitat variety, reducing reproduction and connectivity within the analysis unit. Under this scenario, the condition of SIG 1 would decline to low resiliency.

SIG 2 (Kelsey Creek) – SIG 2 experiences an increase in aridity during some years due to climate change in this scenario. Similar to SIG 1, the increase in aridity would reduce natal habitat variety

and tributary availability, reducing both reproduction and recruitment to a moderate and low level, respectively. In Scenario 3, the resiliency of SIG 2 will decrease to low.

SIG 3 (Adobe Creek and Clear Lake) – The resiliency of the SIG 3 analysis unit will decrease to a low condition under Scenario 3 for the same reasons SIG 2 declined. Although reproduction and recruitment decline under this scenario, they only decline to a moderate condition. This is due to the presence of the lake within this unit and the increasing reliance on the lake for spawning during drought conditions.

SIG 4 (Rodman Slough) – Conditions in SIG 4 under Scenario 3 will decrease to a low condition. The increase in aridity due to climate change will reduce flow conditions within the tributary streams, reducing connectivity throughout the watershed. Because this unit includes a backwater-like area of the lake, the condition of reproduction and recruitment is maintained at moderate.

SIG 5 (Middle, Clover, and Seigler Canyon Creeks) – Under Scenario 3, the condition of the SIG 5 analysis unit is maintained at low, with reductions in the conditions of some factors/elements. Effects from climate change and a slight increase in agricultural production will reduce tributary availability during the spawning season and ultimately, reproduction.

Table 6.5a Future condition for each of the Clear Lake population analysis units and the overall future condition of the Clear Lake hitch under Scenario 3. See Table 6.5b for the detailed future recruitment analysis under Scenario 3.

Clear Lake Population Analysis Unit (AU)	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment (see Table 6.5b)	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Cole Creek (SIG1)	Low	Low	Moderate	Low	Low	Low	Low
Kelsey Creek (SIG2)	Moderate	Low	Low	Low	Low	Low	Low
Clear Lake, Adobe Creek (SIG3)	Moderate	Moderate	Low	Low	Low	Low	Low
Rodman Slough (SIG4)	Moderate	Moderate	Moderate	Low	Low	Low	Low
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Low	Low	Low	Low	Low
Overall Condition	Low	Low	Low	Low	Low	Low	Low

Table 6.5b Future recruitment condition analysis for the Clear Lake population of Clear Lake hitch under Scenario 3.

Clear Lake Population Analysis Unit (AU)	Demographic Factor - Recruitment		Overall Recruitment Condition
	Wetland Habitat	Otolith Analysis	
Cole Creek (SIG1)	Low	Low	Low
Kelsey Creek (SIG2)	Low	Low	Low
Clear Lake, Adobe Creek (SIG3)	Low	Moderate	Moderate
Rodman Slough (SIG4)	Moderate	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Low

Overall Clear Lake Population – Under Scenario 3, the Clear Lake population declines to a low level of resiliency. The effects of climate change may reduce or eliminate stream based spawning in some years and will likely increase tributary erosion due to increased incidence of fire and flooding, further reducing lake water quality. Increased reliance on water resources for agricultural purposes further reduces the amount of water retained within tributary streams, especially during drought conditions.

Table 6.6 Future resiliency for each of the Clear Lake hitch populations under Scenario 3.

Population	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Thurston Lake	--	--	--	--	--	--	Moderate
Clear Lake	Low	Low	Low	Low	Low	Low	Low

Scenario 3 provides an idea of the Clear Lake hitch's condition over the next 50 years when the effects of agricultural production slightly increase in areas where production is not currently concentrated, effects from climate change impact the entire watershed, and little to no restoration actions occur in the watershed. Overall, Thurston Lake would decline to a moderate condition and the Clear Lake population would decline to a low condition. Within the Clear Lake population, SIG's 1-4 would all decline to a low condition and SIG 5 would be maintained at a low condition.

Over the next 50 years, this scenario could occur, but is not the most likely. Effects due to climate change are projected to continue and the amount of water use within the watershed will only slightly increase due to urban development and agricultural production within the Clear Lake area over time. With the implementation of SGMA, analysis units within the Big Valley groundwater basin may not experience any increase in agriculture; however, this may not limit agricultural expansion into the other groundwater basins within the range. Because various restoration projects have been periodically implemented throughout the watershed, the lack of restoration described under this scenario is not likely to occur, but is possible.

6.4.2 Representation

Clear Lake hitch representation under Scenario 3 will continue to be at a low level. Because of deteriorated conditions throughout the watershed, the subspecies may not have all spawning strategies to utilize in any given year.

6.4.3 Redundancy

Under Scenario 3, the level of redundancy for the Clear Lake hitch will likely decrease to low. Although both populations will still be extant, the Thurston Lake population will decline to moderate resiliency and the Clear Lake population will decline to low resiliency due to the deteriorated condition of the watershed under this scenario. In addition, each of the different natal habitats available to each of the populations may no longer be available or may have only limited availability in the future. The availability of tributary streams for the Clear Lake population in particular are likely to decrease. Under this scenario, the Clear Lake hitch would be particularly susceptible to a potential catastrophic event.

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6.5 Summary of Future Condition

We used the best available information to forecast the likely future condition of the Clear Lake hitch. Our goal was to describe the viability of the subspecies in a manner that will address the needs of the subspecies in terms of resiliency, representation, and redundancy. We considered the possible future condition of the subspecies under three different potential scenarios, using the following current and future influencing factors consistently throughout each scenario:

1. The loss of spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams. The lack of consistent tributary flow will continue due to the effects of past instream gravel mining, deforestation, and grazing practices, existing flood control project infrastructure, fire activity, and water utilization for agricultural and urban uses. We do not expect the rate of agricultural production or urban development to increase substantially into the future. Furthermore, future climate change is projected to further exacerbate the degradation and inaccessibility of tributary streams by increasing the incidence of fire activity, flood events, and aridity. Various passage barriers, both physical barriers and lack of flow, will continue to persist in the watershed;

2. The loss of wetland/tule habitat. The current remaining wetland/tule habitat surrounding the lake will persist into the future, primarily due to the implementation of Lake County's shoreline ordinance;

3. Continued reductions in lake water quality due to the past loss of wetland/tule habitat surrounding the lake, contamination from past mercury mining along the lake's shore and pesticide use for agricultural and urban uses, the input of sediment and nutrients from degraded tributary streams, and nutrient inputs from surrounding urban and agricultural development. Like mentioned above, we do not project agricultural production or urban development to increase substantially into the future. Increased nutrient and sediment inputs continue to contribute to periodic cyanobacteria blooms, further reducing water quality. Periodic fish kills continue to occur;

4. Non-native fish species are still established within the lake from past introductions; and

5. Drought incidence and intensity increase due to climate change, reducing tributary flow during the spawning season in some years; and

6. The implementation of current regulatory mechanisms (i.e., CESA, Lake County's Clear Lake Shoreline Ordinance) and management actions (i.e., Lake County's Aggregate Resources Management Plan, other miscellaneous restoration actions occurring throughout the watershed).

These influencing factors were used to assess the possible future condition of the Clear Lake hitch under three different scenarios, in terms of the 3 Rs. These influencing factors are likely to continue to both negatively and positively affect the Clear Lake hitch, primarily due to reductions or increases in reproductive success, recruitment, and survival. A summary of our analysis under each of the three different potential future scenarios are as follows (see Figures 6.7 and 6.8):

Scenario 1, those factors that are currently having an influence on each of the Clear Lake hitch populations continue at current rates, or may slightly increase, for all of the influencing

factors. Under Scenario 1, we project both Clear Lake hitch populations would be at moderate condition.

Scenario 2, those factors that are currently having a negative influence on each of the Clear Lake hitch populations continue at current rates, or slightly increase. Scenario 2 is the best case scenario for the Clear Lake hitch because all of the analysis units within the Clear Lake population either retain or improve their current condition due to restoration and enhancement activities being implemented throughout the watershed. Under Scenario 2, we project both Clear Lake hitch populations would be at a moderate condition.

Scenario 3: Under Scenario 3, some of the risks would continue to occur at their current rates, and some that are predicted to stay constant may increase. In Scenario 3 we project the Thurston Lake population would decline to a moderate condition and the Clear Lake population would decline to a low condition.

Table 6.7 Summary of Clear Lake population analysis unit resiliency under current conditions and under each future scenario

Clear Lake Population Analysis Unit (AU)	Current Condition	Scenario 1 Future Condition	Scenario 2 Future Condition	Scenario 3 Future Condition
Cole Creek (SIG1)	Moderate	Moderate	Moderate	Low
Kelsey Creek (SIG2)	Moderate	Moderate	Moderate	Low
Clear Lake, Adobe Creek (SIG3)	Moderate	Moderate	Moderate	Low
Rodman Slough (SIG4)	Moderate	Moderate	Moderate	Low
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Moderate	Low

Table 6.8 Summary of Clear Lake hitch population resiliency under current conditions and each of the future scenarios.

Population	Current Condition	Scenario 1 Condition	Scenario 2 Condition	Scenario 3 Condition
Thurston Lake	High	Moderate	Moderate	Moderate
Clear Lake	Moderate	Moderate	Moderate	Low

Over the next 50 years, we believe Scenario 1 is the most likely to occur and Scenario 2 is the least likely to occur. We believe Scenario 1 is the most likely since we expect climate change is likely to continue (thereby increasing the likelihood of aridity, fire incidence, and flood incidence), future drought conditions are likely to increase, CESA will continue to limit direct take, the Lake County shoreline ordinance will continue to maintain the existing amount of available wetland/tule habitat surrounding the lake, and current small scale restoration projects will continue to be implemented into the future. Under this scenario, the Clear Lake hitch will continue to maintain its current low and moderate level of representation and redundancy, respectively.

Scenario 2 is not the most likely to occur because large scale restoration projects like the Middle Creek Project and numerous small scale restoration projects spread throughout the watershed will require extensive funding and coordination. It is possible a small subset of restoration projects will occur over the next 50 years, potentially even the Middle Creek Project; however, the wide scale restoration of the entire watershed as described in this scenario is not likely to occur. It is probable Scenario 3 could occur, but it is not the most likely when compared to Scenario 1. This is primarily because various restoration projects have been implemented throughout the watershed and the lack of restoration described under this scenario is not likely occur.

The Clear Lake hitch faces a variety of risks from habitat loss, degradation, and modification, increased predation and competition from the introduction of non-native fish, drought, and climate change. These risks, and the level in which they act upon the Clear Lake watershed, play a large role in the future viability of the Clear Lake hitch. If populations lose resiliency, the subspecies overall will have a further reduced level of representation and redundancy, which increases their risk of extirpation.

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Fw: [EXTERNAL] Fwd: Peer Review Request from USFWS - Clear Lake hitch

Powelson, Katherine W <katherine_powelson@fws.gov>
Mon 3/2/2020 12:15 PM
To: Aguilera, Amber <amber_aguilera@fws.gov>

1 attachments (19 MB)
20200106_CLH SSA_peer review by Moyle CLHITCH.docx;

Kat Powelson
Science Support Coordinator
(916) 278-9448 office
(916) 915-2692 cell

From: Peter Moyle <pbmoyle@ucdavis.edu>
Sent: Thursday, February 27, 2020 5:01 PM
To: Powelson, Katherine W <katherine_powelson@fws.gov>
Subject: Re: [EXTERNAL] Fwd: Peer Review Request from USFWS - Clear Lake hitch

Kat Powelson, USFWS

Here is the Status Assessment Report for Clear Lake Hitch with a few minor comments. I apologize for taking so long but eye surgery then a severe cold prevented me from getting much done for a couple of weeks.

Overall, the report is excellent and extremely thorough. The writing is clear and jargon is minimized. The viability analysis is convincing. Some minor comments:

Page 4, main report. The reference to Moyle et al. 2014 is apparently to a draft of the hitch account in the 2015 edition (3rd) of Fish Species of Special Concern in California. Moyle, P.B., R. M. Quiñones, J.V.E. Katz, and J. Weaver. 2015. Fish Species of Special Concern in California. 3rd edition. Sacramento: California Department of Fish and Wildlife. *https://www.wildlife.ca.gov/Conservation/Fishes/Special-Concern*

Your discussion of subspecies status is good. The population structure found in the genomic studies of Baumsteiger et al. was equivalent or stronger than found in salmonid populations listed as T&E even though they are 'only' have DPS/ESU designations. We thought there was no question the three recognized forms were sufficiently different to fit the formal listing requirements but also thought rather than argue about what level of difference makes subspecies vs a DPS, we would just indicate that the three subspecies already were described and named and fit the patterns showed by the genomics, so why not just retain the names?

I thought the scenarios were good but because scenario 1 and 2 both come out projecting the populations would be in moderate condition, the results could be interpreted that investment in habitat restoration would not be worth the effort. To me the different between the two is that in the long run, hitch populations are likely to decline under scenario 1 but scenario 2 restoration and enhancement activities are likely to at least maintain populations at the present level indefinitely, hence is the best scenario for keeping CL hitch from extinction.

Again, you and your team have done an excellent job with the analysis and this should be a useful document to managers. Please keep me on the list to receive a copy once it is formally approved.

Species Status Assessment for the Clear Lake Hitch (*Lavinia exilicauda chi*) Version 1.0

Clear Lake hitch displaying spawning behavior in a tributary to Clear Lake. Photo credit USGS, Fred Feyrer

January 2020
U.S. Fish and Wildlife Service
Region 8
Sacramento, California

Acknowledgements

This document was prepared by the U.S. Fish and Wildlife Service's Sacramento Field Office with assistance from the Pacific Southwest Regional Office and the….. Additionally, valuable peer reviews of a draft of this document were provided by XXX, CCC, WWW, and other partners, including members of YYY. We appreciate their comments, which resulted in a more robust status assessment and final report.

Suggested reference:
U.S. Fish and Wildlife Service. Year. Species Status Assessment for the Clear Lake Hitch (*Lavinia exilicauda chi*), Version 1.0. Month Year. Sacramento, California.

EXECUTIVE SUMMARY

On September 25, 2012, the U.S. Fish and Wildlife (Service) received a petition from the Center for Biological Diversity (CBD 2012, entire) to list the Clear Lake hitch (*Lavinia exilicauda chi*) as a threatened or endangered species under the Endangered Species Act of 1973, as amended (Act). On April 10, 2015, the Service published in the **Federal Register** a positive 90-day finding stating that the petition presented substantial scientific or commercial information indicating that listing the Clear Lake hitch may be warranted (80 FR 19259). As a result, we prepared this Species Status Assessment (SSA) Report to provide the scientific foundation for determining if the Clear lake hitch is warranted for listing under the Act.

The Clear Lake hitch 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 lake is surrounded by numerous tributaries, most of which are ephemeral and low gradient as they drain into the lake.

Historically, the Clear Lake hitch occurred in numerous lakes and ponds found throughout the Clear Lake watershed, including: Clear Lake, Thurston Lake, Upper Blue Lake, Lower Blue Lake, and Lampson Pond. During the spring, the Clear Lake hitch could also be found spawning in the numerous tributaries to these larger water bodies, including: Kelsey, Scott, Middle, Adobe, Seigler Canyon, Manning, Cole, Morrison, and Schindler Creeks. Currently, the subspecies is thought to be extirpated from the Blue Lakes, but still resides in Clear and Thurston Lakes throughout the year until the spring when reproductive adults migrate into tributary streams to spawn. The current status of the subspecies in Lampson Pond is unknown. Although all of the described waterbodies were hydrologically connected in the past, Thurston Lake and its tributary Thurston Creek are currently isolated from the other waterways. Although survey efforts have been conducted within the Clear Lake watershed, most were incidental to survey efforts that had a different purpose or were random documented observations; therefore, we do not have data on past or current population estimates for the subspecies.

Early accounts considered the hitch inhabiting Clear Lake to be identical to the hitch found in the Sacramento River (*Lavinia exilicauda*); however, in 1973 John D. Hopkirk described the Clear Lake hitch 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. Early genetic studies suggested the more wide spread species of hitch (*Lavinia exilicauda*) and the roach (*Hesperoleucus symmetricus*) are so genetically similar that they could be considered conspecifics, and further analysis found the two species showed such little genetic divergence that they could actually be considered congeners. A subsequent genetic analysis found the Clear Lake hitch shares mitochondrial DNA haplotypes with different forms of California roach outside of the Clear Lake watershed, and their status as a subspecies was not supported. However, a later analysis using nuclear and mitochondrial DNA had differing results. The nuclear DNA analysis supported the subspecies designation for the Clear Lake hitch, but the mitochondrial DNA analysis did not. A more recent genomic analysis suggests the three forms of hitch within California show strong population structuring but only weak subspecies structuring.

Adult Clear Lake hitch 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. Like other native juvenile cyprinids found in California, juvenile Clear Lake hitch 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.

The Clear Lake hitch grows much faster than other hitch subspecies found in lacustrine environments, most likely due to Clear Lake's high productivity and water temperatures. Females 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. Clear Lake hitch are thought to live 4 to 6 years, but it is possible some individuals can live longer. Because Clear Lake hitch females are much larger than the other subspecies of hitch within California, they are more fecund. A female Clear Lake hitch that is reproductive at age 3 and lives to age 6 could produce, on average, over 100,000 eggs over her lifetime.

For most of the year, Clear Lake hitch are only found within their lacustrine environment. However, between February and May, they begin to migrate into the surrounding tributaries to spawn. Spawning activities include one to five males pursuing a gravid female to fertilize her freshly extruded eggs, which are deposited on fine to medium sized gravel within the tributary stream. Fertilized eggs develop and hatch within 7 to 10 days, fry are free-swimming after another 7 to 10 days, and young migrate to the lake at about a month old before the streams dry up. Juvenile hitch are found within the nearshore habitat of the lake where they depend on submerged aquatic vegetation for cover and prey. Adult hitch move from the nearshore portion of the lake into open water. There is evidence that Clear Lake hitch do not require tributary streams with gravel to spawn, but can also spawn successfully in different portions of the lake (i.e., along the shore, the mouths of tributaries, and Rodman Slough) that lack a gravel substrate.

Clear Lake Hitch Viability Analysis

In order to assess the Clear Lake hitch's viability, we used the three conservation biology principles of resiliency, representation, and redundancy (together, the 3 Rs). These principles rely on assessing the subspecies at an individual, population, and subspecies level in order to help evaluate the likelihood that the Clear Lake hitch can sustain its persistence into the future. The Clear Lake hitch has two distinct, reproducing populations of Clear Lake hitch within the Clear Lake watershed: one in Clear Lake and its associated tributaries, and the other in Thurston Lake and its associated tributary, Thurston Creek. These two separate populations of Clear Lake hitch will be analyzed separately; however, the larger population within Clear Lake requires a more focused analysis of how different portions of Clear Lake contribute to the subspecies' overall viability. Therefore, in order to evaluate the 3 Rs and assess the subspecies' viability within Clear Lake we divided the Clear Lake watershed into Hydrologic Unit Code (HUC) 12 sub-watersheds and, because some of the sub-watersheds do not have all of the components that the subspecies requires to complete its life history and we have demographic data associated with more specific areas, we further grouped them into one of five SIG (strontium isotope groups) units. This further grouping was based on adult otolith strontium signatures that indicates natal origin, which provides information about reproduction and recruitment in those areas associated with the SIG.

A number of factors influence the resiliency of a Clear Lake hitch population, including reproduction, recruitment, and survival at all life stages. Influencing those factors is the quality and accessibility of

Clear Lake hitch habitat, which determines how well the spawning areas allow for successful reproduction, or whether the nearshore nursery areas allow for young-of-year survival and subsequent recruitment. Within the tributary streams, water quality and quantity are important factors influencing survival at all life stages, reproductive success, and recruitment, and is important for connectivity between spawning habitat and the lake. The presence of spawning gravel may influence reproductive success by increasing egg survival; however, there are instances of the subspecies successfully reproducing in areas that lack gravel, so this need may not be absolutely required for successful reproduction. The presence of instream and streamside vegetation within the tributary streams may increase survival for early life stages by providing cover from predators, instream temperature regulation, and prey.

Within the lake environment, both juvenile and adult Clear Lake hitch require clean water for survival. To increase juvenile survival and the likelihood that juveniles will be able to contribute to recruitment, the Clear Lake hitch require tules and/or other submerged vegetation within nearshore habitats to provide cover from predators and for prey. Adults require prey items in the open waters of the lake, which contributes to adult survival and provides resources to produce eggs and milt for reproduction.

Our analysis of the current condition of the subspecies revealed there are two populations of Clear Lake hitch, one of which has a high level of resiliency and the other a moderate level of resiliency. Because both populations of Clear Lake hitch occur within the same watershed and occupy the same ecological niche, the subspecies has never had much environmental diversity and it is likely it does not have much genetic diversity. Therefore, the Clear Lake hitch has likely never shown a high level of representation and currently has a low level of representation. For the Clear Lake hitch, representation is best measured by assessing the different spawning strategies available to the subspecies. The Clear Lake hitch has redundancy by having two isolated distinct populations. It also shows within population redundancy in the number of different types of spawning habitats they can utilize for reproduction (i.e., tributary, lake, or interface between the two), and the number of available tributary streams within the watershed. However, because redundancy gauges the probability that a species has a margin of safety to withstand or bounce back from a catastrophic event, and the Clear Lake hitch has such a narrow range, the Clear Lake hitch currently expresses moderate redundancy,.

Our analysis of the past, current, and future factors influencing the Clear Lake hitch revealed that there are six factors influencing the future viability of the subspecies. These factors influencing viability are primarily related to habitat changes (both negative and positive), although the introduction of non-native species is also a major influence. These influencing factors include: the loss of spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams, which reduces early life stage survival, reproductive success, and the likelihood of recruitment; the loss of wetland/tule habitat that juveniles require for rearing, which also reduces early life stage survival and the likelihood of recruitment; the effects from poor lake water quality, which reduces adult and juvenile survival; the effects of increased competition from a combination of introduced fish species and habitat loss, which reduces survival of all life stages, reproduction, and the likelihood of recruitment; drought, which further reduces tributary flow; and the implementation of regulatory mechanisms (i.e., CESA, Lake County's Clear Lake Shoreline Ordinance, and SGMA) and management actions (i.e., Lake County's Aggregate Resources Management Plan, Middle Creek Flood Damage Reduction and Ecosystem Restoration Project, and other miscellaneous restoration actions occurring throughout the watershed), which improve conditions in the watershed and provide protection to individual hitch. Furthermore, the negative influencing factors, especially drought, are all exacerbated by the effects of climate change.

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The influencing factors described above play a large role in the future viability of the Clear Lake hitch. Given our uncertainty regarding the rates at which future influencing factors may act on each of the populations and the uncertainty regarding funding or support for future beneficial actions (i.e., Middle Creek Flood Damage Reduction and Ecosystem Restoration Project), or the continuation of current beneficial actions to occur in the future (contaminant remediation, tributary function, barrier removal), we forecasted how possible future conditions could impact the resiliency, redundancy, representation, and overall condition of the Clear Lake hitch. In order to assess future condition, we developed three plausible future scenarios. The following is a description of the three future scenarios, the status of the Clear Lake hitch when analyzed under each scenario, and a summary of the assumptions we made under each scenario:

Scenario 1: Under Scenario 1, those factors that are currently having an influence on each of the Clear Lake hitch populations will either continue at current rates or may slightly increase, such as the incidence of drought and implementation of restoration actions. Under Scenario 1, we project the Thurston Lake population to decline to a moderate condition. The analysis units that make up the Clear Lake population will maintain a moderate condition except for SIG 5, which will maintain its low condition. The overall resiliency of the Clear Lake population will be maintained at a moderate level under Scenario 1.

Factors that are currently having an influence on the Clear Lake hitch continue at current rates for all of the influencing factors under this scenario. Projections under Scenario 1 include:

1. Climate change results in more arid conditions in some years throughout most of the range. Because the timing of precipitation is projected to change, some years the number of spawning tributaries available to the subspecies over the spawning season will be reduced. In addition, increased fire and flooding incidence due to climate change will increase the amount of erosion occurring in the tributary streams, further decreasing water quality within the lake.

2. Future drought conditions are projected to increase, both the number of years drought conditions persist and the intensity of drought. This will also impact the number of spawning tributaries available to the subspecies over the spawning season and will impact the water quality within the lake.

3. Direct take of Clear Lake hitch will be limited due to the subspecies listing under CESA.

4. The existing wetland/tule habitats surrounding the lake will continue to persist due to Lake County's shoreline ordinance.

5. Current restoration projects (contaminant remediation, tributary function, barrier removal) continue to be implemented at a small scale throughout the watershed. However, the Middle Creek Project has not yet been fully constructed.

6. Very little urban development occurs and the rate of agricultural production is similar to current rates.

Under Scenario 1, the Clear Lake hitch continues to have two populations within its range, although the resiliency of the Thurston Lake population declines from high to moderate. The level of

representation continues to be low under this scenario and although redundancy stays at a moderate level, it slightly declines within that level due to the loss of resiliency in the Thurston Lake population.

Scenario 2: Under Scenario 2, those influencing factors that are currently having a negative influence on each of the Clear Lake hitch populations continue at current rates, or slightly increase. Scenario 2 is the best case scenario for the Clear Lake hitch because all of the analysis units within the Clear Lake population either retain or improve their current condition due to restoration and enhancement activities being implemented throughout the watershed. Under Scenario 2, the overall level of resiliency for the Clear Lake and Thurston Lake populations will be moderate.

Similar to Scenario 1, those factors that are currently having an influence on both Clear Lake hitch populations continue at current rates for all of the influences. However, under this scenario, large-scale restoration and enhancement activities are implemented throughout the Clear Lake population watershed, benefiting the Clear Lake population. Projections under Scenario 2 include:

1. Climate change results in more arid conditions in some years throughout most of the range. Because the timing of precipitation is projected to change, some years the number of spawning tributaries available to the subspecies over the spawning season will be reduced. In addition, increased fire and flooding incidence due to climate change will increase the amount of erosion occurring in the tributary streams, further decreasing water quality within the lake.

2. Future drought conditions are projected to increase, both the number of years drought conditions persist and the intensity of drought. This will also impact the number of spawning tributaries available to the subspecies over the spawning season and will impact the water quality within the lake.

3. Direct take of Clear Lake hitch will be limited due to the subspecies listing under CESA.

4. The existing wetland/tule habitats surrounding the lake will continue to persist due to Lake County's shoreline ordinance.

5. Current restoration projects (contaminant remediation, tributary function, barrier removal) continue to be implemented throughout the watershed at an increased rate. In addition, the Middle Creek Project has been constructed, benefiting the Clear Lake population (the Thurston Lake population does not experience any additional benefit from the Middle Creek Project).

6. Very little urban development occurs and the rate of agricultural production is similar to current rates.

Under Scenario 2, the Clear Lake hitch continues to have two populations within its range, although, similar to Scenario 1, the resiliency of the Thurston Lake population declines from high to moderate. The level of representation continues to be low under this scenario and although redundancy stays at a moderate level, it slightly declines within that level due to the loss of resiliency in the Thurston Lake population.

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Scenario 3: Under Scenario 3, some of the factors would continue to occur at their current rates, and some that are predicted to stay constant may increase. In Scenario 3 we project the Clear Lake and Thurston Lake populations will decline to a low and moderate level of resiliency, respectively.

Similar to Scenarios 1 and 2, those factors that are currently having an influence on each of the Clear Lake populations continue at current rates for all of the influences. However, under this scenario, agricultural production slightly increases in areas not prioritized under the Sustainable Groundwater Management Act (SGMA) and restoration projects are not implemented (i.e., no or very few small scale restoration projects are implemented, the Middle Creek Project is not constructed, no passage barriers are removed). Projections under Scenario 3 include:

1. Climate change results in more arid conditions in some years throughout most of the range. Because the timing of precipitation is projected to change, some years the number of spawning tributaries available to the subspecies over the spawning season will be reduced. In addition, increased fire and flooding incidence due to climate change will increase the amount of erosion occurring in the tributary streams, further decreasing water quality within the lake.

2. Future drought conditions are projected to increase, both the number of years drought conditions persist and the intensity of drought. This will also impact the number of spawning tributaries available to the subspecies over the spawning season and will impact the water quality within the lake.

3. Agricultural production slightly increases in areas currently not prioritized by SGMA.

4. Direct take of Clear Lake hitch will be limited due to the subspecies listing under CESA.

5. The existing wetland/tule habitats surrounding the lake will continue to persist due to Lake County's shoreline ordinance.

6. Current restoration projects (contaminant remediation, tributary function, barrier removal) are no longer being implemented, or are greatly reduced, and the Middle Creek Project is not constructed.

7. Very little urban development occurs.

Under Scenario 3, the Clear Lake hitch continues to have two populations within its range, although, the resiliency of the Thurston Lake population declines from high to moderate and the resiliency of the Clear Lake population declines from moderate to low. The level of representation continues to be low under this scenario and because of the loss of population resiliency in both populations, the level of redundancy declines to low.

Over the next 50 years, we believe Scenario 1 is the most likely to occur and Scenario 2 is the least likely to occur. We believe Scenario 1 is the most likely since we expect that climate change is likely to continue (thereby increasing the likelihood of aridity, fire incidence, and flood incidence), future drought conditions are likely to increase, CESA will continue to limit direct take, the Lake County shoreline ordinance will continue to maintain the existing amount of available wetland/tule habitat

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surrounding the lake, and current small scale restoration projects will continue to be implemented into the future.

Scenario 2 is not the most likely to occur because large scale restoration projects like the Middle Creek Project and numerous small scale restoration projects spread throughout the watershed will require extensive funding and coordination. It is possible a small subset of restoration projects will occur over the next 50 years, potentially even the Middle Creek Project; however, the wide scale restoration of the entire watershed as described in this scenario is not likely to occur. Scenario 3 could occur, but is not the most likely when compared to Scenario 1. This is primarily because various restoration projects have been implemented throughout the Clear Lake watershed and the lack of restoration described under this scenario is not likely occur.

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ACRONYMS AND DEFINITIONS

AB 32: Assembly Bill 32, also known as the Global Warming Solutions Act

Analysis unit: Units used to conduct an in-depth analysis of the Clear Lake population of Clear Lake hitch within its range. The analysis units include: Cole Creek (SIG1); Kelsey Creek (SIG2); Clear Lake and Adobe Creek (SIG3); Rodman Slough (SIG4); and Middle Creek, Clover Creek, and Seigler Canyon Creek (SIG5). Thurston Lake is its own analysis unit.

CalTrans: California Department of Transportation.

CAPP: Conceptual Area Protection Plans. A CAPP allows different organizations and agencies to apply for land acquisition funding through CDFW's Wildlife Conservation Board.

Caudal peduncle: Portion of the tail that holds the tail fin.

CDFW: California Department of Fish and Wildlife

CEQA: California Environmental Quality Act

CESA: California Endangered Species Act

CLIWMP: Clear Lake Integrated Watershed Management Plan

Cyprinids: Fish in the freshwater minnow family, Cyprinidae

DWR: California Department of Water Resources

EPA: Environmental Protection Agency

GIS: Geographic Information Systems

HUC-12: 12-digit Hydrologic Unit Code

Lacustrine: Associated or living within a lake.

Limnetic: Inhabiting the open water of a body of fresh water (i.e., lake).

Littoral: Inhabiting the near shore area of a body of water (i.e., lake).

Middle Creek Project: Middle Creek Flood Damage Reduction and Ecosystem Restoration Project. This project is both a flood risk reduction project for 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.

Milt: Semen of a male fish.

Mitochondrial DNA: DNA found exclusively in the mitochondria and is maternally inherited.

NEPA: National Environmental Policy Act

Nuclear DNA: DNA contained within each cell nucleus of most living organisms and is inherited from both parents.

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Pharyngeal teeth: Teeth found in the throat area, behind the mouth and nose.

PIT tag: Passive Integrated Transponder tag

RCP 4.5: Representative Concentration Pathway 4.5. A greenhouse gas concentration trajectory in which greenhouse gas emissions stabilize by mid-century and then decline to levels seen in the 1990's by the end of the century.

RCP 8.5: Representative Concentration Pathway 8.5. A greenhouse gas concentration trajectory in which greenhouse gas emissions continue to increase into the next century.

Recruitment: The process of adding new, reproducing individuals to a population or subpopulation.

Reproduction: The act or process of reproducing, or the process by which plants and animals give rise to offspring.

Reproductive success: An individual's successful production of offspring per breeding event or lifetime. The passing of genes onto the next generation.

SGMA: Sustainable Groundwater Management Act. A California state law which provides a framework for sustainable, groundwater management in California.

SIG: Strontium Isotope Grouping

SL: Standard Length. Length of a fish measured from the tip of their mouth/snout to the end of the tail, excluding the caudal (tail) fin.

SWRCB: California State Water Resources Control Board.

Terminal mouth: Location of a fish's mouth. Both jaws are the same length with the mouth located in the middle of the head pointing forward.

USFS: United States Forest Service

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CHAPTER 1: INTRODUCTION

1.1 Petition History and Previous Federal Actions

The Clear Lake hitch (*Lavinia exilicauda chi*) (Hopkirk 1973, pp. 55–56) is a large cyprinid (freshwater minnow) that is endemic to the Clear Lake watershed in Lake County, California. The subspecies resides in Clear and Thurston Lakes throughout the year until the spring when hitch migrate into tributary streams to spawn and then return to the lake. The U.S. Fish and Wildlife Service (Service) received a petition from the Center for Biological Diversity on September 25, 2012 (CBD 2012, entire), to list the Clear Lake hitch as threatened or endangered under the authority of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543) (Act). The Service issued a 90-day finding on April 10, 2015 (80 FR 19259), stating the petition presented substantial information that listing the Clear Lake hitch may be warranted. This conclusion was based on our review of the petition and sources cited in the petition, indicating that the petitioned action may be warranted due to: (1) the present or threatened destruction, modification, or curtailment of the species habitat or range from urban and agricultural development, dams, water diversions, migration barriers, mining activities, and grazing; (2) overutilization for commercial fishing, recreational fishing, and tribal harvest; (3) disease and predation; and (4) other natural or manmade factors affecting its continued existence, including effects from climate change, contaminants, and introduced fish. Therefore, a review of the status of the subspecies was initiated to provide the scientific information from which a determination will be made. Based on the information prepared for this SSA, the Service will issue a 12-month finding for the Clear Lake hitch.

1.2 Methodology

This assessment draws scientific information from resources such as primary peer-reviewed literature, reports submitted to the Service and other public agencies, species occurrence information in Geographic Information Systems (GIS) databases, habitat information in GIS databases, and expert experience and observations. It is preceded by and draws upon analyses presented in other Service documents, including the 90-day finding (80 FR 19259). Finally, we coordinated closely with our partners engaged in ongoing research and conservation efforts. This assures consideration of the most current scientific and conservation status information.

<u>Analytical Framework</u>

The Species Status Assessment (SSA) framework (Service 2016, entire) and the SSA Report developed from the framework are intended to support an in-depth review of the species' biology and influencing factors, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, the SSA Report will be a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

This SSA Report for the Clear Lake hitch is intended to provide the biological support for the decision on whether to recommend listing the subspecies as threatened or endangered and, if so, where to recommend proposing to designate critical habitat. Importantly, the SSA Report does not result in a decision by the Service on whether the Clear Lake hitch should be proposed for listing as a threatened or endangered species under the Act. Instead, this SSA Report provides a review of the available information strictly related to the biological status of the Clear Lake hitch. The decision whether to list the subspecies will be made by the Service after reviewing this document and all

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relevant laws, regulations, and policies. The results of our review of the best available scientific information will be announced in the *Federal Register*. If listing is warranted, the proposed listing rule will be published with appropriate opportunities for public input.

For the purpose of this assessment, we generally define viability as the ability of the Clear Lake hitch to sustain itself within its natural ecosystem throughout the Clear Lake watershed up through and beyond a biologically meaningful timeframe, in this case, 50 years. We chose 50 years because the available climate models for the North Coast Region, where Clear Lake is located, show similar precipitation and temperature projections under the two different emissions scenarios (RCP 4.5 and RCP 8.5) into the mid-century (2040-2069). Beyond this time period (2070-2099), both temperature and precipitation projections begin to diverge under the two emissions scenarios. Since it is unknown what emissions scenario we will be tracking in the later part of the century, and that uncertainty increases with time, we will be conservative in using the shorter, 50-year timeframe. Using the SSA framework (Figure 1.1), we consider what the subspecies needs to maintain viability by characterizing the status of the subspecies in terms of its resiliency, representation, and redundancy (Wolf *et al.* 2015, entire).

- **Resiliency** describes the ability of populations to withstand stochastic events. Measured by the size and growth rate of each population, resiliency gauges the probability that the populations comprising a species are able to withstand or bounce back from environmental or demographic stochastic events. For the Clear Lake hitch, resiliency was evaluated by assessing the subspecies' demographic factors of reproduction and recruitment, and habitat elements of connectivity, water quality and quantity, and availability of wetland/tule habitat.

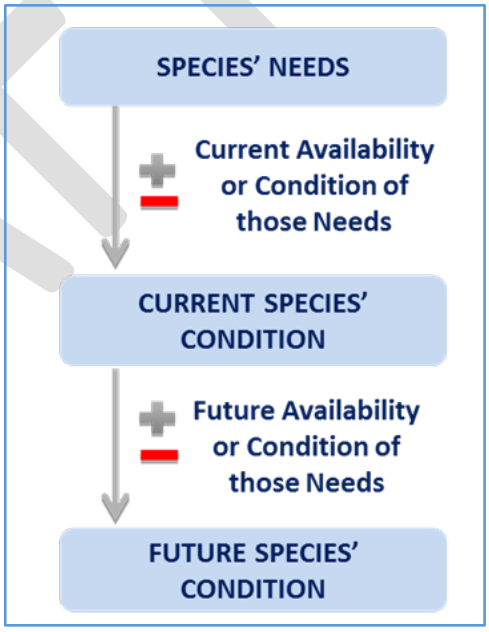

Figure 1.1 Species Status Assessment framework

- **Representation** describes the ability of a species to adapt to changing environmental conditions. Measured by the breadth of genetic or environmental diversity within and among populations, representation gauges the probability that a species is capable of adapting to environmental changes. Because the Clear Lake hitch has such a narrow range with similar habitat characteristics, the subspecies has never had much environmental diversity and likely does not have much genetic diversity. Therefore, it is likely the Clear Lake hitch has never had a high level of representation. For the Clear Lake hitch, representation was evaluated by assessing the different spawning strategies they can utilize under variable environmental conditions.

- **Redundancy** describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can

bounce back from catastrophic events. We evaluated redundancy of Clear Lake hitch in the context of its extant range that includes two populations, one that occupies Thurston Lake and its tributary (Thurston Creek), and one that occupies Clear Lake and its tributaries. In addition, we will also be describing how the subspecies expresses within population redundancy based on types of spawning habitats (tributary, lake, or interface between the two) and the number of available tributary streams within the watershed. Although this is not entirely consistent with the SSA framework's definition of redundancy, we believe this is important to describe since a plausible catastrophic event may be prolonged drought and having different spawning habitats available to the subspecies may increase the ability of the Clear Lake hitch to withstand a catastrophic drought event.

To evaluate the biological status of the Clear Lake hitch both currently and into the future, we assessed a range of conditions to allow us to consider the subspecies' resiliency, representation, and redundancy (together, the 3 Rs). This SSA Report provides a thorough assessment of the Clear Lake hitch's biology and natural history, and assesses demographic risks, influencing factors, and limiting factors in the context of determining the viability and risk of extinction for the subspecies.

The format for this SSA Report includes: (1) a description of the Clear Lake hitch, its life history, and habitat (Chapter 2); (2) the resource needs of individuals and populations, and a framework for determining population resiliency and how the distribution of populations across the subspecies' range can affect the hitch's viability (Chapter 3); (3) a review of the influencing factors that affect the subspecies' viability and to what degree (Chapter 4); (4) an analysis of the subspecies' current and future conditions (Chapters 5 and 6); and (6) a conclusion that describes the viability of the subspecies in terms of resiliency, representation, and redundancy (Chapter 7). This document is a compilation of the best available scientific and commercial information and a description of the past, present, and likely future risk factors to the Clear Lake hitch.

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CHAPTER 2: SUBSPECIES DESCRIPTION

In this chapter, we provide basic biological information about the Clear Lake hitch, including its taxonomic history and relationships; genetics; morphology; physical environment; known life history traits; and habitat requirements. Here, we report those aspects of the life history of the Clear Lake hitch that are important to our analysis. For further information about the Clear Lake watershed and the Clear Lake hitch, refer to Bairrington (2000), CDFW (2014), Moyle (2002), Suchanek et al. (2003), the Chi Council for the Clear Lake Hitch website (https://lakelive.info/chicouncil/), and the Clear Lake Environmental Research Center website (https://www.clerc.co).

2.1 Taxonomy and Genetics

The Clear Lake hitch is a fish subspecies classified in the Lavinia genus in the family Cyprinidae (freshwater minnows; see Table 2.1). 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, p. 139). However, after investigations of the geographic variation of another fish species, the tule perch, it was hypothesized that the Clear Lake watershed may be isolated and a center for speciation (Hopkirk 1973, p. 1). The type specimen of Clear Lake hitch was a reproductive female collected from Seigler Creek in 1964 by Paul R. Needham, John D. Hopkirk, and a group from the University of California, Berkeley (Hopkirk 1973, p. 55). The first biologist to describe the Clear Lake hitch as a distinct subspecies was John D. Hopkirk (Hopkirk 1973, p. 55). Hopkirk described the subspecies as "lake-adapted" and found it could be differentiated from the more wide-spread species by its deeper body form, larger scales and eyes, and its greater number of gill rakers (Hopkirk 1973, pp. 55–56; Moyle et al. 1995, p. 153). Similarly, the now extinct Clear Lake splittail (*Pogonichthys ciscoides*) and the extant Clear Lake tule perch (*Hysterocarpus traskii lagunae*), both have a greater number of gill rakers compared to the splittail and tule perch species found within the Sacramento River watershed (Hopkirk 1973, p. 56).

Table 2.1 Taxonomic Chart for the Clear Lake Hitch

Kingdom	Phylum	Class	Order	Family	Genus	Species	Subspecies
Animalia	Chordata	Actinopterygii	Cypriniformes	Cyprinidae	Lavinia	exilicauda	chi

Hitch are closely related to the California roach (*Hesperoleucus symmetricus*), which they are known to hybridize with and produce both fertile and infertile offspring outside of Clear Lake (Miller 1945, p. entire; Hubbs 1961, p. 11–12; Moyle et al. 1995, p. 153). Hitch have also been known to hybridize with other cyprinids, including the Sacramento blackfish (*Orthodon microlepidotus*), which produce sterile hybrids, and thicktail chub (*Gila crassicauda*), which is now extinct (Miller 1963, pp. 20, 24–27; Hopkirk 1973, p. 51; Moyle and Massingill 1981, entire; Moyle et al. 1995, pp. 5, 153). Hitch-roach hybrids are known to occur more frequently, whereas hitch-chub and hitch-blackfish hybrids have only been documented a few times (Moyle and Massingill 1981, p. 196).

The Clear Lake roach is now only found within the tributaries to Clear Lake and not within Clear Lake itself, likely due to the presence of numerous non-native predators within the lake (Moyle 2002, pp. 141, 142; Baumsteiger and Moyle 2019, p. 237). Although hitch outside of Clear Lake are known to hybridize with the various other cyprinid species described above, and those species currently or historically co-occurred with the hitch within the Clear Lake watershed, there are no verified records of Clear Lake hitch hybridizing with any of these species (Moyle et al. 2014, p. 1; CDFW 2014, p. 5). However, there is some disagreement in the literature about whether 12 specimens collected from Clear Lake in 1939 and 1940 were hitch-blackfish hybrids or another

species of *Lavinia* that subsequently went extinct before being formally described (Hopkirk 1973, pp. 56–59; Hubbs 1974, pp. 808–809; Jones 2001, p. 109). Therefore, although it is unlikely that Clear Lake hitch are currently hybridizing with other cyprinids within Clear Lake, it is possible.

Early genetic studies showed the hitch (*Lavinia exilicauda*) and the roach (*Hesperoleucus symmetricus*) are so genetically similar that they could be considered conspecifics; however, some minor genetic differences, differences in habitat use, and the extensive morphological differences between the two supported their separate species status (Avise et al. 1975. p. 417–421). Further genetic analysis completed by Avise and Ayala (1976, pp. 49–51) found hitch and roach showed very little genetic divergence despite their morphological differences, and they postulated that the two are congeners. Because of these findings, subsequent researchers considered the California roach to be in the same genus as hitch, *Lavinia*; however, more recent studies suggest the roach/hitch complex is actually comprised of two separate genera (Baumsteiger et al. 2017, entire; Baumsteiger and Moyle 2019, pp. 4–5; 223–224). Furthermore, changing the roach genera to *Lavinia* was not universally recognized and the American Fisheries Society still considers the species as *Hesperoleucus symmetricus* (Moyle 1980, p. 200; Moyle and Massingill 1981, p. 196; Page et al. 2013, p. 71).

Analyses of the taxonomic status of the different hitch and roach forms found throughout California were completed in both the early and late 2000's (decade between 2000 and 2009). A study done in the early 2000's found the Clear Lake hitch shares mitochondrial DNA haplotypes with different forms of the California roach outside of the Clear Lake watershed, and therefore, does not form a monophyletic group. However, due to differences in nuclear and mitochondrial DNA between the Clear Lake form of the California roach and the Clear Lake hitch, the author suggested treating the Clear Lake hitch as an Evolutionary Significant Unit instead of a subspecies because subspecies status was not supported by their analysis (Jones 2001, pp. 25–26). An analysis in the late 2000's using nuclear and mitochondrial DNA had differing results. The nuclear DNA analysis of ten microsatellite loci supported the subspecies designation for the Clear Lake hitch; however, the analysis of two mitochondrial DNA fragments did not find the Clear Lake form of hitch to be distinct from other hitch found throughout California (Aguilar and Jones 2009, p. 380). Despite the conflicting results, the authors conclude that the Clear Lake hitch should be considered a valid subspecies due to its geographic isolation from other hitch within California, their considerable morphological differences compared to other hitch forms, and the lack of known hitch-roach hybridization within the Clear Lake watershed (Aguilar and Jones 2009, p. 380).

More recent genomic analysis suggests the three forms of hitch within California show strong population structuring, but show only weak support for subspecies structuring. The authors further suggest their data reflects the three hitch forms found throughout California may actually be a single species that once had high gene flow occurring among the populations, but have recently become isolated from each other (Baumsteiger et al. 2019, p. 407). Since this analysis is still fairly recent and does not definitively conclude that the Clear Lake hitch is not a subspecies, and because the hitch is still currently considered a valid subspecies by the scientific community (ITIS 2019, Taxonomic Serial No.: 914028), we will continue to consider the Clear Lake hitch a subspecies for the purposes of this SSA Report.

2.2 Subspecies Description

Adult Clear Lake hitch 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 the adults have been described as round and the juveniles as oval.

The Clear Lake hitch 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, p. 197; Moyle et al. 1995, p. 153; Moyle 2002, p. 136–137; CDFW 2014, p. 5). As typical for other native juvenile cyprinid species found in California, 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, p. 55; Moyle et al. 1995, p. 153). As individuals age, their silvery coloring fades and their dorsal surface become a brownish-yellow (Moyle 1976, p. 177; Moyle et al. 1995, p. 153). As mentioned previously, compared to other subspecies of hitch the Clear Lake hitch has larger scales and eyes (Hopkirk 1973, pp. 55–56; Moyle et al. 1995, p. 153; CDFW 2014, p. 5).

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 water temperatures in Clear Lake (Murphy 1951, pp. 444–447; Moyle 1976, p. 178; Geary 1978, pp. 22–24; Moyle et al. 1995, p. 153; Moyle 2002, pp. 137–138). 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, pp. 7, 9). Males are sexually mature within their first or second year, whereas females are sexually mature in their second or third year (Murphy 1948b, pp. 103–104, 109; Moyle et al. 1995, p. 153). Hitch are thought to live 4 to 6 years based on scale analysis, but it is possible some individuals can live longer (Moyle 2002, p. 138; CDFW 2014, p. 8). The larger size of female hitch within Clear Lake compared to the other subspecies of hitch within California equates to greater fecundity. For female Clear Lake hitch 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, p. 387). 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, p. 55; Moyle et al. 1995, p. 153; Moyle 2002, p. 137). It is unknown why *Lavinia*, a feminine Latin name, was applied to the hitch (Moyle 2002, p. 137). The native Pomo referred to the Clear Lake hitch as *chy* or *chigh* and the eastern band used the name *hitch* or *hitc* for the Clear Lake splittail (Jordan and Gilbert 1895, p. 139; Barrett 1908, pp. 322, 327; Hopkirk 1988, pp. 185, 186).

2.3 Geographic Distribution

The Clear Lake hitch is restricted to the Clear Lake watershed in Lake County, California, in the central Coast Range. Most of the subspecies' range occurs on private land; however, some of the spawning tributaries and nearshore habitats are owned by county, state, or federal agencies (see Figure 2.1). In addition to Clear Lake itself, there are other small lakes found throughout the watershed that either currently or historically contained Clear Lake hitch. Historically, the species occurred in Clear Lake, Thurston Lake, the Blue Lakes, Lampson Pond, and numerous tributaries to Clear Lake, including Kelsey, Scott, Middle, Adobe, Seigler Canyon, Manning, Cole, Morrison, and Schindler Creeks (Moyle et al. 1995, p. 154; CDFW 2014, p. 6; see Figure 2.2). 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, p. 5). Although they are hydrologically connected to Clear Lake, the Clear Lake hitch is currently thought to be extirpated from the Blue Lakes (CDFW 2014, p. 6). Just to the west of the lower arm of Clear Lake is Thurston Lake, a small lake that is currently supporting a robust population of Clear Lake hitch (Ewing 2019, pers. comm.). Although Thurston Lake and its tributary Thurston Creek are currently isolated from Clear Lake and its associated tributaries, historically they may have been connected during flooding events (Ewing 2019, pers.

comm.). Because Thurston Lake is not currently hydrologically connected to Clear Lake during flood events, we do not anticipate it to be re-connected in the future. The status of the Clear Lake hitch in Lampson Pond is unknown.

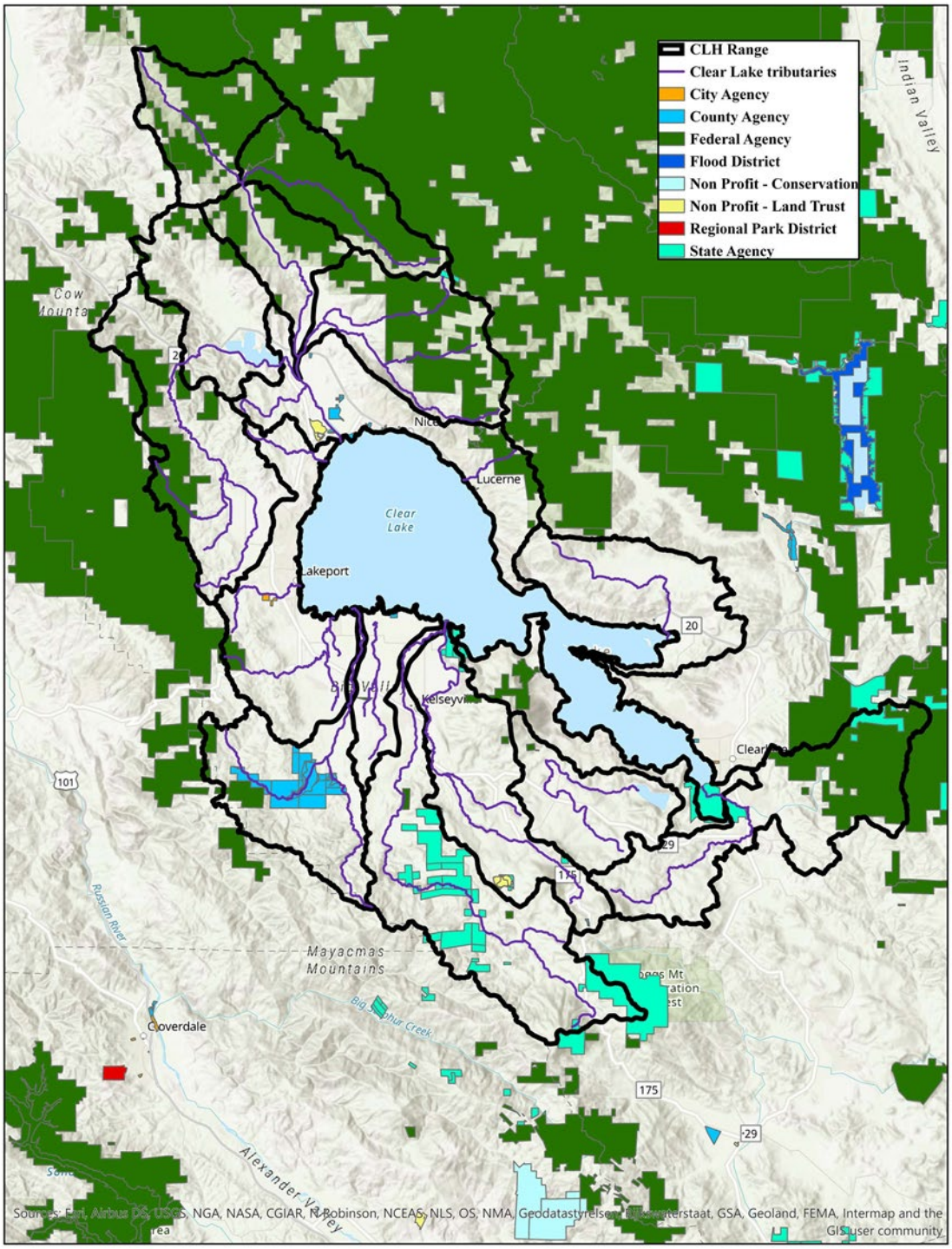

Figure 2.1 Land ownership within the range of the Clear Lake hitch

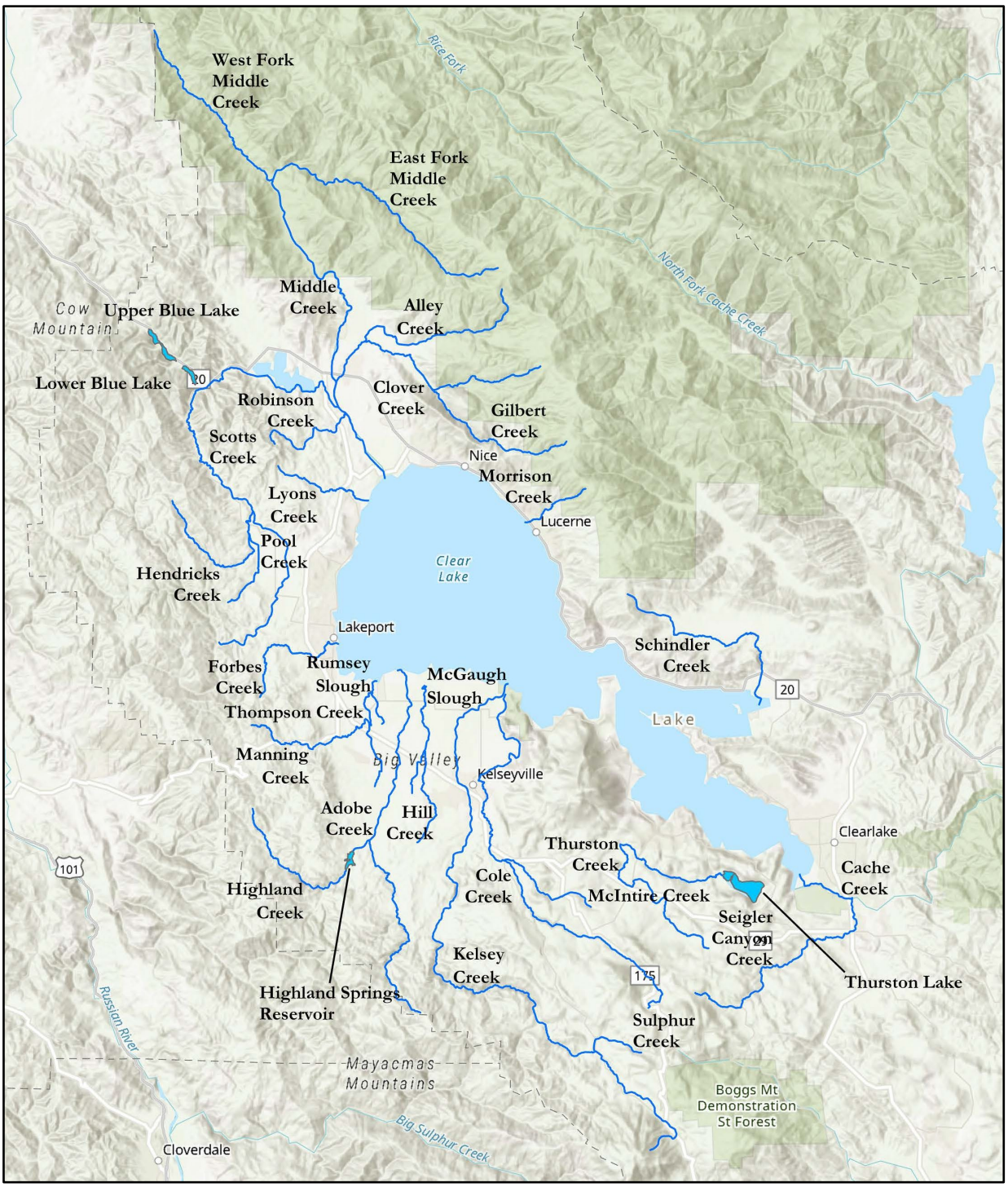

Figure 2.2 Clear Lake watershed

2.4 Habitat and Life History

Clear Lake Watershed

The Clear Lake watershed is located within the northern portion of the California Coast Ranges, approximately 100 miles north of the City of San Francisco (Bairrington 2000, pp. 1–2). The general

area is distinguished by mostly eastern-sloped mountains interspersed with several large valleys, and elevations vary from over 1,300 feet (surface of Clear Lake) to over 4,800 feet (High Grade Lookout) (Bairrington 2000, pp. 4–5). The Clear Lake area has a Mediterranean climate, characterized by hot, dry summers and cool, wet winters. The wet season is typically from October through April, although most precipitation occurs between the months of November and March (Bairrington 2000, p. 6).

Life History

Hitch 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, p. 2; CDFW 2014, p. 1). 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 Clear Lake hitch have not evolved a strong jumping ability (Murphy 1948b, p. 102; Macedo 1994, p. 4; CDFW 2014, p. 8). 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 1948b, p. 103; Kimsey 1960, p. 212; Moyle 1976, p. 179; Moyle et al. 1995, p. 154; CDFW 2014, pp. 8–9; Feyrer 2019b, p. 227). While some adults are actively engaged in spawning behaviors, schools of non-spawning hitch hold in pool habitat and feed on invertebrates (Feyrer 2019b, p. 228).

Eggs are deposited on fine to medium sized gravel that is along the margin or mid-channel of the stream (Shapovalov 1940 *in* Murphy 1948b, p. 102; Kimsey 1960, p. 211; CDFW 2014, p. 8). After the eggs are fertilized, they sink to the gravel covered stream bottom and become wedged between the gravel interstices (Moyle et al. 1995, p. 154; Feyrer 2019b, pp. 227, 229). Freshly extruded eggs that have not been fertilized are a light orange; however, once fertilized, eggs become a pale yellow (Swift 1965, p. 75). 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 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154). 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, p. 212).

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, p. 199; Geary and Moyle 1980, p. 388; Franson 2012, p. 15; CDFW 2014, pp. 8–9). 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, p. 199; Geary 1978, pp. 17, 25; Geary and Moyle 1980, p. 388; Moyle et al. 1995, p. 153; Moyle 2002, pg. 137–138; Moyle et al. 2014, p. 3). Clear Lake hitch feed primarily during the daylight hours (Geary 1978, p. 17; Moyle et al. 1995, p. 153). See Figure 2.3 for a basic life history model for the Clear Lake hitch.

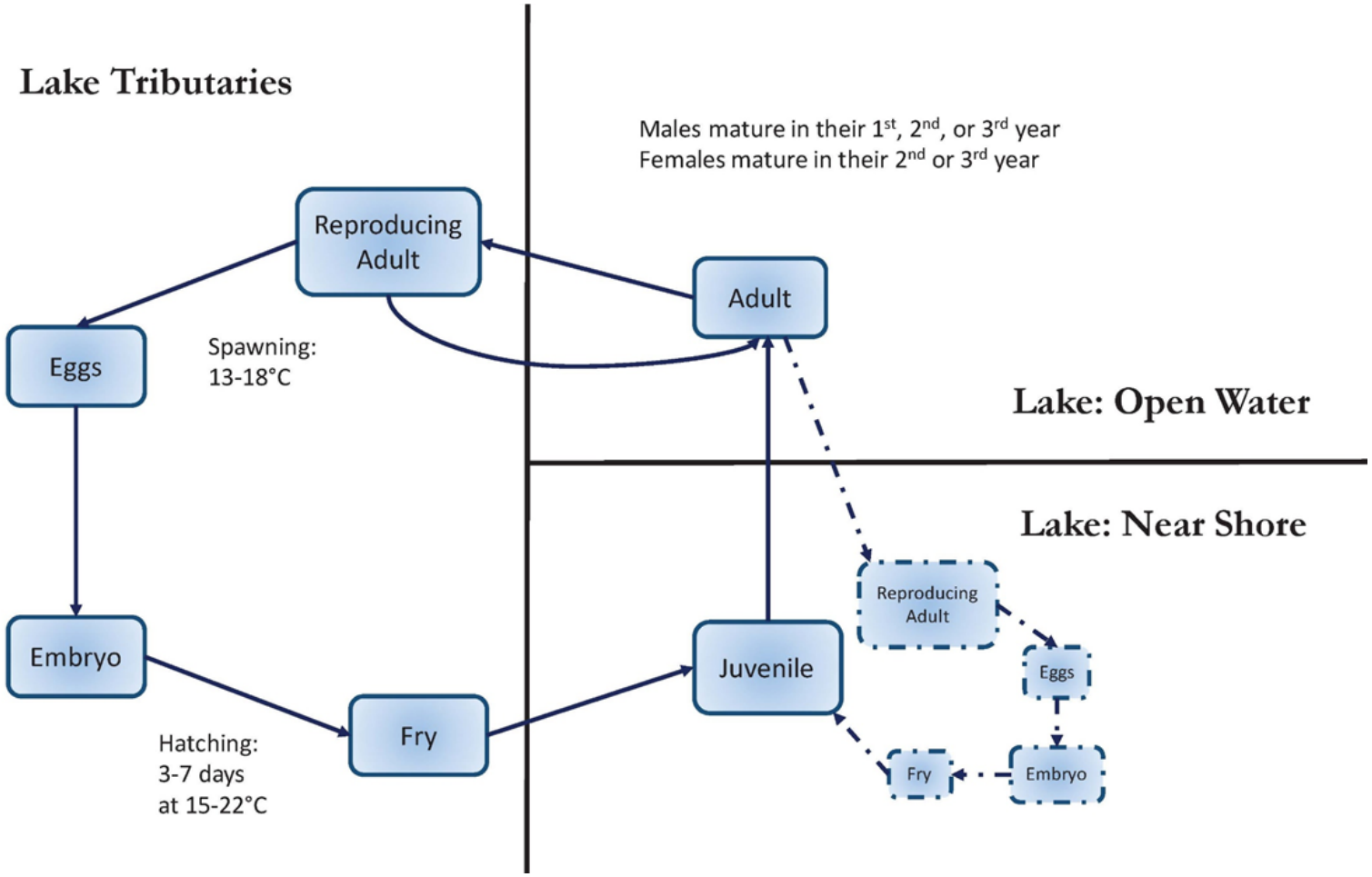

Figure 2.3 Clear Lake hitch basic life history model. Dashed lines represent individuals that spawn in the lake

Murphy (1948b, pp. 101–102) stated that Clear Lake hitch required gravel stream bottoms in order to spawn; however, Kimsey (1960, p. 211) detailed his personal observation of approximately 50 individuals exhibiting typical spawning behavior (chasing, swimming rapidly, 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 1960, p. 211). 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, pp. 211–212). 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, p. 212).

Kimsey (1960, p. 213) also documented a self-sustaining Clear Lake hitch 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, pp. 213–214). 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 stream habitat (Kimsey 1960, p. 214; Geary 1978, p. 22). More recent studies suggest the subspecies may be utilizing Clear Lake for spawning more frequently than first thought, especially during drought conditions. The areas of the lake that the subspecies is likely utilizing 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. 2019a, p. 1695).

CHAPTER 3: SUBSPECIES ECOLOGY

In this chapter we report what the subspecies needs at the individual and population level, which are best described when categorized by needs during each life stage (see Tables 3.1 and 3.4). We also define what a Clear Lake hitch population is and define an analysis unit, which is used to conduct a more in-depth analysis of the Clear Lake population. In addition, this chapter will also describe what each population, and the subspecies overall, needs for viability. Using the SSA framework, we describe the subspecies' viability by characterizing the status of the Clear Lake hitch in terms of its **resiliency**, **representation**, and **redundancy** (the 3 Rs).

3.1 Individual Needs

The following subsection, Individual Tributary Needs, will describe the subspecies' individual needs while within the tributaries to Clear Lake or Thurston Lake. In contrast, the next subsection, Individual Lacustrine Needs, will describe what an individual requires while residing within the lake. This separation is important as there are different subspecies needs within the different environments. A summary of individual needs by life stage is shown in Table 3.1.

Table 3.1 Clear Lake hitch individual needs by life stage. The last column categorizes the individual needs into whether they effect breeding (B), feeding (F), sheltering (S), or migration (M).

Life Stage	Needs	B/F/S/M
Egg/Embryo	Low gradient streams containing riffles with clean, fine to medium gravel	S
	Water temperatures of 15-22°C for multiple days for hatching	B
	Instream water depth that allows eggs to remain submerged	S
Larvae/Fry	Maintenance of water flow within tributary streams for downstream migration to the lake	M
	Instream and overhanging vegetation for cover and instream temperature regulation	S
	Food source (yolk sac/aquatic invertebrates)	F
Juveniles	Food source (insects, planktonic crustaceans, chironomid midges)	F
	Emergent vegetation (nearshore within the lake, wetland, marsh)	S
	Well oxygenated and uncontaminated lake water (nearshore and in wetlands/tule habitat)	S
	Water temperatures of 15°C or greater for survival	S
Adults	Food source (Daphnia, zooplankton, adult midges/insects)	F
	Maintenance of water flow within the tributary streams during the spawning season to allow adult access to spawning habitat	M/B
	Well oxygenated and uncontaminated lake water	S
	Water temperatures of 13-18°C in streams to initiate spawning	B
	Low gradient streams containing riffles with clean, fine to medium gravel	B

3.1.1 Individual Tributary Needs

The Clear Lake hitch is only found in the tributary streams during the spawning season. A reproductive adult that is attempting to spawn requires an adequate amount of flow within the tributaries to migrate upstream to appropriate spawning locations. In addition, spawning adults require unimpeded passage within those tributaries. Because the species is not a strong jumper like salmonids (Murphy 1948b, p. 102; Macedo 1994, p. 4; CDFW 2014, p. 8), small obstructions such as bridge footings, boulders, or a steep gradient can act as migration barriers. Reproductive females require at least one reproductive male, although several males typically spawn with one female. Once fertilized, the eggs require adequate stream flow to stay submerged and oxygenated, and require fine to medium sized clean gravel along the margin or within the mid-channel of the stream to hold

position during development (Shapovalov 1940 *in* Murphy 1948b, p. 102; Kimsey 1960, p. 211; Moyle et al. 1995, p. 154; CDFW 2014, p. 8).

The subspecies requires water temperatures between 13°C and 18°C to trigger spawning activity and presumably need water temperatures to be in a similar range for successful egg development (Swift 1965, pp. 75, 77; Moyle 2002, p. 138; Feyrer 2019b, p. 227). To initiate hatching, water temperatures must be maintained at 15-22°C for multiple days (Swift 1965, pp. 75, 77; Moyle 2002, p. 138). Laboratory studies show newly hatched hitch have a small yolk sac which they depend on for nourishment until they are able to swim freely (about 3 days). Once able to swim freely, young Clear Lake hitch require aquatic invertebrate prey (Kimsey 1960, p. 212). For cover and temperature regulation, downstream migrating fry likely require instream and/or overhanging streamside vegetation. The fry/juvenile life stage requires adequate stream flow to stay alive, and adequate flow needs to be maintained for at least a month to migrate downstream into the lake (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154). Recent otolith analysis shows the time until lake entry is associated with how long water is retained within the natal habitat. The time until lake entry ranged from 11 days to over 21 weeks (Feyrer et al. 2019a, p. 1693).

3.1.2 Lacustrine Needs

Outside of the spawning season, the Clear Lake hitch is primarily found in Clear or Thurston Lakes. They can be found in either the littoral zone (nearshore) as juveniles or the limnetic zone (sun-lit, offshore open water) as adults. During the spawning season, a majority of adults likely migrate into the lake tributaries; however, some reproductive adults may stay within the lake and spawn along the shore, the mouth of tributaries, or in back-water like areas of Clear Lake, like Rodman Slough. During extreme drought conditions, the only successful reproduction may be within the lakes.

Littoral Zone

Within a month of hatching, young Clear Lake hitch migrate into the lake before their natal stream dries (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154; Feyrer et al. 2019a, p. 1693). Once in the lake juveniles require stands of tules and/or other submerged aquatic vegetation to act as cover from aquatic and avian predators. Nearshore habitats containing vegetation also provide for invertebrate prey items, including insects, planktonic crustaceans, and chironomid midges. Juveniles also require the lake water to be of sufficient quality (i.e., well oxygenated and uncontaminated) and for water temperatures to be 15° or greater for survival (Franson 2012, p. 15; CDFW 2014, p. 9). During a recent year-long electro-fishing survey of the Clear Lake shoreline, hitch were the 7th most common species collected (Ewing et al. 2016, pp. 50–51). Over the course of the study, habitat parameters were recorded and there was a positive relationship found between weed cover and hitch presence, and amount of vegetated shoreline and hitch presence (Ewing et al. 2016, p. 54–55), which is reasonable as the subspecies uses the weeds and vegetation as cover from predators.

Some reproductive adults likely elect to spawn within the lake instead of migrating into the lake tributaries. Spawning observations along the Clear Lake shoreline have been noted in the past and self-sustaining populations of Clear Lake hitch have been documented in isolated ponds without a tributary access. Lake or pond spawning Clear Lake hitch have been documented spawning in areas with only a mud substrate that contains no gravel, so it is possible lake spawning individuals do not require gravel to successfully spawn (Kimsey 1960, p. 214; Geary 1978, p. 22). In addition, more recent studies suggest lake spawning occurs more frequently than first thought, especially during

drought conditions. Lake spawning includes spawning along the shoreline, in the mouths of tributaries, and in Rodman Slough, which is a backwater-like area in Clear Lake (Feyrer et al. 2019a, p. 195).

Limnetic Zone

Juvenile hitch transition to adulthood when they reach about 50 mm and they move from the lake's nearshore habitat out into open water. At this stage of life the hitch require a diet almost exclusively composed of *Daphnia*, but also other zooplankton species and adult midges and insects (Lindquist et al. 1943, p. 199; Geary 1978, pp. 17, 25; Geary and Moyle 1980, p. 388; Moyle et al. 1995, p. 153; Moyle 2002, pg. 137–138; Moyle et al. 2014, p. 3). Adult Clear Lake hitch require adequate water quality (i.e., well oxygenated and uncontaminated) within Clear and Thurston Lakes to ensure they continue to survive (Franson 2012, p. 15; CDFW 2014, p. 9). A recent lake monitoring effort suggests adult hitch can be found throughout the lake where dissolved oxygen conditions are adequate (i.e., not hypoxic) and do not restrict themselves to open water (Feyrer et al. 2019b, pp. 5–7).

3.2 Population Needs

In this section, we define what a Clear Lake hitch population is and how we further divide the Clear Lake population into separate analysis units. The reason we further divide the Clear Lake hitch population into is to conduct a more focused analysis of how different portions of the lake contribute to the Clear Lake population's overall resiliency.

3.2.1 Definition of a Population and Population Analysis Unit

There are likely only two separate populations of Clear Lake hitch within the Clear Lake watershed: one is found in Clear Lake and its associated tributaries, and the other in Thurston Lake and its associated tributary. Although historically these two populations may have been hydrologically connected during wet years, they currently are isolated from each other and we do not anticipate them to be connected in the future. Because conditions can vary throughout Clear Lake and its associated tributaries, we did a more detailed analysis of the Clear Lake population. This was conducted by further dividing the Clear Lake watershed into Hydrologic Unit Code (HUC) 12 sub-watersheds, which better capture aquatic habitat features at a local, sub-watershed level. The HUC 12 sub-watershed units within the range of the Clear Lake hitch include (see Figure 3.1): West Fork Middle Creek, East Fork Middle Creek, Salt Flat Creek-Middle Creek, Lower Scotts Creek, Middle Scotts Creek, Clover Creek, Rodman Slough - Frontal Clear Lake, Manning Creek - Frontal Clear Lake, Adobe Creek, Kelsey Creek, McGaugh Slough - Frontal Clear Lake, Cole Creek, Thurston Lake, Clear Lake, Schindler Creek - Frontal Clear Lake, and Seigler Canyon - Cache Creek.

Because some of the sub-watersheds do not have all of the components that the subspecies requires to complete its life history, and because we have recent information about how different regions of the watershed have contributed to reproduction and recruitment, the two primary demographic factors limiting population growth, we further grouped some of the HUC 12 units into larger units (see Table 3.2). This further grouping was based on otolith strontium signatures that indicated natal origins can be assigned to one of five strontium isotope groups (SIG) throughout the watershed (Feyrer et al. 2019a, entire; see Section 5.2 for a detailed description of the strontium isotope analysis). The use of adult otoliths for the natal habitat strontium groupings indicates those areas associated with the SIG is contributing to reproduction and recruitment. The HUC 12 units in each SIG are shown in Figure 3.2.

Throughout the rest of this SSA Report, the analysis units used to analyze the overall condition of the Clear Lake population will be the five SIG's. Since the entire Thurston Lake watershed is completely within the Thurston Lake HUC 12, just that sub-watershed unit will be used to analyze the Thurston Lake population. It should be noted that just because the Clear Lake population is first analyzed at an analysis unit level before determining the overall condition of the population, the individuals that may occur within each analysis unit at any point in time are actually interbreeding with individuals from other analysis units and should not be considered separate, discrete populations in a genetic or population biology sense.

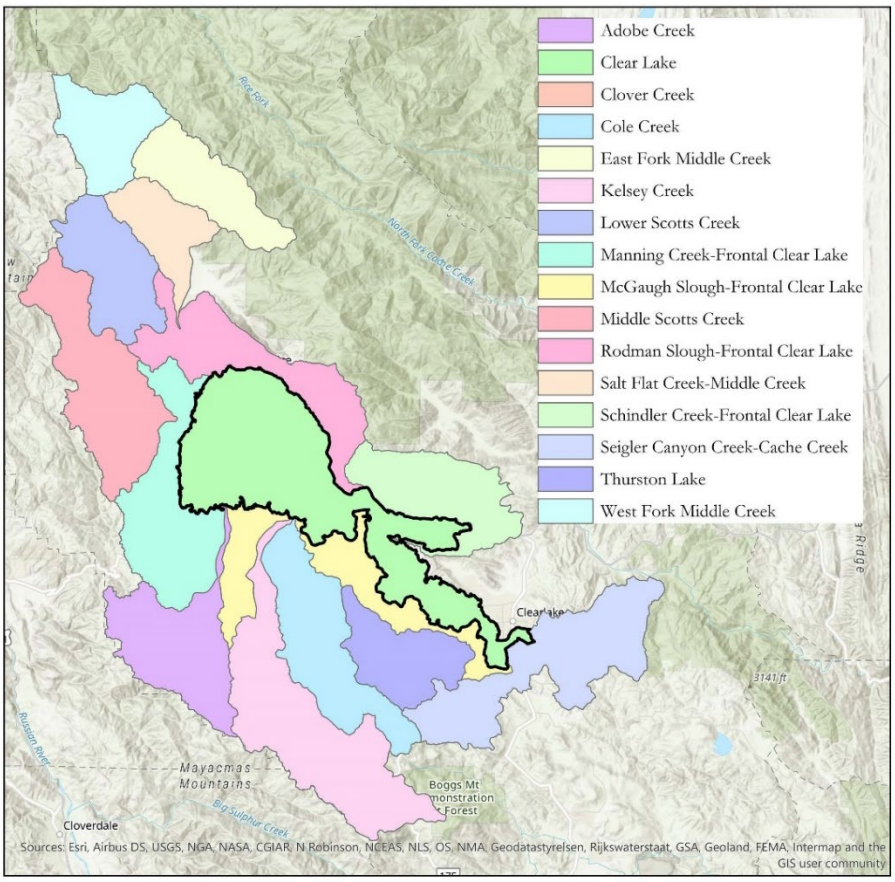

Figure 3.1 Clear Lake hitch HUC 12/analysis units. Clear Lake is outlined in bold

Table 3.2 Clear Lake hitch HUC 12 sub-watersheds within each SIG unit.

SIG #	HUC 12 UNIT
1	Cole Creek, Schindler Creek - Frontal Clear Lake, McGaugh Slough - Frontal Clear Lake
2	Kelsey Creek
3	Adobe Creek, Lower Scotts Creek, Middle Scotts Creek, Manning Creek - Frontal Clear Lake
4	Rodman Slough - Frontal Clear Lake
5	Clover Creek, West Fork Middle Creek, East Fork Middle Creek, Salt Flat Creek-Middle Creek, Seigler Canyon - Cache Creek

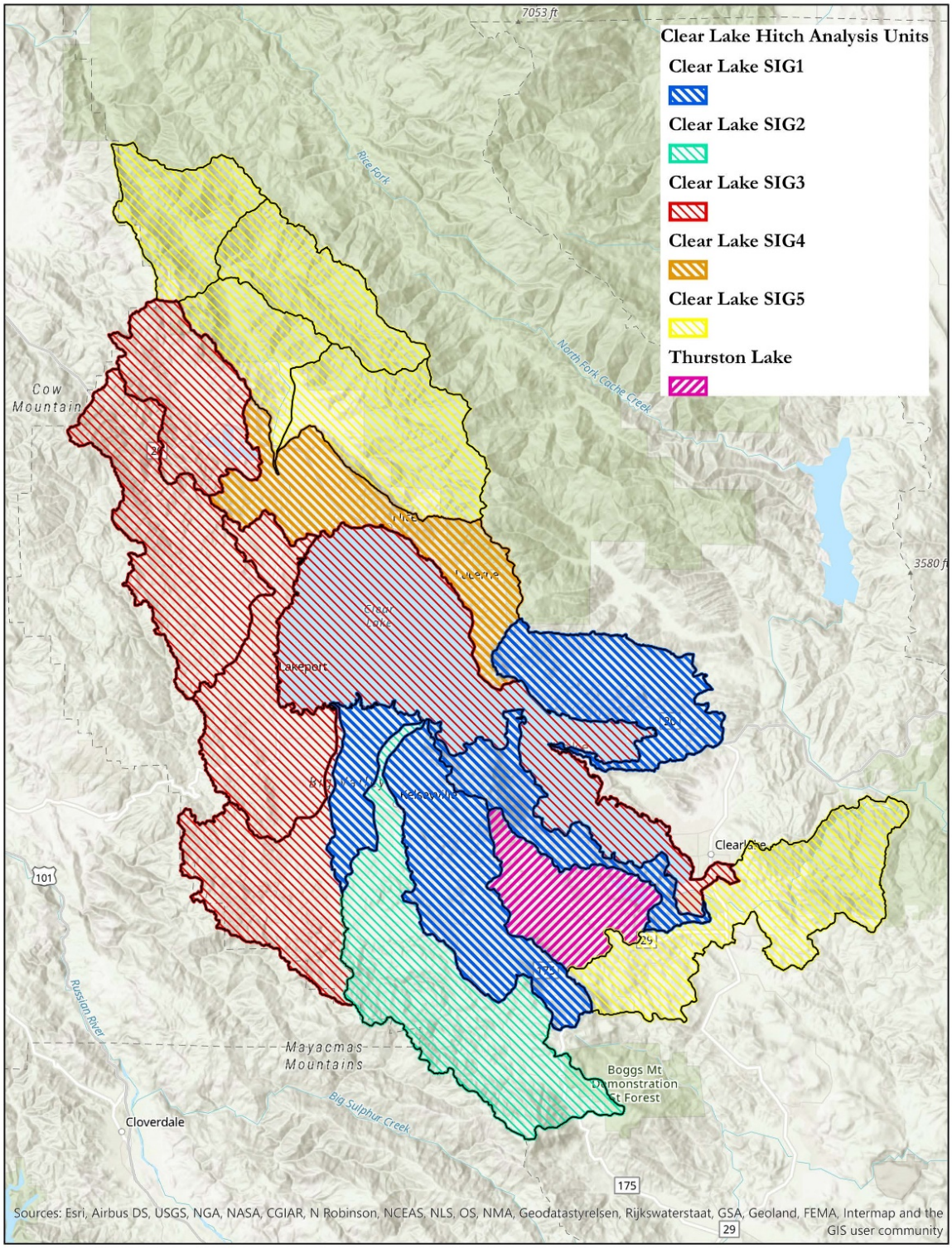

Figure 3.2 Clear Lake hitch analysis units: SIG1-SIG5 are associated with the Clear Lake population and the Thurston Lake HUC 12 sub-watershed is associated with the Thurston Lake

3.2.2 Population Resiliency

For the Clear Lake hitch to maintain viability, the habitat that supports each population, or some portion thereof, must be of sufficient quality to support resilient populations. Environmental stochastic events that have the potential to affect the Clear Lake hitch include severe storms, drought, contaminant exposure, and the modification of habitat via natural (i.e., fire, drought, etc.) and anthropogenic means (i.e., conversion to agriculture, vegetation management). A number of factors influence the resiliency of a population, including reproduction, recruitment, and survival at both the adult and juvenile life stages. Influencing those factors is the quality and connectivity of Clear Lake hitch habitat, which determines how well the spawning areas allow for successful reproduction, whether the nearshore nursery areas allow for young-of-year survival and subsequent recruitment or whether individuals can move between tributary spawning habitats and the lake. These demographic factors and habitat elements are discussed below and are shown in Figure 3.3. A summary of demographic factors and habitat elements that were ultimately eliminated from the analysis, and a reason for why they were eliminated, are shown in Table 3.3.

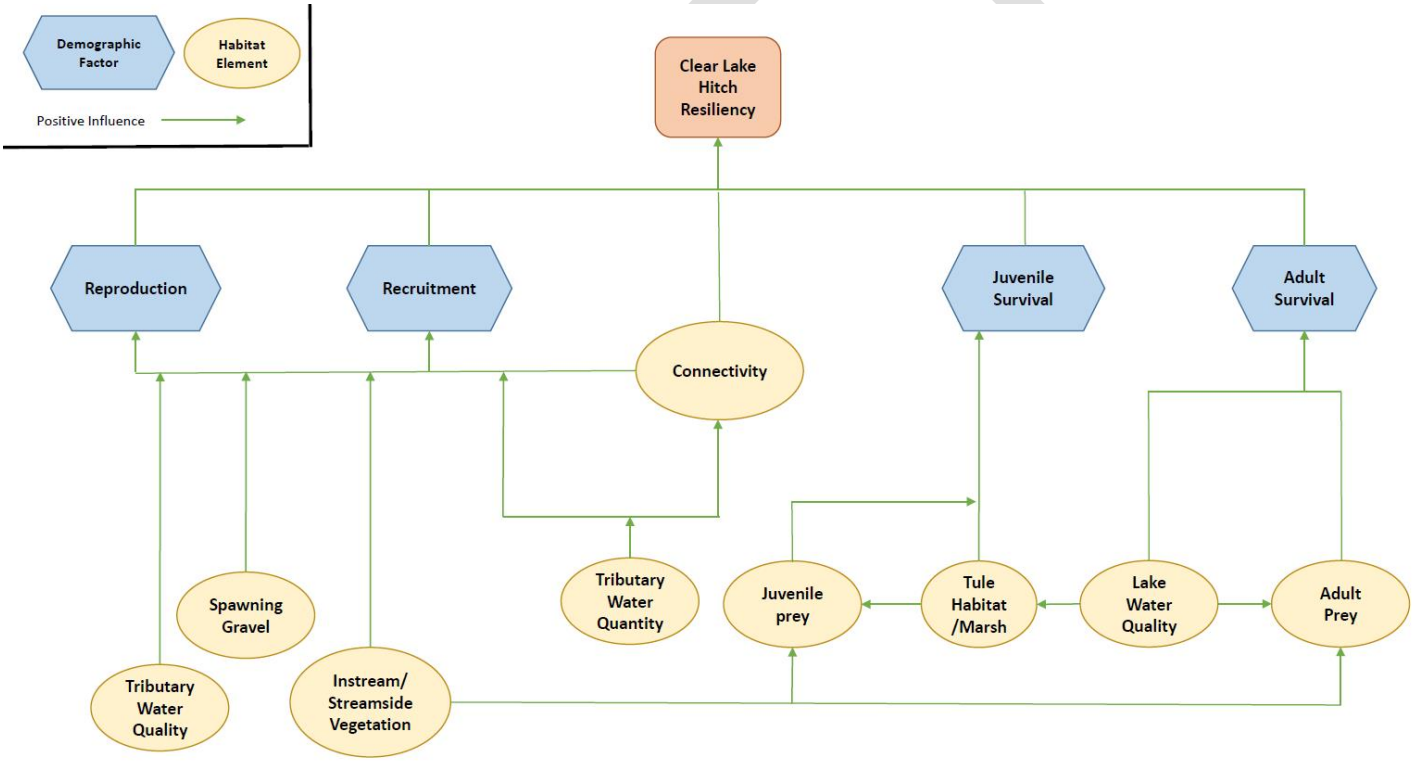

Figure 3.3 Clear Lake hitch resiliency conceptual model

Demographic Factors

<u>Reproduction and Recruitment</u>

Resilient Clear Lake hitch populations must have accessible spawning habitat and water flow must be maintained within tributary streams during the spawning season so any spawning efforts are successful and result in new reproducing individuals into the overall population (i.e., recruitment). The accessibility of spawning habitats available to a population may reflect the overall productivity

of that population. Accessibility to suitable spawning habitat and the ability to recruit is influenced by annual environmental conditions and anthropogenic pressures (i.e., water use, non-native introductions, wetland habitat loss, etc.), which then influence overall population trends that may be stable, increasing, or decreasing. For example, some spawning tributaries within the watershed that historically supported spawning hitch no longer do, or do so on a very limited basis. This loss of accessibility in certain spawning streams is likely a result of unfavorable environmental conditions, the construction of in-water infrastructure (e.g., bridge footings, culverts, fish ladders, etc.), the modification of tributary habitat that decreases in-stream water retention, and an increased reliability on ground and in-stream water for urban and agricultural uses. The success of each spawning and rearing habitat influences overall survival and is collectively reflected in the subsequent season's population estimate because any new individuals produced the previous spawning season are now included in the overall population. However, until those new individuals are able to access appropriate spawning habitat to reproduce, they may not be actively recruiting new individuals into the overall population. The limiting factor for Clear Lake hitch reproduction is access to suitable spawning habitat. However, a portion of the population is spawning in habitats within the lake that should be accessible during the spring spawning season, even in years when streams are inaccessible.

Reproductive success has not been estimated for the Clear Lake hitch; however, in the current environment, reproductive success is likely low because the tributary streams do not always retain water flow long enough to complete early life stage development and/or migration to the lake. Because the Clear Lake hitch is larger than other subspecies of hitch found in California, it also has a higher average fecundity. The annual average fecundity for the Clear Lake hitch is about 36,000 eggs and fish measuring 312 mm SL range can range from having 9,000 to 63,000 eggs (Geary and Moyle 1980, p. 387). The length-fecundity relationship for the Clear Lake hitch is F = 504(SL mm) - 30,384, so as adults grow larger, they are able to produce more eggs (Moyle 2002, pg. 138). Although the Clear Lake hitch is able to produce a large number of eggs during the spawning season, a majority of those eggs will not then go on to develop into reproductive adults (see Survival below). Thus, much of an individual female's reproductive effort does not contribute to the overall population (i.e., recruitment). The primary factors influencing Clear Lake hitch recruitment are the loss of wetland habitats within the watershed and the presence of non-native fish species within those remaining wetland habitats (see Sections 4.1.2 and 4.5 for more information about wetland loss and the introduction of non-native fish species).

<u>Survival</u>

Clear Lake hitch need to maintain a fairly high adult survival rate in order to compensate for their potentially low average reproductive success. The subspecies needs to maintain a high adult survival rate so that they can spawn when environmental conditions allow, which could be once every several years during severe drought conditions. Some proportion of the population utilizes habitats within the lake to spawn and thus, may be able to spawn annually even during drought conditions.

The survival rate for Clear Lake hitch early life stages is likely low. The rapid decline of flow within the tributary streams during the spawning season can leave fertilized eggs, larvae, and juveniles exposed and at risk of desiccation or suffocation. Average annual survivorship has not been estimated for any Clear Lake hitch life stage and may be difficult to obtain as very few recaptures are recovered during surveys. Because survival rates are unknown for any of the life stages of hitch, we will not be carrying forward this factor in our analysis.

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Tributary Habitat Elements

During the spawning season, a large proportion of adult Clear Lake hitch migrate into the surrounding tributary streams to reproduce. Their fertilized eggs develop in the interstitial spaces of the gravel-lined streams until the larvae ultimately hatch. Once the larvae become free swimming, they migrate down the rapidly drying tributary streams to suitable rearing habitat surrounding the lake.

Connectivity

In order for individuals to migrate up and down the tributary streams or to potential spawning habitat during the spring spawning season, hydrological connectivity within the watershed must be maintained. After spawning, adults leave the spawning habitats and move back into the open water of the lake, but the young remain within their natal habitat from as little as 11 days to as long as 152 days to develop (Feyrer et al. 2019a, p. 1693). Therefore, a hydrologic connection between spawning habitat and the main lake must be maintained until the young-of-year have finished their early development and are present in the lake. In addition to having enough water within the tributaries to allow for up- and down-stream passage during the spawning season, the streams must also be free of passage barriers that prevent hitch access. Because the species is not a very strong jumper, the spawning tributaries must be free of large obstacles that the subspecies is unable to clear (Murphy 1948b, p. 102; Macedo 1994, p. 4; CDFW 2014, p. 8).

Connectivity is considered a habitat element for this analysis because it analyzes the hydrological connectivity of two habitats (stream and lake) within a population, not the connectivity between separate populations. If we were to analyze the connectivity of two separate populations, then connectivity would be considered a demographic factor.

Tributary Water Quantity

As explained above, the Clear Lake hitch requires the maintenance of water flow within their tributary streams in order to successfully reproduce and recruit new individuals into the overall population. Adults need maintenance of water flow within the tributary streams during the spawning season to migrate upstream to areas with the appropriate spawning habitat. The eggs require an instream water depth that keeps the eggs submerged to avoid desiccation and larvae need water flow to be maintained within the tributary streams for downstream migration into the lake. The fry/juvenile life stage not only requires the maintenance of tributary flow to stay alive and avoid suffocation, but also requires the maintenance of flow within the tributary streams until they are able to migrate downstream into the lake (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154).

Tributary Water Quality

In addition to having enough water flow in the tributary creeks, the Clear Lake hitch also requires water temperatures to be within a specific range to trigger spawning and to initiate egg hatching. Reproductive adults require water temperatures of 13-18°C to initiate spawning and for egg hatching water temperatures must be maintained between 15°C and 22°C for multiple days (Swift 1965, pp. 75, 77; Moyle 2002, p. 138; Feyrer 2019b, p. 227). Currently, tributary water quality does not appear to be a factor limiting population growth for the Clear Lake hitch and therefore, will not be carried over through the analysis.

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Spawning Gravel

Clear Lake hitch eggs require fine to medium sized clean gravel so fertilized eggs can hold their place within the stream channel while developing (Shapovalov 1940 *in* Murphy 1948b, p. 102; Kimsey 1960, p. 211; Moyle et al. 1995, p. 154; CDFW 2014, p. 8). Individuals that spawn within the lake may also require gravel as a spawning substrate; however, a self-sustaining population of Clear Lake hitch occupied a farm pond that only had mud and vegetation as a bottom substrate, and did not have any tributary streams (Kimsey 1960, pp. 211, 213–214). Because the subspecies may not always require a gravel substrate to successfully spawn and due to the lack of evidence that spawning gravel is a factor limiting population growth, we will not be carrying forward this factor in our analysis.

Instream/Streamside Vegetation

While rearing within the tributary streams, Clear Lake hitch fry may require instream and/or overhanging streamside vegetation for cover from predators and for temperature regulation (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154). This cover likely increases early life stage survival, primarily by keeping portions of the stream cool and by providing shelter from predators. In addition, instream and streamside vegetation may also contribute to early life stage and adult prey base. Any young that survive through egg hatching and egg yolk absorption will require aquatic invertebrate prey and adults not actively involved in spawning activities have been documented holding in pool habitat while possibly feeding on invertebrates (Kimsey 1960, p. 212; Feyrer 2019b, p. 228). However, because the subspecies has been documented spawning in tributary streams without any vegetative cover, and because their prey items do not necessarily have to originate at that specific spawning site, this factor will not be carried forward in the analysis. In addition, there is no evidence this habitat element is limiting population growth.

Lacustrine Habitat Elements

The Clear Lake hitch spends most of its life in Clear Lake or Thurston Lake. As juveniles, the subspecies is found in littoral habitats, using tules and other aquatic vegetation for cover and preying on invertebrates found in the vegetation. As the juveniles develop into adults, they move out into the open water of the lake where they feed primarily on *Daphnia*. Some spawning does occur within the lake and past observations suggest the subspecies may not always require a gravel substrate for egg placement. Lake spawning is successful and can result in recruitment, but it is unknown how frequent lake spawning occurs and whether it results in a significant amount of recruitment (Kimsey 1960, p. 214; Geary 1978, p. 22; Feyrer et al. 2019a, pp. 1693, 1695).

Wetland/Tule Habitat

Young Clear Lake hitch that originate in the tributary streams have to migrate into the nearshore habitat of the lake before the tributaries dry up (Murphy 1948b, pp. 105, 106, 109; Swift 1965, pp. 75, 77–79; Moyle et al. 1995, p. 154). While in the littoral habitats, juvenile hitch require tules and/or other submerged vegetation to provide cover from the many avian and aquatic predators found in the lake (Franson 2012, p. 15; CDFW 2014, p. 9). Having vegetative cover in the littoral zone increases juvenile hitch survival and the likelihood that juveniles will transition to reproductive adults that will then recruit new individuals into the population. In addition to providing cover to juvenile hitch, the submerged aquatic vegetation found in the nearshore portions of the lake also provide for invertebrate prey items. Juvenile hitch prey on various invertebrate prey items, including insects, planktonic crustaceans, and chironomid midges (Franson 2012, p. 15; CDFW 2014, p. 9).

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Lake Water Quality

While in the lake, both juveniles and adults require well oxygenated and clean (i.e., uncontaminated) water. Some years Clear Lake develops a hypoxic layer that can then be mixed throughout the lake, resulting in fish kills. The high productivity of Clear Lake and the various nutrient inputs from throughout the watershed often result in toxic algae blooms that can also have detrimental effects on the hitch (see Chapter 4 for more information about lake mixing and toxic algae blooms). Water temperature within the lake is also important as juveniles in particular require water temperatures to be 15° or greater for survival (Franson 2012, p. 15; CDFW 2014, p. 9).

Adult Prey Items

Adult hitch live in the limnetic zone of the lake, where they primarily feed on *Daphnia*, but also rely on other prey items such as other zooplankton species, adult midges, and insects (Lindquist et al. 1943, p. 199; Geary 1978, pp. 17, 25; Geary and Moyle 1980, p. 388; Moyle et al. 1995, p. 153; Moyle 2002, pg. 137–138; Moyle et al. 2014, p. 3). Because there is nothing in the literature suggesting adult prey is currently limiting population growth, and we do not believe it will be a limiting factor in the future, this element will not be carried forward for the analysis.

Table 3.3 Summary of subspecies needs identified for the Clear Lake hitch and whether they were used in the analysis. For those demographic factors and habitat elements that were not carried through the analysis, the third column identifies why they were eliminated.

Demographic Factor/ Habitat Element	**Used in analysis? (Y/N)**	**Reason for eliminating the demographic factor or habitat element from the analysis**
Reproduction	Y	--
Recruitment	Y	--
Survival	N	We do not have enough information regarding survival at any life stage to analyze this need
Connectivity	Y	--
Tributary Water Quantity	Y	--
Tributary Water Quality	N	This habitat need is not likely a factor limiting population growth
Spawning Gravel	N	This habitat need is not likely a factor limiting population growth. In addition, there is evidence the subspecies may not require gravel for successful spawning
Instream/Streamside Vegetation	N	This habitat need is not likely a factor limiting population growth. In addition, the subspecies has been documented spawning in waterways without vegetative cover
Wetland/Tule Habitat	Y	--
Lake Water Quality	Y	--
Adult Prey Items	N	This habitat need is not likely a factor limiting population growth

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3.3 Representation

Maintaining representation in the form of genetic or ecological diversity is important to maintain the Clear Lake hitch's capacity to adapt to future environmental changes. Genetic studies within the subspecies have not been conducted; however, as discussed above, recent genetic analyses have indicated strong population structuring between the three forms of hitch that are currently referred to as subspecies (Baumsteiger et al. 2019, p. 407), and therefore, it is not likely there is strong population structuring within the Clear Lake entity. Even though there are two separate populations of Clear Lake hitch, they occur within the same watershed and occupy the same ecological niche. For the Clear Lake hitch, representation is best measured by assessing the different spawning strategies available to the subspecies under varying environmental conditions.

3.4 Redundancy

The Clear Lake hitch has redundancy by having two isolated populations, one that occupies Thurston Lake and its tributary, and one that occupies Clear Lake and its tributaries. Although redundancy gauges the probability that a species has a margin of safety to withstand or bounce back from a catastrophic event, due to the hitch's narrow range it may not actually express much redundancy. Depending on the scale of a catastrophic event happening within the watershed, it is possible a catastrophe could impact the entire watershed, and therefore, both populations and all tributary streams. Realistic catastrophic events that could potentially impact the Clear Lake hitch include earthquakes, volcanic activity, fires, drought, and flooding.

Because drought events are likely to occur in the future due to climate change (see Section 4.8), some of which will likely be considered catastrophic, we also describe within population redundancy that could potentially increase the ability of that population to withstand a prolonged, catastrophic drought event. The Clear Lake hitch expresses within population redundancy in the type of natal habitat used for reproduction (tributary, lake, or interface between the two) and the number of available tributary streams within the watershed. As the number of tributaries available increases and/or the types of habitat used for reproduction increases within a population, the more redundancy that population will exhibit.

3.5 Summary of Population Needs

This section provides a summary of Clear Lake hitch population needs at all life stages (see Table 3.4). Needs are described in terms of demographic factors and the habitat elements that are required to provide those factors.

The demographic factors required for Clear Lake hitch population resiliency include:

- **Reproduction/Recruitment:** Sustained water flow within the tributaries and accessibility to spawning habitats increase reproductive success and the possibility for future recruitment. Availability of wetland/tule habitat surrounding the lake increase early life stage survival, and therefore, recruitment. The accessibility and/or availability of spawning and rearing habitats reflect environmental conditions, anthropogenic uses (i.e., water use, development, etc.), and the presence of passage barriers, both natural and anthropogenic.

- **Survival:** To compensate for years when reproductive success and recruitment are low, adult Clear Lake hitch need to maintain a fairly high survival rate. A high survival rate allows the subspecies to maintain a viable population in an area where environmental conditions do not

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always allow for successful reproduction and recruitment. The most influential factors acting on the subspecies are influencing survival at the early life stages. The lack of consistent flow and presence of barriers within the tributaries, the loss of tule habitat along the shores of Clear Lake, and the effect of competition and predation while in the nearshore habitat all have a negative impact on juvenile survival. Due to the lack of information regarding survival at any life stage, this factor will not be carried forward for our analysis.

The habitat elements required to provide for the demographic factors described above include:

- **Connectivity:** Hydrological connectivity within the watershed is required for adult upstream spawning migrations and for the young to migrate downstream to the lake. In addition to having enough water within the tributaries to allow for up- and down-stream migrations, the streams must also be free of barriers that prevent hitch passage.

- **Tributary Water Quality:** Hitch require clean, uncontaminated tributary water. Water temperatures need to be within a specific range to initiate spawning activity (14-18°C) and egg hatching (15-22°C for multiple days). Tributaries with suitable water quality parameters allow for successful reproduction and early life stage survival. Because this habitat need is not likely a factor limiting population growth, it will not be carried forward for our analysis.

- **Tributary Water Quantity:** For successful reproduction and recruitment, the Clear Lake hitch requires tributary streams maintain consistent flow throughout the spawning season. Reproducing adults need adequate water flow to access suitable spawning habitat upstream, and their early life stages need consistent flow to avoid desiccation and to allow young to migrate downstream to the lake.

- **Spawning Gravel:** To maintain their position within their natal tributary stream while developing, fertilized Clear Lake hitch eggs require clean fine to medium sized gravel. When freshly extruded eggs are fertilized, they sink to the stream bottom and become wedged in the gravel interstices, increasing egg survival. Eggs that are fertilized during shoreline spawning may also require gravel to maintain position while developing; however, observations of successful spawning along shorelines only containing mud suggest gravel may not be required in some situations or areas. This factor will not be carried forward for our analysis because it is not likely a factor limiting population growth and there is evidence the subspecies may not require gravel for successful spawning

- **Instream/Streamside Vegetation:** Instream and streamside vegetation increase survival for early life stages of Clear Lake hitch by acting as cover from predators, providing instream temperature regulation, and by providing aquatic invertebrate prey. Because the subspecies can spawn without any vegetative cover, their prey items do not necessarily have to originate at that specific spawning site, and there is no evidence this habitat element is limiting population growth, this factor will not be carried forward for our analysis.

- **Wetland/Tule Habitat:** Juvenile Clear Lake hitch continue to develop and grow in the nearshore habitat of the lake until they transition to adults. The juveniles rely on tules and/or other submerged vegetation for cover from predators and that same vegetation provides

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invertebrate prey. Having adequate vegetative cover in the littoral zone increases juvenile hitch survival and the likelihood that juveniles will be able to contribute to recruitment.

- **Lake Water Quality:** Both juvenile and adult Clear Lake hitch require clean water. Hypoxic conditions, sediment and nutrient inputs, algae blooms, and contaminants all influence lake water quality and can negatively impact both juvenile and adult survival. Maintaining water temperatures above 15°C is also required for juvenile survival.

- **Adult Prey Items:** Adult hitch reside in the open water of the lake and feed on zooplankton, adult midges, and other invertebrates found in this habitat. Having an adequate adult prey base contributes to adult survival and provides resources for reproduction. This factor will not be carried forward for our analysis because adult prey is not likely a factor limiting population growth.

Table 3.4 Clear Lake hitch population needs by life stage. The last column categorizes what demographic need the habitat element fulfills: reproduction/recruitment (R) or survival (S)

Scale	Life Stage	Needs	R/S
Population	Eggs/Embryo/Larvae	Clean, uncontaminated tributary water	R/S
	All	Maintenance of water flow within tributary streams for survival and to migrate up and down tributaries	R/S
	Eggs/Embryo	Riffles with clean, fine to medium gravel substrate	R/S
	Larvae	Instream or streamside vegetation for cover and prey	R/S
	Juveniles	Emergent vegetation in littoral zone for cover and prey	R/S
	Juveniles/Adults	Well oxygenated and uncontaminated lake water for adult and juvenile survival	S
	Adults	Food supply to support adults in open water habitat	R/S

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CHAPTER 4: FACTORS INFLUENCING VIABILITY

In this chapter, we evaluate the past, current, and future factors that are affecting what the Clear Lake hitch needs for long term viability (see Figure 4.1). Current and potential future effects to the subspecies due to the influencing factors, along with current and expected distribution and abundance of the subspecies throughout its range, affect present viability and, therefore, vulnerability to extinction.

4.1 Habitat Loss, Degradation, and Modification

Beginning in the mid-1800's when Europeans 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, 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 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 (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 impact adult hitch survival, especially when poor lake conditions result in large fish kills.

4.1.1 Tributaries

The reduction in stream spawning fish, including the Clear Lake hitch, 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, p. 480). 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, p. 480). 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, possibly 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, p. 480).

<u>Loss of Consistent Tributary Flow</u>

Gravel mining activities in the Clear Lake watershed 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, pp. 1253-1254, Figure 10; Thompson et al. 2013, p. 19). Gravel mining originally occurred as scattered operations throughout the watershed until the early- to mid-20th century when operations became centralized within the creeks (County of Lake 1992, p. 48; Richerson et al. 1994, p. III-19). This time period coincides with improved automobile technology and increased pressure to build more reliable roads (County of Lake 1992, p.48). 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, p.

48; Richerson et al. 1994, p. VIII-150). 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, pp. III-19–III-20; CDFW 2014, p. 29). Although gravel mining no longer occurs within the Clear Lake tributaries, gravel accumulation within the stream channel can also act as a passage barrier; therefore, approximately 5,000 cubic yards of gravel is removed annually from Scotts Creek (Murphy 1948b, p. 106; Richerson et al. 2008, p. A260; CDFW 2014, p. 29).

Past gravel mining in tributary streams not only removed spawning substrate that the species uses for reproduction and egg development, but it also lowered streambeds and destabilized channels, causing increased erosion, incision, and channelization. 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 (see Section 4.1.2) (CDFG 1955, entire; Richerson et al. 1994, p. III-19, VIII-2; Suchanek et al. 2003, p. 1254; CDFW 2014, pp. 29, 45). 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, p. 29). There are almost 14 miles of levee structures that are maintained by the U.S. Army Corps of Engineers (Corps) on Scotts, Middle, Clover, and Alley Creeks (Corps 2012, p. 3).

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, pp. 1243–1245, 1246–1247). Numerous fires have occurred in the Clear Lake area in the recent past, with several large 10,000+ acre fires occurring directly in the watershed (Suchanek et al. 2003, pp. 1244, 1248, Figure 121.4 and Table 121.2). 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, entire). The 2018 Mendocino Fire Complex, a portion of which occurred in Lake County, was the largest fire on record in California (CalFire 2019b, entire). 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, p. 1247). Fire activity within the watershed results in increased erosion and bank incision, which channelizes the stream. This channelization can decrease the amount of time water is retained within the tributary channel (Murphy 1948b, p. 106; County of Lake 1992, p. 13).

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, pp. 1247–1248). Increased erosion and bank cutting further decrease the amount of time water is retained within the tributaries.

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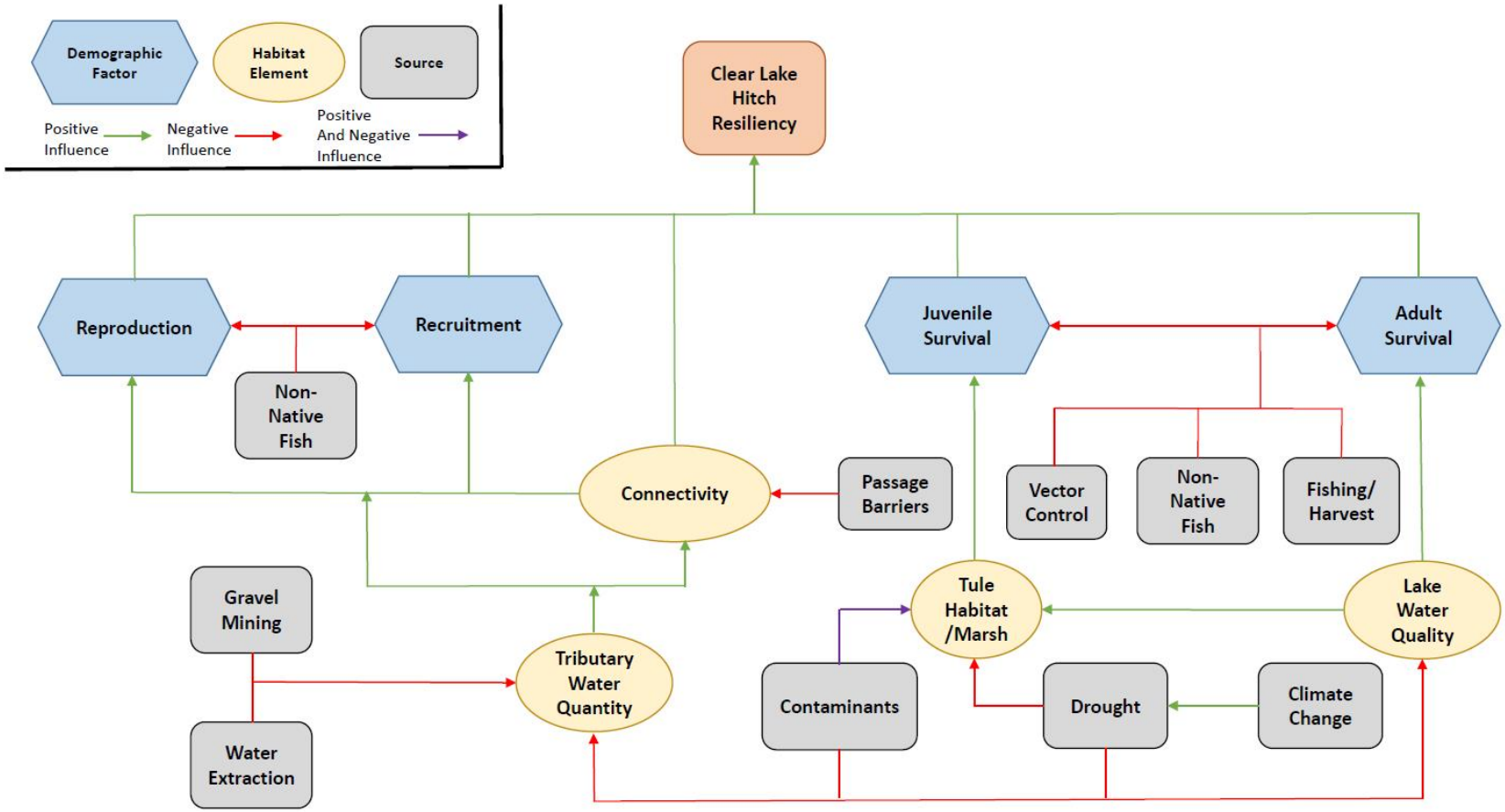

Figure 4.1 Clear Lake hitch resiliency influence diagram

Livestock grazing, primarily cattle and sheep, began in the Clear Lake watershed in the mid-1800's and still continues today. Although overgrazing no longer appears to be occurring in 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, p. 1257). 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 creeks, effectively reducing the amount of time water is retained within the channel (Murphy 1948b, p. 106; Suchanek et al. 2003, p. 1257). Although the amount of grazing pressure has decreased in the watershed, the impacts of past practices are still contributing to the issues seen in the watershed today.

Although a majority of instream gravel removal and all large-scale deforestation no longer occur in the watershed, the rate of runoff within the tributary streams is not likely to decrease into the future unless restoration actions are implemented. Likewise, fire activity will likely continue to increase within the Clear Lake watershed as the incidence of drought increases and intensifies due to climate change. In addition, some attribute 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, p. 1256).

Water extraction and the early drawdown of the tributary streams, in conjunction with habitat modifications throughout the watershed, likely led to the extinction of the Clear Lake splittail, another stream spawning native fish restricted to the Clear Lake watershed (Moyle 2002, pp. 138–139; CDFW 2014, p. 27). The Clear Lake splittail spawned later in the season than hitch and as the tributaries began to dry earlier in the season, their young were not able to migrate to the lake (Cook et al. 1966, p. 146; Moyle 2002, pp. 138–139; CDFW 2014, p. 27). Cook et al. (1966, p. 146) describes a "drastic reduction" in the number of splittail seen in Clear Lake during the 1940's and he attributed the reduction to increased water demand. The last time the Clear Lake splittail was recorded in Clear Lake was May 1972, when one individual was captured (Puckett 1972, pp. 1, 7; CDFW 2014, p. 27).

Water extraction continues throughout the watershed today. Both surface and ground water is being diverted from Clear Lake tributaries for agricultural purposes and domestic use (CDFW 2014, p. 27), with about 60% of supply coming 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, p. 27). 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 Clear Lake hitch (Big Valley 2015, p. 4). 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, entire).

Water extractions are 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 Clear Lake tributaries or the Clear Lake hitch. The California Department of Fish and Wildlife (CDFW) compared stream flow conditions at the USGS gauge on Kelsey Creek (USGS Station 11449500) and catch data from the early 1990's. 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, p. 27).

Agricultural production in the Clear Lake area 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, p. 1256; 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, p. 1257).

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, p. 3). 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, pp. 2–4). The acreage of fruit, nut, field, seed, and vegetable crops in Lake County only slightly increased from 2008 to 2017, with just over 107,100 acres in 2008 compared to 108,226 acres in 2017 (Lake County undated, pp. 3, 6, 7; Lake County 2018, pp. 4, 7, 8). 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 (see Figure 4.2; USDA 2019). The presence of agricultural production in the watershed not only has an impact on the amount water flowing in the tributaries to Clear Lake, but it likely also increases the amount of contaminants, in the form of pesticides and fertilizers, and sediment entering the lake. A description of pesticide and other contaminant use in the watershed is described in a later section (see Section 4.7).

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, entire). A few months later in June 2014, over 1,400 hitch were rescued 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, pp. 3, 6). 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, p. 7).

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 during the spring of 2018. 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, p. 1). It is unknown to what extent Clear Lake hitch were historically stranded within the tributary streams.

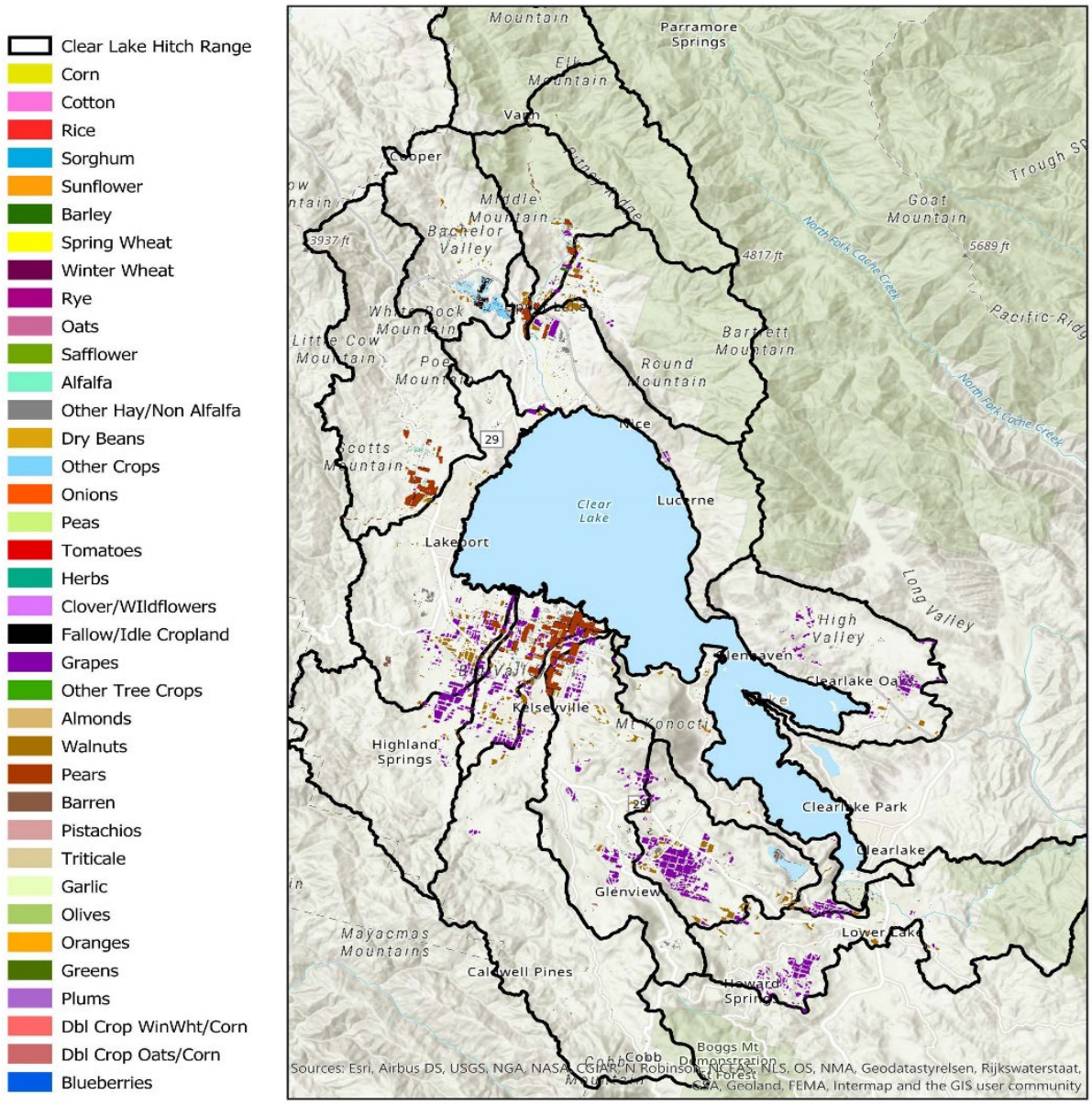

Figure 4.2 Agricultural production within the Clear Lake watershed during 2018

Regulatory mechanisms and management actions that are or could potentially provide some protection or benefit to tributary streams include: California Environmental Quality Act (CEQA) - any stream altering projects will be required to complete CEQA, which will direct all local and State agencies to avoid or minimize environmental damage, where feasible; US Forest Service (USFS) sensitive species designation – any USFS project within the Clear Lake hitch's range will avoid or minimize impacts to the subspecies. The USFS will also have to complete an analysis under the National Environmental Policy Act (NEPA); Lake County's Aggregate Resources Management Plan

– completely eliminated instream gravel mining in certain creeks and limits current mining activities to certain areas; Clear Lake Integrated Watershed Management Plan – has documented the historical and current conditions of the watershed (and specific tributary streams) and detail any specific implementation actions that will enhance and/or protect the watershed; and the Sustainable Groundwater Management Act (SGMA) – once implemented, will reduce or halt any overdraft from occurring and will bring groundwater basins into balance (i.e., water inputs are in balance with the amount of water extracted from the basin). Reducing overdraft from groundwater pumping in the Big Valley groundwater basin could improve flow conditions in Thompson Creek, Adobe Creek, Kelsey Creek, and Cole Creek. None of the regulatory mechanisms or management actions fully ameliorate habitat loss, degradation, and modification within the watershed, primarily because much of the degradation occurred in the past, although the effects are still occurring today. For a more thorough description of regulatory mechanisms and management actions, see Section 4.9 Regulatory Mechanisms and Management Actions below.

The loss of consistent tributary flow during the spawning season are seen throughout the Clear Lake hitch's range. This influence is affecting the subspecies at the individual, population, and subspecies level and is likely to continue into the future. The loss of consistent tributary flow has and will continue to reduce population resiliency by reducing reproductive success, early life stage survival, and the likelihood of recruitment. This reduction in resiliency results in a reduction to the subspecies' overall representation and redundancy.

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, p. 1254; CDFW 2014, pp. 45, 69–70; see Figure 4.3). 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, pp. 24-25). 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. Fertilized eggs have been known to accumulate just below a barrier to the point that they will die due to oxygen deprivation (Robinson Rancheria 2015, p. 1).

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, p. 1248). In addition, during the spring of 2016 CDFW identified potential barriers on Lyon's Creek, Scott's Creek, Seigler Canyon Creek, Clover Creek, and Kelsey Creek (Ewing 2016a, entire). 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, p. 69).

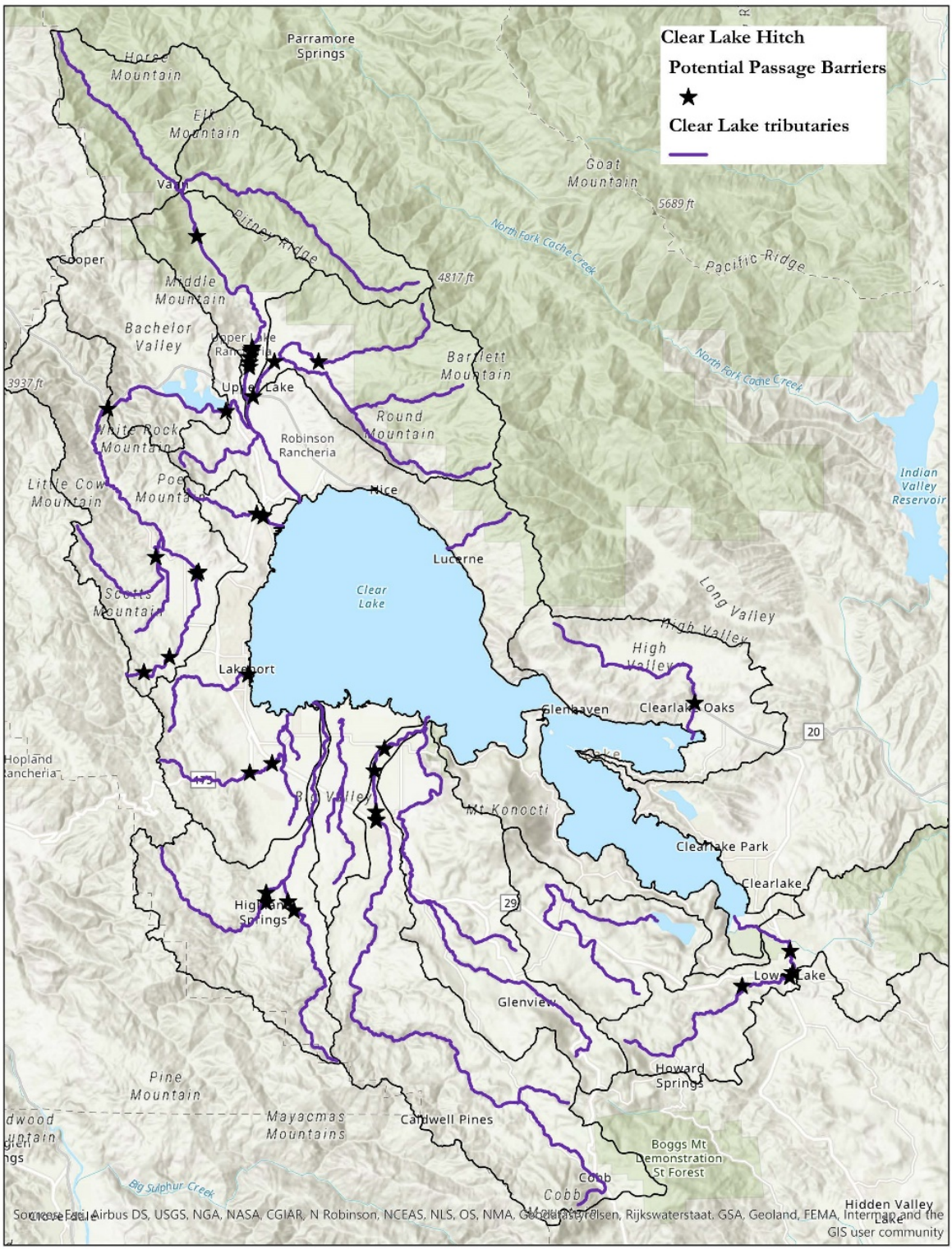

Figure 4.3 Potential passage barriers within the Clear Lake watershed. Data from: McGinnis and Associates 2006; County of Lake et al. 2010b, 2010c, and 2010d; CDFW 2014; and Windrem 2019.

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. 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, entire). 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, entire).

The presence of passage barriers are seen throughout the Clear Lake hitch's range; however, most physical barriers are concentrated to the west and northwest portions of the watershed (see Figure 4.3 above). This influence is affecting the subspecies at the individual, population, and subspecies level and is likely to continue into the future. The presence of barriers has and will continue to reduce population resiliency by reducing reproduction and early life stage survival. This reduction in resiliency results in a reduction to the subspecies overall representation and redundancy. There are currently no regulatory mechanisms or management actions that fully ameliorate the presence passage barriers.

4.1.2 Lakes

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, pp. 1256, 1257; CDFW 2014, p. 21). However, 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 historical mercury mining 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, which will be discussed in a future section (see Section 4.7).

<u>Wetland/Tule Habitat Loss</u>

Prior to early European settlement, large wetland/marsh complexes surrounded Clear Lake (CDFW 2014, p. 21). The conversion of these large wetland complexes was largely driven by the desire for agricultural production and urban development (Suchanek et al. 2003, pp. 1256, 1257; CDFW 2014, p. 21). 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, p. 1255). 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, p. 31). It has been estimated that there were at least 9,000 acres of marsh habitat 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 85% of Clear Lake's nearshore, wetland/tule habitat (Week 1982, p. 16; Suchanek et al. 2003, p. 1241). Figure 4.4

shows the concentration of development within the Clear Lake hitch's range and Figure 4.5 shows the remaining wetland habitats surrounding the lake.

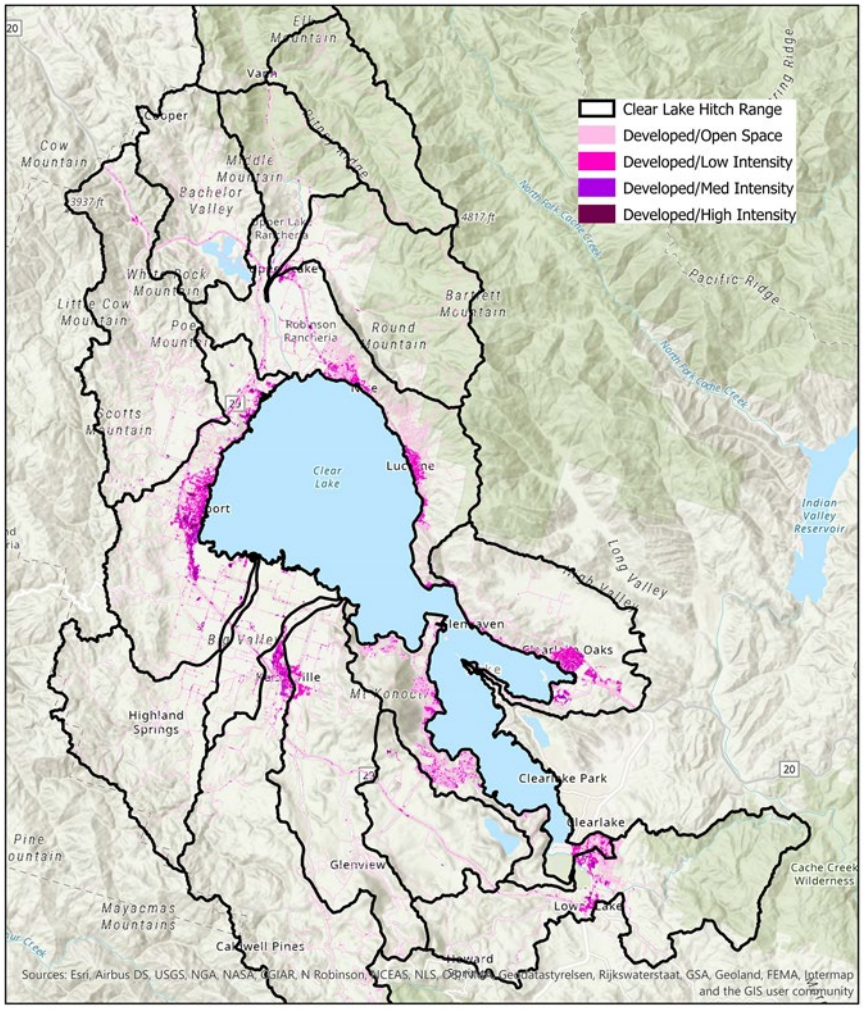

Figure 4.4 Urban development in the Clear Lake watershed

As seen in Figures 4.2 and 4.4, 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, p. 1239; Thompson et al. 2013, p.18). 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/PST045218). 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, p. 20; CDFW 2014, p. 37). 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, p. 37).

Guidance for future development within Lake County can be found in the Lake County General Plan, which was developed in 2008 and provides guidance through 2028. The county plans to implement "smart growth" by aiming to direct growth within existing developed areas and by discouraging urban sprawl (Lake County 2008, pp. 3-15–3-18, 3-51–3-55). 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, which will have different negative effects to the watershed (i.e., decreased tributary flow, decreased lake water quality).

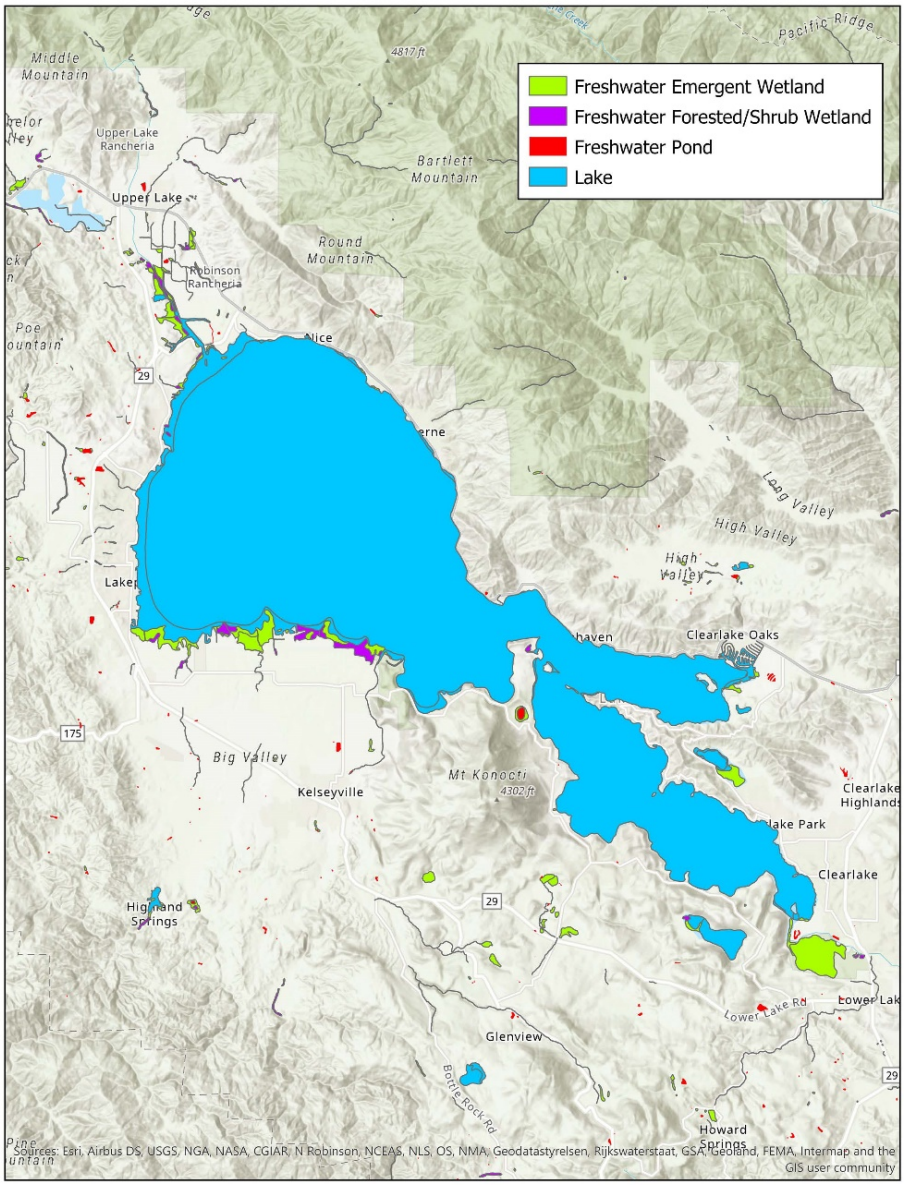

Figure 4.5 Remaining wetland habitat in the Clear Lake watershed

Regulatory mechanisms and management actions that are or could potentially provide some protection or benefit to wetland/tule habitats surrounding Clear Lake include: the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project – if this project is constructed in the future, it could potentially increase the amount of wetland/tule habitat surrounding the lake and improve the condition of currently degraded wetland habitat. Construction of this project would greatly benefit juvenile hitch by providing increased cover from predators and competitors, and increased prey abundance; and the Clear Lake Shoreline Ordinance – this county ordinance has prohibited the destruction of tules on residential properties along the shoreline around Clear Lake and requires full mitigation for any tule habitat that is destroyed. This ordinance benefits the Clear Lake hitch by providing a consistent amount of tule habitat for juveniles. None of the regulatory mechanisms or management actions fully ameliorate wetland habitat loss, primarily because the loss occurred in the past and the county ordinance only maintains the amount of existing tule habitat. For a more thorough description of regulatory mechanisms and management actions, see Section 4.9 Regulatory Mechanisms and Management Actions below.

The existing loss of wetland/tule habitat is affecting the subspecies at the individual, population, and subspecies level, and is likely to continue into the future. The loss of wetland/tule habitat has reduced the amount of habitat available to juvenile hitch, increasing intra-species competition for available cover and prey items. In addition, the introduction of non-native fish species that also utilize this habitat type further increases competition for the limited available resources (see Section 4.5). The loss of wetland/tule habitat has and will continue to reduce population resiliency by reducing juvenile survival and the likelihood of recruitment. This reduction in resiliency results in a reduction to the subspecies overall representation and redundancy.

<u>Cyanobacteria "Blue-Green Algae" Blooms</u>
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, p. 21). 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, pp. III-1, V-1, VIII-1; Suchanek et al. 2003, p. 1255). 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 increased incidence of these blooms currently are likely indirectly caused by this wetland loss (Stone 1876, p. 381; Suchanek et al. 2003, p. 1255; 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, p. III-9). 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, pp. III-9, III-11). Phosphorus is found naturally in underlying sediments within the Clear Lake watershed (Richerson et al. 1994, p. V-99) 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, pp. 37–38). Blue-green

algae blooms can be toxic to fish (Gorham 1960, p. 242; Prine et al. 1975, p. 23; Richerson et al. 1994, p. III-9); however, it is unknown what impact they have on the Clear Lake hitch. There are currently no regulatory mechanisms or management actions addressing blue-green algae blooms.

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, p. 381). 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, p. 453). The most recent large fish kill was documented in 2017 (USGS 2018, p. 9). 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, p. 84; Murphy 1951, p. 448; Cook et al. 1966, p. 152). Whatever the ultimate cause, a hypoxic zone frequently develops in the summer at the bottom of the lake (Cook et al. 1966, p. 152; Hopkirk 1973, p. 4; Feyrer et al. 2019b, p. 6). Lake monitoring during the summer of 2017 and 2018 found both juvenile and adult hitch were abundant in areas where dissolved oxygen levels are suitable (Feyrer et al. 2019b, p. 6), so it is likely the hitch actively avoid hypoxic areas. Fish kills have been observed in the absence of algae blooms and these have been attributed to surface water temperature changes (Macedo 1991, p. 5). Due to the wind action that frequently occurs at Clear Lake and the lake's relatively shallow depth, the lake is mixed numerous times throughout the year (Thompson et al. 2013, p. 9).

Regulatory mechanisms and management actions that are or could potentially prevent fish kills due to decreased lake water quality include: the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project – if this project is constructed in the future, it will improve degraded water quality by reducing the amount of sediment and nutrients entering Clear Lake, potentially reducing the incidence of large fish kills; and the Aggregate Resources Management Plan – this plan has reduced, and will continue to limit, the amount of instream gravel mining activities being conducted throughout the watershed. Limiting gravel mining has reduced the rate of erosion in the tributary streams and the amount of sediment entering Clear Lake. In addition, Lake County, the California Department of Transportation, USFS, and the Bureau of Land Management have undertaken various actions to prevent or reduce nutrients and contaminants from entering Clear Lake. There are no regulatory mechanisms or management actions that are fully ameliorating lake water quality degradation. For a more thorough description of regulatory mechanisms and management actions, see Section 4.9 Regulatory Mechanisms and Management Actions below.

Declines in Clear Lake water quality are affecting the subspecies at the individual level, and depending on the extent of the fish kill, it could be affecting the Clear Lake hitch at the population level as well (Clear Lake population). This influence is likely to continue into the future. The impacts of reduced lake water quality and the occurrence of periodic fish kills reduce both juvenile and adult survival, reducing overall resiliency, representation, and redundancy.

4.2 Overutilization for Commercial, Recreational, or Educational Purposes

Commercial fishing in Clear Lake began in the early 1900's and has been shut down and reinstated several times for different fish species (Murphy 1951, pp. 451, 452; Moyle and Holzhauser 1978, p. 574; Thompson et al. 2013, p. 18). 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 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, pp. 16–18; CDFW 2014, p. 11). There is one record from 1976 that documented the catch and sale of over 1,500 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 subspecies (CDFG 1961-2001; CDFW 2014, p. 33). Although there is a documented instance of the Clear Lake hitch 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, p. 33).

Clear Lake is known for its recreational fishery, with largemouth bass 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, pp. 1, 8, Figure 3). Hitch comprised 2% of the reported catch and all of the hitch caught were in the southern portion of the lake (Macedo 1991, pp. 8, 10, 11, Figures 3–5). 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, p. 8, Figure 3). 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 for the period between August 14, 2019, and December 5, 2020, there are currently 66 fishing contests that have been approved and 2 are 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, pp. 37-38).

Commercial and recreational fishing affect the subspecies at the individual level and it is likely only a negligible amount of hitch are actually caught. In addition, because the subspecies is listed as threated under the California Endangered Species Act (CESA), anglers are prohibited from taking the subspecies unless authorized by a permit. Although CESA may not completely ameliorate the loss of individuals due to overutilization for commercial or recreational purposes, the loss is already negligible since any fishing efforts are not targeting the subspecies. For a more thorough description of CESA, see Section 4.9 Regulatory Mechanisms and Management Actions below.

4.3 Tribal Harvest/Cultural Use

The Clear Lake area is one of the earliest known sites to be occupied by Native Americans, approximately 10,000 years ago (Richerson et al. 2008, p. A259). The local Pomo tribes historically relied on the large spawning runs of hitch during the spring for subsistence, drying and storing them to eat throughout the year. The hitch was such an important diet staple that the local tribes went to war over access to the abundant resource (Barrett 1908, p. 14; Kniffen 1939, p. 362, 370; Scotts Valley 2013 *in* CDFW 2014, p. 34). The local tribes collected hitch in the tributary streams by constructing a series of willow-made dams in the creek after the adults completed their upstream migration to spawn. Hitch would collect above the dams as they made their migration back to the lake and the Pomo would capture the hitch using woven baskets (Kniffen 1939, p. 363).

It is unknown how many hitch were historically collected for tribal harvest; however, early tribal accounts suggest the subspecies spawned in large numbers (Scotts Valley 2013 *in* CDFW 2014, p.

34). Tribes continued to harvest hitch until the mid-1980's when the spawning runs began to decline (Big Valley Environmental Protection Agency 2013 *in* CDFW 2014, p. 26). State regulations allowed capture of hitch on tributary streams by hand or dip-net until the species was designated a candidate for state listing under CESA (CDFW 2014, p. 26). Prior to the state listing of the subspecies and while it was still considered a candidate for listing, CDFW issued a Memoranda of Understanding to three tribes for collection of hitch for scientific and educational purposes (Kratville, D. pers. comm., October 7, 2013, unreferenced *in* CDFW 2014, p. 26). Because large spawning runs continued to be maintained annually, historical harvest for tribal subsistence did not appear to have a substantial population-level effect on the species. Because tribes no longer harvest large quantities of hitch from their limited spawning runs, tribal harvest only affects the hitch at an individual level. There are currently no regulatory mechanisms or management actions that fully ameliorate individual loss due to tribal harvest; however, any current or future tribal harvest of hitch will require authorization from CDFW since the subspecies is listed as threated under CESA.

4.4 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 Clear Lake hitch. Parasites, such as anchor worms (*Lernaea* spp.), do infect the Clear Lake hitch 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, p. 3). Anchor worms are a parasitic crustacean (copepod) that infect freshwater fish (Steckler and Yanong 2012, p. 1). 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, p. 2). Heavy anchor worm infections have not been reported for Clear Lake hitch (CDFW 2014, p. 36).

In addition to anchor worm infections, there have been three instances of Clear Lake hitch having facial deformities. 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, slide 16; Clear Lake Hitch Conservation Strategy Meeting Notes 2019, p. 2). 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, entire; Schmitt and Orth 2015, entire). 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.

The effects of parasites and deformities will continue to act on the subspecies into the future. There are no accounts of disease, parasites, or deformities causing mass mortality or extreme detrimental effects to the subspecies, and therefore, this influence only affects the hitch at an individual level. There are no regulatory mechanisms or management actions that address parasites and/or deformities.

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4.5 Predation and Competition

Twenty-five different species of non-native fish have been introduced into Clear Lake for recreational or biological control purposes, and although not all of them have become established, about 20 are still found in the lake today (Thompson et al. 2013, pp. 12–17, Table 1). Even early accounts in the late 1800's document the presence of non-native fish in Clear Lake. The first recorded introduction is from 1873 when Livingston Stone introduced lake whitefish (*Coregonus clupeaformis*) into Clear Lake; however, this attempt proved to be unsuccessful (Stone 1876, p. 377–378; Murphy 1951, p. 450). The introduction of carp is believed to be accidental when a resident of the Clear Lake area installed a carp pond in 1880 on the north shore of the lake. When the pond flooded the next winter, some of the carp were able to reach Clear Lake and become established (Murphy 1951, p. 449). White catfish (*Ameiurus catus*) and brown bullhead (*Ameiurus nebulosus*) were also introduced around 1880, although the specifics regarding their introduction are unknown (Murphy 1951, p. 450). Largemouth bass were first stocked in Clear Lake for a recreational fishing in 1888 and by 1910, the lake was known for its excellent bass fishing (Murphy 1951, p. 450, 451, 452, Table 6). By 1894, the brown bullhead, white catfish, carp, and largemouth bass were documented as inhabiting Clear Lake (Jordan and Gilbert 1895, p. 140). Smallmouth bass were introduced in 1895 and although considered unsuccessful, they have been documented in the lake since (Murphy 1951, p. 451; Thompson et al. 2013, p. 16). The California Fish Commission introduced golden shiners (*Notemigonus crysoleucas*) into Clear Lake in 1896 as forage for planted sport fish, and the bluegill, black crappie, and possibly the green sunfish were all introduced between 1909 and 1910, likely for recreational fishing (Murphy 1951, p. 450; Dill and Cordone 1997, p. 53; Thompson et al. 2013, p. 17). The initial introduction of golden shiners proved to be unsuccessful; however, subsequent plantings were successful (Thompson et al. 2013, p. 15, Table 1).

Western mosquitofish were introduced to the lake in 1925 to help control the gnat and mosquito populations (Murphy 1951, p. 451; Thompson et al. 2013, p. 17). The fathead minnow and redear sunfish were introduced in the 1950's as a forage fish and sport fish, respectively (Cook et al. 1966, p. 156; Dill and Cordone 1997, p. 56; Thompson et al. 2013, p. 16, Table 1). The local vector control district introduced the Mississippi silverside (*Menidia audens*) to Clear Lake and the Blue Lakes in 1967 to help control outbreaks of the Clear Lake gnat population (Geary 1978, pp. 1; Cook and Moore 1970, p. 70; Prine et al. 1975, p. 26, 28). By 1969, the Mississippi silverside was considered established within Clear Lake and Lower Blue Lake, but not within Upper Blue Lake (Cook and Moore 1970, p. 72). Threadfin shad were illegally introduced into Clear Lake in the 1980's to provide forage for sport fish (Bairrington 2000, p. 23). During the 2017 lake monitoring surveys conducted by USGS, threadfin shad comprised the largest proportion of catch (USGS 2018, p. 12). It is unknown when pumpkinseed were introduced and white crappie were likely introduced during the early 1900's (Bairrington 2000, p. 12; Thompson et al. 2013, p. 16, Table 1).

The introduction of the many non-native fish to Clear Lake have had effects on the native fish fauna and the habitat found in Clear Lake. All of the native fish populations within Clear Lake have undergone declines and four species that historically occurred in the lake (Pacific lamprey, hardhead, thicktail chub, and Clear Lake splittail) are now considered extirpated (Thompson et al. 2013, p. 12). Although the loss of these species can most likely be attributed to habitat modifications throughout the watershed or a combination of different factors, the introduction of non-native fish species led to the decline, and the possible extirpation, of the Sacramento perch population within Clear Lake (Murphy 1948a, pp. 99, 100; Murphy 1951, p. 475; Cook et al. 1966, pp. 155, 157–158; Thompson et al. 2013, p. 38; CDFW 2014, p. 34).

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All of the piscivorous fish species in Clear Lake are potential predators of Clear Lake hitch and there have been accounts of hitch in the stomach contents of both largemouth bass and channel catfish (Moyle et al. 2014, p. 10). In conjunction with a recent assessment of the Clear Lake fishery, a proportion of the black bass and catfish species that were captured had their gut contents analyzed to determine what fish species they were consuming in the lake (Ewing et al. 2016, p. 4). Surveys were conducted by electro-fishing the shoreline of the lake and the largemouth bass was the most common species collected (Ewing et al. 2016, pp. 50–51). Gut analysis revealed inland silversides were the most commonly identified fish species eaten by largemouth bass; however, the largest proportion of items removed from the gut were unidentifiable fish or fish parts (Ewing et al. 2016, p. 52). The main gut contents in the channel catfish stomachs analyzed were aquatic invertebrates and the most common fish species were inland silversides (Ewing et al. 2016, p. 53). No hitch were identified in any of the gut contents analyzed; however, it is possible the unidentifiable fish parts were from hitch (Ewing et al. 2016, pp. 52–53).

In addition to preying on hitch when they grow to larger sizes, smaller largemouth bass are also known to feed on insects and zooplankton, directly competing with both juvenile and adult hitch for food resources (Moyle and Holzhauser 1978, pp. 577–578, 581). Threadfin shad and silversides are also known to compete with the hitch since they also depend on the same aquatic prey base (Anderson et al. 1986, entire; Bairrington 2000, p. 33; CDFW 2014, p. 35). During years when silverside or shad abundance is especially high, they could deplete prey resources that the hitch depends on. A comparison of hitch trend data and abundances of silversides and threadfin shad suggests there may be a correlation between their abundances (CDFW 2014, p. 35); however, more detailed studies need to be completed. Silversides are also known to prey on larval fish, so it is possible some predation of hitch larvae by silversides is occurring in Clear Lake (Bennett and Moyle 1996, pp. 526, 529; Moyle et al. 2014, p. 9-10).

Besides the numerous piscivorous fish species that occur within Clear Lake, the Clear Lake hitch is also susceptible to predation from various bird and mammal species, especially during spawning migrations when they are more exposed. These species may include, but are not limited to, common merganser (*Mergus merganser*), hooded merganser (*Lophodytes cucullatus*), red-breasted merganser (*Mergus serrator*), pied-billed grebe (*Podilymbus podiceps*), horned grebe (*Podiceps auritus*), eared grebe (*Podiceps nigricollis*), western grebe (*Aechmophorus occidentalis*), Clark's grebe (*Aechmophorus clarkii*), white pelican (*Pelecanus erythrorhynchos*), double-crested cormorant (*Phalacrocorax auritus*), great blue heron (*Ardea herodias*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), green heron (*Butorides virescens*), black-crowned night-heron (*Nycticorax*), osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), river otter (*Lontra canadensis*), raccoon (*Procyon lotor*), striped skunk (*Mephitis*) and possibly black bear (*Ursus americanus*) (R. Macedo and S. Hill, pers. comm. 2009 *in* Moyle et al. 2014, p. 3; CDFW 2014, p. 9; Big Valley 2015, p. 6; eBird 2019).

Predation and competition will continue to affect the Clear Lake hitch at the individual, population, and species level into the future throughout its range. Predation and competition pressure within Clear Lake impacts the subspecies by reducing survival and recruitment, which reduces resiliency by decreasing the size of the overall population. Predation pressure within the tributaries to Clear Lake impacts the subspecies by reducing survival, reproduction, and recruitment, which further reduces resiliency by decreasing the size of the spawning population in any given year and by reducing the overall population altogether. This loss of resiliency reduces the subspecies' overall representation and redundancy since it results in fewer individuals spawning in each of the tributary streams and

natal habitat types. There are currently no regulatory mechanisms that address predation or competition.

4.6 Drought

Drought conditions within the Clear Lake watershed can have detrimental effects on the Clear Lake hitch by reducing the amount of flow within the tributary streams over the spawning season, reducing water quality in the lake, and possibly reducing emergent vegetation growth in the lake. Murphy (1948b) describes the almost complete lack of spawning runs in 1946 and 1947 due to the lack of water flow in the tributaries (Murphy 1948b, p. 105). However, the subspecies' ability to spawn along the lake shore provides an alternative to tributary spawning for at least a small proportion of the population. In addition, the subspecies' long lifespan is likely an adaptation to natural drought conditions in California, which can last for years.

Annual average air temperatures in California have increased by 1.5°F since the beginning of the 20th century (Bales 2013, p. 2). This coincides with increased aridity or drought conditions recorded within California since the early 1900s (Cook et al. 2004, p. 1016). This increase in aridity can impact the Clear Lake hitch by reducing the amount of time water is retained within the tributary streams and wetland habitats, which the hitch requires for spawning and rearing. Increases in aridity also reduce wetland/emergent vegetation growth, which the subspecies requires for rearing and for cover from predators. All of these factors can impact the reproductive success and recruitment of the subspecies and could potentially reduce survival if flows drop too drastically in the tributary streams and/or within their wetland habitats, or if they are subject to increased predation due to a reduction in cover.

The reduction of flow in the tributary streams during the spawning season can completely eliminate or greatly reduce the likelihood for successful reproduction and/or recruitment, and due to the Clear Lake hitch's very narrow range, the effects of drought will impact the entire subspecies. The ability to spawn along the shore provides for some redundancy within each population, but it is unknown whether shore spawning would be able to support a viable population over the long-term. Having a longer life-span is likely an adaptation to variable environmental conditions; however, prolonged droughts can have devastating effects on the overall population, especially in conjunction with other factors that are currently acting on the subspecies. There are currently no regulatory mechanisms that address drought.

4.7 Pesticides and Other Contaminants

A variety of pesticides have been applied to the lake in order to control insect or plant outbreaks and numerous contaminants have entered the watershed, primarily due to mining activity, but also from other anthropogenic uses. Clear Lake has been listed as an impaired water waterbody by the California State Water Resources Control Board (SWRCB) under Section 303(d) of the California Clean Water Act, due to both mercury contamination and increased nutrient input from sedimentation (SWRCB 2012; SWRCB 2019).

<u>Pesticides</u>

Clear Lake gnat outbreaks occur regularly in Clear Lake and have been 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, pp. 284–285; Cairns and Parfitt 1980, p. 504; Suchanek et al. 2003, pp. 1249–1250). Although the highest levels of DDD concentrations were seen in piscivorous fish species, fish species at lower trophic levels like the Clear Lake hitch also had concentrations of the larvicide in their tissues (Cook 1965, pp. 44, 46). 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, pp. 504, 509). 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, pp. 505–506). 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, p. 44; Cairns and Parfitt 1980, p. 504).

The application of DDD not only had a direct impact on the hitch through contamination, but it also likely impacted the subspecies 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, pp. 5, 10, 13; Hunt and Bischoff 1960 *in* Suchanek et al. 2003, p. 1249). The application of DDD not only eliminated or greatly reduced gnat populations, it was also known to reduce another prey item of juvenile Clear Lake hitch, chironomid larvae. However, chironomid larvae populations were able to recover faster than gnat populations post-DDD treatment (Lindquist and Roth 1949, p. 13).

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, p. 44; Suchanek et al. 2003, p. 1250). 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, p. 1250). The Clear Lake gnat still occurs in Clear Lake and their population in 2010 and 2012 were at a high level not seen for some time. The gnat population is thought to fluctuate in response to the silverside population in the lake, which was specifically introduced to help control the gnat outbreaks (Cook and Moore 1970, p. 70; Prine et al. 1975, p. 26, 28; Geary 1978, pp. 1; CDFW 2014, p. 32).

In addition to the insecticides used to control the Clear Lake gnat population, the aquatic herbicides Komeen™ (copper sulfate) and SONAR™ (fluridone) have also been applied in the lake to control *Hydrilla verticillata*, a highly invasive submerged aquatic weed (Suchanek et al. 2003, p. 1250, 31; CDFW 2014, p. 32). Two herbicides were used to target different parts of the plant, Komeen targets *Hydrilla* vegetative growth while SONAR treats the tubers (Suchanek et al. 2003, p. 1250). Komeen is not known to directly kill fish; however, it is known to affect various aquatic invertebrates within the treatment areas and, therefore, may indirectly impact fish, including the hitch through a reduction in prey base (Bairrington 2000, p. 63). SONAR is considered less toxic than Komeen, but because it is a systemic herbicide that is slowly absorbed in the vascular system, it also impacts

similar non-target vegetation such as tules and other submerged vegetation (Bairrington 2000, pp. 64–65; CDFW 2014, p. 32). Because juvenile Clear Lake hitch require tule habitat for cover, the use of Komeen can indirectly impact the subspecies (CDFW 2014, p. 32).

Other pesticides are also used throughout the watershed on private homeowner and agricultural lands. Pesticide use on private 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, pp. 1250–1251). 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 poundage increased to almost 759,000 lbs. (CALPIP 2019). However, it is unknown what effect terrestrial pesticides are having on the aquatic environment or if they are being transported through tributary streams into the lake (Suchanek et al. 2003, p. 1252). Furthermore, it is unknown what effect they could be having on the Clear Lake hitch.

Mercury

In addition to the gravel mining operations throughout the watershed, 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, p. 1253). 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, p. A259). The company continued to mine sporadically throughout the 1950's until the Sulphur Bank Mercury Mine was officially closed in 1957, although waste continued to contaminate the lake well into the 1990's (Suchanek et al. 2008, p. A153).

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, p. A257). 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, pp. A267–269). 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 (^{15}N) 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, pp. A257, A268–270). 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, p. A271). 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, p. A260).

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, p. A275). Since 1992 the EPA has implemented numerous remediation projects to address the continued mercury contamination originating from the Sulphur Bank

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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, pp. A265, A275; EPA 2019).

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, p. 1; Suchanek et al. 2003, p. 1253; Thompson et al. 2013, p. 19). 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 Clear Lake hitch (Crump and Trudeau 2008, pp. 902, 904; CDFW 2014, p. 32–33). Mercury concentrations found in hitch caught in Clear Lake from the 1980's and 1990's averaged 0.19 mg/kg, while the larger piscivorous fish such as adult largemouth bass averaged .54 mg/kg (CEPA 2002, pp. *ii*, 9; CDFW 2014, p. 33). 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 Clear Lake hitch (CEPA 2002, p. *ii*). Consumption advisories for fish removed from Clear Lake were first issued in the 1980's and the California Office of Environmental Health Hazard Assessment continues to provide advisories for Clear Lake fish and invertebrates (Thompson et al. 2013, p. 19; OEHHA 2018).

Regulatory mechanisms and management actions that are or could potentially prevent effects to the Clear Lake hitch due to pesticide and mercury contamination in Clear Lake include the Middle Creek Flood Damage Reduction and Ecosystem Restoration Project, which if constructed in the future will improve degraded water quality by filtering some of the contaminants that enter Clear Lake from the tributary streams. In addition, Lake County, the California Department of Transportation, USFS, and the Bureau of Land Management have undertaken various actions to prevent or reduce and contaminants from entering Clear Lake. There are currently no regulatory mechanisms or management actions that are fully ameliorating habitat degradation due to contamination from pesticides or other sources. For a more thorough description of regulatory mechanisms and management actions, see Section 4.9 Regulatory Mechanisms and Management Actions below.

The effects of mercury contamination, and possibly pesticide use, will continue to act on the subspecies into the future; however, it is unknown what effects pesticide and mercury contamination are having on the Clear Lake hitch and there are no accounts of either causing mass mortality or extreme detrimental effects to the subspecies.

4.8 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 2013a, p. 1450). 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, p. 1450).

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, pp. 35–54, 82–85; IPCC 2013b, pp. 3–29; IPCC 2014, pp. 1–32). 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, pp. 21–35; IPCC 2013b, pp. 11–12 and Figures SPM.4 and SPM.5).

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, entire; Ganguly et al. 2009, pp. 11555, 15558; Prinn et al. 2011, pp. 527, 529). 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, pp. 760–764 and 797–811; Ganguly et al. 2009, pp. 15555–15558; Prinn et al. 2011, pp. 527, 529; IPCC 2013b, pp. 19–23). See IPCC 2013b (entire), 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, pp. 15–16). Therefore, we use "down-scaled" projections 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, pp. 58–61, 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, pp. 12423–12424, Figure 1). 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, pp. 12424–12425, Supplemental Figure 11).

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 Clear Lake hitch 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, pp. 841, 842, 844, Figure 1). 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, pp. 848–850). 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 Clear Lake hitch. 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, p. 855).

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, entire). 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 1990's by the end of the century (RCP 4.5) (Grantham 2018, p. 15). 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, pp. 17–18, Figure 2.4).

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, p. 20; Grantham 2018, p. 19). There is also less difference between the two different emissions scenarios than was seen for the temperature predictions (Pierce et al. 2018, p. 20). 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, p. 19, Figure 2.7).

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, pp. 23–24, Figures 13 and 14). 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, pp. 22-24). In general, the winter months (December–February) are projected to be wetter and the spring months (March–May) are projected

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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, pp. 6, 19–20). 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, p. 23). 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, pp. 27–28).

Because the Clear Lake hitch 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 subspecies. Moyle et al. (2013) conducted an assessment to determine the Clear Lake hitch's vulnerability to the effects of climate change. They determined that the subspecies was "critically vulnerable" to the effects of climate change (specifically, the change in spring hydrograph) and that the subspecies "…is extremely likely to be driven to extinction by year 2100 without conservation measures (Moyle et al. 2013, pp. 3, 7, Table S1)."

Regulatory mechanisms and management actions that are or could potentially provide some protection from the effects of climate change include the Clean Air Act and the California Global Warming Solutions Act. Both address climate change by reducing greenhouse gas emissions within the United States and California, respectively. There are no regulatory mechanisms or management actions that fully address the effects of the climate change. For more information on the Clean Air Act and the California Global Warming Solutions Act, see Section 4.9 Regulatory Mechanisms and Management Actions below.

The effects of climate change will impact the Clear Lake hitch at the individual, population, and subspecies level into the future. The loss and/or reduction of suitable spawning streams throughout the subspecies' range and the declining quality of riparian and rearing habitat will likely reduce reproductive success, recruitment, and survival. The reduction in tributary streams available to the hitch for spawning will further decrease the subspecies' overall representation and redundancy.

4.9 Regulatory Mechanisms and Management Actions

<u>California Endangered Species Act (CESA)</u>
On August 6, 2014, the California Fish and Game Commission determined the Clear Lake hitch 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. It should be noted that the state's definition of take is not the same as the Service's definition of take under the Federal ESA.

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.

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 Clear Lake hitch 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.

Clean Air Act

The Clean Air Act of 1970 (42 U.S.C. 7401 et seq.) provides the platform for the Environmental Protection Agency (EPA) to develop and enforce regulations to protect the general public from exposure to airborne contaminants known to be hazardous to human health. In 2007, the Supreme Court held that gases such as carbon dioxide fit within the Clean Air Act's definition of "air pollutant," and thus that EPA has the authority to regulate the emissions of such gases from new motor vehicles (Massachusetts et al. v. EPA, 549 U.S. 497, 532 (2007)).

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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.

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, entire). 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, entire; County of Lake et al. 2010c, entire; County of Lake et al. 2010d, entire).

Aggregate Resources Management Plan

Lake County developed an Aggregate Resources Management Plan (County of Lake 1992, entire) 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, pp. 83–86). 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. In-stream sources of gravel are no longer the primary source of aggregate in Lake County, gravel is now acquired from other sources (CEPA 2008, pp. 8, 89).

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 was once approximately 1,400 acres of wetland habitat that was lost in the early 1900's 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. Final 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

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appropriated to start project design; however, funding for land acquisition has been acquired (Corps 2012, pp. 1–2).

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. It will also increase the existing amount of wetland habitat within the Clear Lake watershed by approximately 79 percent (Corps 2012, p. 3). 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.

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 (County of Lake et al. 2010a, pp. ES-16, 3-10; CDFW 2014, p. 42). These ordinances benefit the Clear Lake hitch by providing a consistent amount of tule habitat for juveniles.

Clear Lake Hitch Conservation Strategy

A group including local tribes, local government, state agencies, and federal agencies have been working on the development of a conservation strategy for the hitch. The strategy will document the past and current status of the subspecies, will describe the negative influences that have resulted in the subspecies' current status, and will identify the actions that will address those negative influences in order to maintain a viable population of Clear Lake hitch throughout its range. This strategy will benefit the hitch by helping to inform the public on how they can help the hitch and to direct funds to implement actions or projects that will specifically benefit the hitch.

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, pp. 2, A-1). 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. Groundwater Sustainability Agencies have been formed for the Big Valley and Scotts Valley basins; however, a Groundwater Sustainability Plan has not yet been developed for the Big Valley basin (DWR 2019b; DWR 2019c;

DWR 2019d). Reducing overdraft from groundwater pumping in the Big Valley basin could improve flow conditions in Thompson Creek, Adobe Creek, Kelsey Creek, and Cole Creek.

Miscellaneous

Lake County, the California Department of Transportation, US Forest Service, and the Bureau of Land Management have undertaken various actions to prevent or reduce nutrients and contaminants from entering Clear Lake (West Lake Resource Conservation District, undated; CDFW 2014, p. 41). These actions include the Eightmile Valley Sediment Reduction and Habitat Enhancement Project, which the Bureau of Land Management and Scotts Valley Band of Pomo Indians have recently received a grant for (CDFW 2014, p. 41). 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 Clear Lake hitch during early life stages (CDFW 2014, p. 42).

4.10 Cumulative Effect of Combined Factors Influencing Viability

Multiple influencing factors can act on a species or its habitat at the same time, which can result in impacts that are not accounted for when factors are analyzed separately. Factors that appear minor when considered alone may have greater impacts on individuals, populations, or habitat when analyzed in combination with other factors.

The Clear Lake hitch evolved in Lake County, California, which has always had a highly variable climate with natural periodic droughts. However, the degradation and loss of water retention within their spawning streams and the loss of large stretches of suitable spawning habitat due to various instream barriers has likely reduced reproductive success and recruitment. During drought conditions this can completely or almost completely eliminate all stream based spawning in a given year. If drought conditions persist over multiple years, stream based reproduction can also be reduced or eliminated for multiple years. Furthermore, climate change projections suggest the Clear Lake area will see more varied precipitation and higher temperatures during the spring, which could result in even less water flow being retained within the tributary streams during the subspecies spawning season (Pierce et al. 2013, pp. 842, 844, 848–850, Figure 1). Although the subspecies has the ability to spawn within the lake, it is unknown whether that method of reproduction would be able to sustain a viable population of hitch in Clear Lake.

The combination of wetland habitat loss and drought can result in increased predation pressure and competition. Past habitat loss have left only a small proportion of wetland habitat surrounding Clear Lake and drought conditions can reduce the amount of emergent vegetation growth within those remaining wetland habitats. This reduction in emergent vegetative growth reduces the amount of cover the hitch uses to hide from predators, increasing predation pressure. It can also increase competition as more fish concentrate into this limited habitat type.

4.11 Summary

Our analysis of the past, current, and future factors influencing viability revealed there are six primary factors affecting the current and future viability of the Clear Lake hitch. These risks to viability are primarily related to habitat changes, both negative and positive:

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1. The loss of spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams;
2. The loss of wetland/tule habitat that juveniles require for rearing;
3. The effects from poor lake water quality;
4. The effects of increased competition and predation from a combination of introduced fish species and habitat loss;
5. Drought, which further reduces tributary flow; and
6. The implementation of regulatory mechanisms (i.e., CESA, Lake County's Clear Lake Shoreline Ordinance, and SGMA) and management actions (i.e., Lake County's Aggregate Resources Management Plan, Middle Creek Flood Damage Reduction and Ecosystem Restoration Project, and other miscellaneous restoration actions occurring throughout the watershed).

Furthermore, most of these influences will all exacerbated by the effects of future climate change. Although we did assess the use or take of Clear Lake hitch for tribal harvest, we will not be carrying this factor forward into the future analysis because these risks do not appear to be occurring at a level that affects the entire population. The six influences listed above, will be carried forward in our assessment of the current condition of the Clear Lake hitch, which is described in the next chapter (Chapter 5). To assess the possible future condition of the Clear lake hitch, we use those same six influences for our analysis but we also include the effects of climate change. The future condition analysis is described in Chapter 6.

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CHAPTER 5: CURRENT CONDITION

In this chapter we report the historical population estimates and observations of the subspecies, and the current survey efforts that are occurring throughout the watershed. We also analyze the current condition of the subspecies by determining the condition of each of the demographic factors and habitat elements carried forward from Section 3.2.2, in light of the past and current influences to Clear Lake hitch viability that were defined in Chapter 4. The past and current influencing factors that have resulted in the current condition of the subspecies include the loss of spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams, the loss of wetland/tule habitat that juveniles require for rearing, the effects of poor lake water quality, the effects of increased competition from a combination of introduced fish species and habitat loss, drought reducing tributary flow, and the implementation of regulatory mechanisms and restoration actions. We describe the subspecies' current condition by characterizing its status in terms of **resiliency**, **representation**, and **redundancy** (3 Rs).

5.1 Historical Population Estimates/Observations

There are not any robust, statistically valid population estimates for the historical population of Clear Lake hitch. 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 Clear Lake hitch 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, entire; Thompson et al. 2013, p. 12). 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, p. 226)." Cook et al. (1966, p. 143–144) 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 (e.g., Clear Lake splittail and Sacramento pikeminnow).

Incidental catch records for commercial fishing operators operating between 1961 and 2001 included information about catch of Clear Lake hitch. 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, pp. 16–18; CDFW 2014, p. 11). 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 caught within the lake can vary widely, with some reported hauls catching no hitch at all and others recording over 10,000 individuals (CDFG 1961-2001; CDFW 2014, pp. 11–13, 17–18). The high variability of hitch incidentally caught could suggest high population variability. This variability would likely be in response to variable environmental conditions in the Clear Lake area, with prolonged dry periods reducing overall abundance. Documented observations from 1961-1963 described great numbers of hitch ascending the flooding tributaries and spilling out into drainage ditches and farm ponds; however, during the dry spring of 1964, very few hitch were seen in the spawning tributaries (Cook et al. 1966, p. 145; CDFW 2014, pp. 11–13, 17–18).

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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, p. 8). However, new research suggest adults can be found in any portion of the lake where conditions are suitable, specifically, where dissolved oxygen levels are normal (Feyrer et al. 2019b, pp. 5–7). 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, pp. 11, 16).

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.

5.2 Current Population Estimates and Distribution

There is not a current population estimate for the Clear Lake hitch; however, more recent survey efforts conducted by CDFW, local tribes, and USGS are accruing more data to aid in providing a more accurate estimate. Current 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 also been conducting visual surveys during the spawning season. The purposes 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 or other large waterbody surveys conducted by CDFW include electrofishing efforts to identify hitch spawning in the lake, assess the population residing in the Soda Bay area 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, pp. 7, 9–10). 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, and 118 hitch were collected from Kelsey Creek (Ewing 2014b, pp. 8–10). There were two recaptures on Adobe Creek, one that contained a PIT (Passive Integrated Transponder) 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, pp. 4–5, 8–10).

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, p. 2). 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, pp. 8–10). 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, pp. 2, 9–10). All of the hitch captured during the 2016 spawning survey were in the 225 mm or greater size class (Ewing 2016c, p. 11). The 2017 mark recapture survey resulted in many more fish captured 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, p. 2). 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, pp. 9–11). Out of all the years of sampling, only one individual that CDFW tagged had truly been recaptured (Ewing 2017b, p. 12).

Beginning in 2005 and continuing until today, members of the Chi Council for the Clear Lake Hitch 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, accessibility to spawning habitat, and surveyor miscalculation due to a lack of in-stream visibility. 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; CDFW 2014, p. 14). Table 5.1 is a summary of tributaries with documented hitch from the Chi Council for the Clear Lake Hitch observational surveys, by year.

Table 5.1 Summary of Chi Council for the Clear Lake Hitch observational surveys by year.

Tributary/HUC12	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Adobe Creek	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Kelsey Creek	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cole Creek	X	X	X	X	X	X	X					X			X
Scotts Creek	X	X	X	X	X	X				X	X	X	X	X	X
Clover Creek	X		X	X	X	X	X				X	X	X	X	X
Middle Creek	X		X	X	X	X		X		X	X	X	X	X	X
Seigler Canyon Creek								X	X	X	X		X	X	X
Rodman Slough	X										X	X			X
Manning Creek	X	X				X	X					X	X	X	X
McGaugh Slough	X	X											X		
Schindler Creek							X	X							

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, p. 2). Surveys were repeated again in 2016, 2017, and 2018, and like the observational surveys conducted by the Chi Council for the Clear Lake Hitch, the results of CDFW's visual spawning surveys varied from year to year. The number of tributaries documented as 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 CCCLH surveys, Adobe Creek had spawning observations every year (Ewing 2014c, p. 5; Ewing 2016b, pp. 2, 5–6; Ewing 2017a, pp. 7, 8; Ewing 2018b, pp. 2, 7). A summary of the CDFW visual spawning surveys are seen in Table 5.2

In addition to the tributary surveys, CDFW conducted electrofishing surveys along the lake's shoreline in 2014 in an attempt to identify any hitch spawning along the lake shore. The survey occurred during the night of May 7, 2014, and resulted in the capture of 36 hitch, all of which were subsequently tagged with either a PIT tag (larger than 275 mm or greater) or a fin clip (individuals between 200 mm and 275 mm). During the electrofishing survey, there was only one male hitch that was in spawning condition (e.g. expressing milt) (Ewing 2014d, pp. 2–3, 5). CDFW also implemented three electrofishing studies in 2015. The first 2015 effort focused on Soda Bay where a total of 75 hitch were captured and many more were seen. All of the fish ranged from 143-194 mm in length, indicating they were 1 to 2 year old fish (Ewing undated, entire). The other two efforts were to determine whether Clear Lake hitch were present within Thurston Lake and Highland Springs Reservoir, which is just south and southwest of Clear Lake, respectively (Ewing 2015b, p. 1; Ewing 2015c, p. 1, see Figure 2.2 above). During the surveys, seven hitch were captured in Thurston Lake and one was captured in Highland Springs Reservoir (Ewing 2015b, p. 2; Ewing 2015c, p. 1). Highland Springs Reservoir is located on Highland Springs Creek, a tributary to Adobe Creek.

Table 5.2 Summary of CDFW visual spawning surveys by year.

Site ID	Tributary	2014	2016	2017	2018
1	McGaugh Slough	--	--	--	--
2	McGaugh Slough	--	--	--	--
3	McGaugh Slough	--	68	5	--
4	Hill Creek	--	--	--	--
5	Hill Creek	--	--	--	--
6	Adobe Creek	140	605	50	200
7	Adobe Creek	371	--	50	200
8	Adobe Creek	48	--	39	318
10	Thompson Creek	--	--	--	--
11	Thompson Creek	--	--	27	--
12	Thompson Creek	--	--	50	--
13	Cole Creek	--	20	--	--
14	Cole Creek	--	--	--	--
15	Cole Creek	--	--	--	--
16	Kelsey Creek	495	--	--	150
17	Kelsey Creek	--	--	3	--
18	Kelsey Creek	55	--	--	150
19	Kelsey Creek	10	--	--	133
21	Manning Creek	--	--	293	2
22	Manning Creek	--	--	--	--
23	Manning Creek	--	--	--	--
TOTAL		1119	693	517	1153

From 2017-2019, USGS surveyed Clear Lake to determine the status, distribution, and habitat preferences of the Clear Lake hitch throughout the lake (USGS 2018, p. 4; Feyrer 2019a). 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, p. 4). 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, p. 8; Feyrer 2019a). In 2017 and 2018, 280 and 297 hitch were captured, respectively. The Clear Lake hitch 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, p. 8). 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 2019a), which may have resulted in hitch avoiding being captured because the gill nets were visible.

Over the course of the lake monitoring effort it become apparent there was a large difference in size distribution of hitch captured over the three survey years (see Figure 5.1). 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 during that year. 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, pp. 9–10; Feyrer 2019a). During the 2017 and 2018 efforts, the younger cohorts were most often encountered in shore habitats while adults were more equally 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, pp. 8–10). Lake surveys may continue into 2020 and 2021.

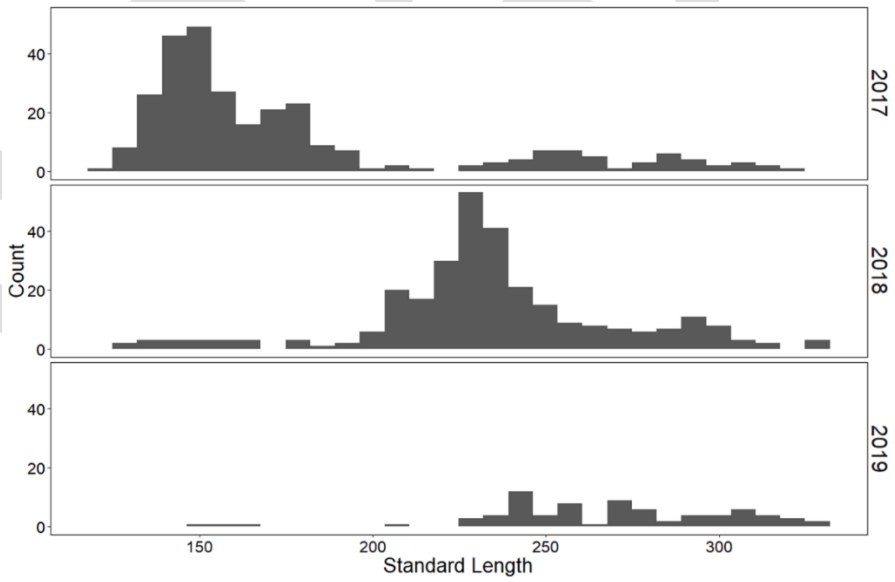

Figure 5.1 Summary of hitch caught during the 2017-2019 lake monitoring effort conducted by USGS. Credit: USGS, Fred Feyrer

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. 2019a, pp. 1690, 1692). Strontium signatures from water samples taken throughout the watershed indicated the

watershed could be assigned to one of five unique strontium isotope groups (SIG) (see Figure 3.2 above). 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 (SIG 1); Kelsey Creek, Burns Valley Creek (SIG 2); Clear Lake, Adobe Creek, Scotts Creek (SIG 3); Rodman Slough (SIG 4); Middle Creek, Clover Creek, Seigler Canyon Creek (SIG 5). 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. 2019a, pp. 1693, 1695).

Each of the five SIG's were represented in the otolith signatures, with most (58%) of the adults being assigned to SIG 3. It is likely the natal habitat associated with a majority of individuals representing SIG 3 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 (SIG 4), 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 SIG 1 and Kelsey Creek is the most likely source for individuals from SIG 2. Middle, Clover, and Seigler Canyon Creeks all likely contribute to SIG5 since they all are well known spawning tributaries. 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 Clear Lake hitch is able to utilize the mouths of streams with little to no flow movement and areas within Clear Lake itself (Feyrer et al. 2019a, pp. 1693–1695).

5.3 Introduction for Current Condition Analysis

We have considered what the Clear Lake hitch needs for viability (Chapter 3) and we have evaluated the past, current, and future influencing factors impacting the Clear Lake hitch (Chapter 4). We now will analyze the subspecies' current condition by considering how those past and current influences described in Chapter 4 have impacted the condition of those demographic factors and habitat elements identified in Chapter 3. We apply the concepts of resiliency, representation, and redundancy to describe the current condition of the Clear Lake hitch.

The various past and current negative influencing factors discussed in Chapter 4 have significantly reduced the current abundance of hitch compared to historical accounts. This decline in abundance is primarily due to reductions in reproductive success, recruitment, and survival, caused by the loss of consistent tributary flow, the loss of wetland/tule habitat surrounding the lake, reductions in lake water quality, effects due to introduced fish species, and the effects of drought conditions. Table 5.3 describes those influencing factors we carried forward for the current condition analysis. These will be used, in addition to implemented management actions, to assess the current condition of each Clear Lake population and the viability of the subspecies overall. The current resiliency of each population will help describe the level of redundancy and representation the subspecies currently expresses. However, neither redundancy nor representation could ever be considered at a high level due to the hitch's narrow range and low variability of habitat characteristics across the subspecies' geographical range.

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Table 5.3 Influences used to determine the current and future condition of the Clear Lake hitch

Negative Factor Influencing Viability	Cause(s)	Past, Current, and/or Future Factor	Effect(s) to the Clear Lake Hitch	Potential Regulatory Mechanism or Management Action
The loss of spawning habitat - altered tributary flow regime	Instream gravel mining	Past activity, currently having effects on the watershed and will continue in the future	Reduced reproduction, early life stage survival, and likelihood of recruitment	CEQA; Lake County's Aggregate Resources Management Plan
	Deforestation	Past activity, currently having effects on the watershed and will continue in the future	Reduced reproduction, early life stage survival, and likelihood of recruitment	CEQA; NEPA; US Forest Service (USFS) sensitive species designation
	Grazing practices	Past activity, currently having effects on the watershed and will continue in the future	Reduced reproduction, early life stage survival, and likelihood of recruitment	There are currently no regulatory mechanisms that address grazing practices
	Existing flood control project infrastructure	Past installation, currently having effects on the watershed and will continue in the future	Reduced reproduction, early life stage survival, and likelihood of recruitment	CEQA; NEPA
	Fire activity; increased incidence due to climate change	Past, Current, and Future	Reduced reproduction, early life stage survival, and likelihood of recruitment	Clean Air Act; California Global Warming Solutions Act
	Water utilization for agricultural and urban uses	Past, Current, and Future	Reduced reproduction, early life stage survival, and likelihood of recruitment	SGMA
The loss of spawning habitat - blocked access	Lack of adequate tributary flow	Past, Current, and Future	Reduced reproduction and early life stage survival	SGMA; Misc. restoration actions
	Physical barriers (dams, diversions, roadways, and crossings)	Past, Current, and Future	Reduced reproduction	Barrier removal and/or fish ladder installation by CDFW and CalTrans

Negative Factor Influencing Viability	Cause(s)	Past, Current, and/or Future Factor	Effect(s) to the Clear Lake Hitch	Potential Regulatory Mechanism or Management Action
The loss of wetland/tule habitat	Conversion to agricultural production and urban development	Past activity, currently having effects on the watershed and will continue in the future	Reduced early life stage survival and likelihood of recruitment	Clear Lake Shoreline Ordinance; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project
Reductions in lake water quality	Loss of wetland/tule habitat surrounding the lake	Past activity, currently having effects on the watershed and will continue in the future	Reduced survival	Clear Lake Shoreline Ordinance; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project
	Mercury contamination	Past activity (mercury mining), currently having effects on the watershed and will continue in the future	Reduced survival	Aggregate Resources Management Plan; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project; Misc. restoration actions
	Increased sediment and nutrient input	Past, Current, and Future	Reduced survival	Aggregate Resources Management Plan; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project; Misc. restoration actions
	Cyanobacteria blooms	Past, Current, and Future	Reduced survival	Aggregate Resources Management Plan; Middle Creek Flood Damage Reduction and Ecosystem Restoration Project; Misc. restoration actions
Increased predation and competition pressure due to the establishment of non-native fish species	Introduction of non-native fish species	Past activity (introduction), currently having effects on the subspecies and will continue in the future	Reduced survival, reproduction, and likelihood of recruitment	There are currently no regulatory mechanisms that address predation and competition.
Drought conditions	Environmental setting; increased incidence due to climate change	Past, Current, and Future	Reduced reproduction and recruitment	There are currently no regulatory mechanisms that address drought.

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5.3.1 Summary of Methods for Current Condition Analysis

We are considering two populations of Clear Lake hitch, one occupying Clear Lake and its tributaries, and the other Thurston Lake and its tributary. In order to analyze the Clear Lake population in more detail, we broke the populations down into HUC 12 sub-watersheds. There are 16 HUC 12 sub-watersheds found throughout the range of the subspecies, each of which occupy different areas within the watershed that contribute to the various hitch needs during their different life history stages. We further grouped some of the HUC 12 units based off of an analysis of strontium signatures throughout the watershed, which indicate the contribution of different natal habitats to the population in Clear Lake. Because the entire Thurston Lake population occurs entirely within the Thurston Lake HUC 12 unit, it will be not be lumped into a SIG and resiliency of that HUC 12 will be used as the analysis unit for that entire population. Since Thurston Lake is a closed system and contains an apparently robust population, we are assuming the current resiliency of the Thurston Lake population is high. The Clear Lake population occupies numerous HUC 12 units, each of which are associated with one of the five SIG's (see Figure 3.2 and Table 3.2 above). Each of the demographic factors and habitat elements carried forward from Section 3.2.2 will be analyzed using the methods/assumptions described below and shown in Tables 5.4a and 5.4b.

<u>Reproduction:</u> Observational data collected by CCCLH and CDFW will be used to analyze reproduction. Specifically, the consistency of spawning observations in those primary natal habitat associated with each SIG, except for SIG 4, will be used to categorize condition. The following are the primary natal habitats for each SIG, minus SIG 4: Cole Creek (SIG 1); Kelsey Creek (SIG 2); Clear Lake and Adobe Creek (SIG 3); Middle Creek, Clover Creek, and Seigler Canyon Creek (SIG 5). SIG 4, Rodman Slough is not typically included in observational surveys, and therefore, the recruitment category level assigned to SIG 4 will also be used for reproduction (moderate, see below).

<u>Recruitment:</u> The recruitment analysis for the Clear Lake hitch will have two components: the presence of wetland habitat and the results from the otolith analysis. Since the otolith analysis confirmed some level of recruitment for each of the SIG's, this component of the analysis will be weighted double. Overall scores are determined by adding the two components. Because we know the remaining amount of wetland habitat surrounding the lake has declined compared to the historical condition, we are assuming for this analysis that this component cannot be in a high condition. Therefore, we will be defining a moderate condition for the wetland habitat component as having remnant habitat within the SIG and a low condition as having very little remnant habitat within the SIG (see Table 5.4b). Figure 5.2 shows the existing wetland habitat within each SIG.

Although only one year of the otolith analysis was conducted, we will be using the proportion of individuals assigned to each SIG to categorize the otolith component of recruitment. We recognize that if all portions of the lake were equally contributing to recruitment, which may have been the case historically, the proportion of individuals representing each SIG would be equal (20%). However, because of the loss of wetland habitat surrounding the lake, we are assuming that each SIG can no longer support an equal amount of recruitment. Therefore, this component of the analysis is really just a comparison of what portion of the lake is currently contributing to recruitment. For the otolith component, we define a high condition as those SIG's that are contributing 20% or more to recruitment, moderate as less than 20% but more that 10%, and low condition as less than 10%. Of the hitch analyzed for the otolith analysis, 57% came from SIG 3, 18% came from both SIG's 2 and 4, and 2% and 5% from SIG's 1 and 5, respectively.

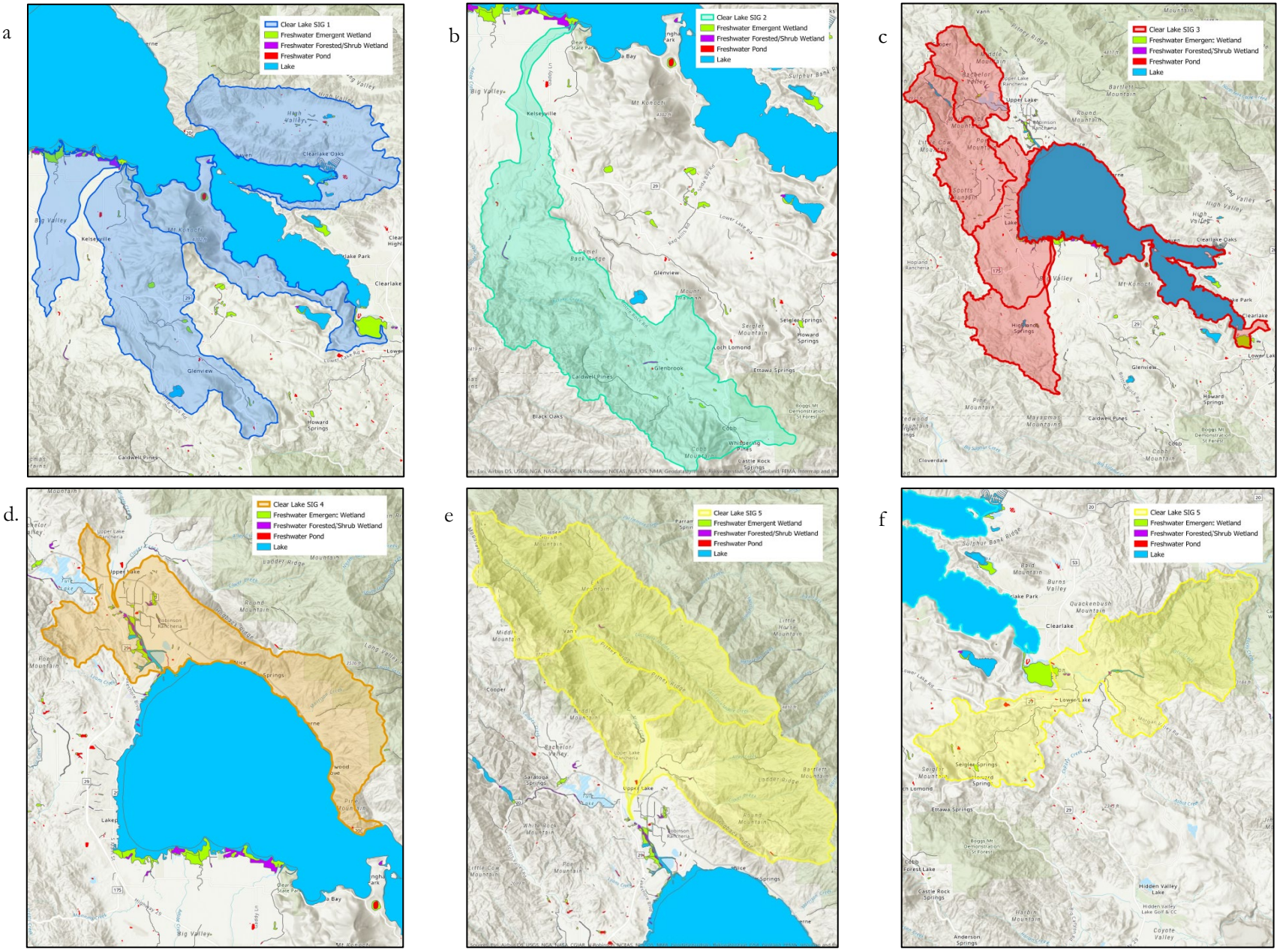

Figure 5.2 Remnant wetland habitat within each SIG. a. SIG 1; b. SIG 2; c. SIG 3; d. SIG 4; e. upper portion SIG 5; f. lower portion SIG 5

Connectivity: Connectivity will be analyzed by considering the presence and concentrations of passage barriers within a SIG (see Figure 5.3). Larger concentrations of potential passage barriers will be considered a low condition (SIG's 2, 3, and 5), whereas SIG's with no or few barriers are considered high condition (SIG's 1 and 4). There will not be an initial moderate category for this factor; however, depending on future projections, passage barriers within a SIG could improve or deteriorate from a high or low current condition to a future moderate condition.

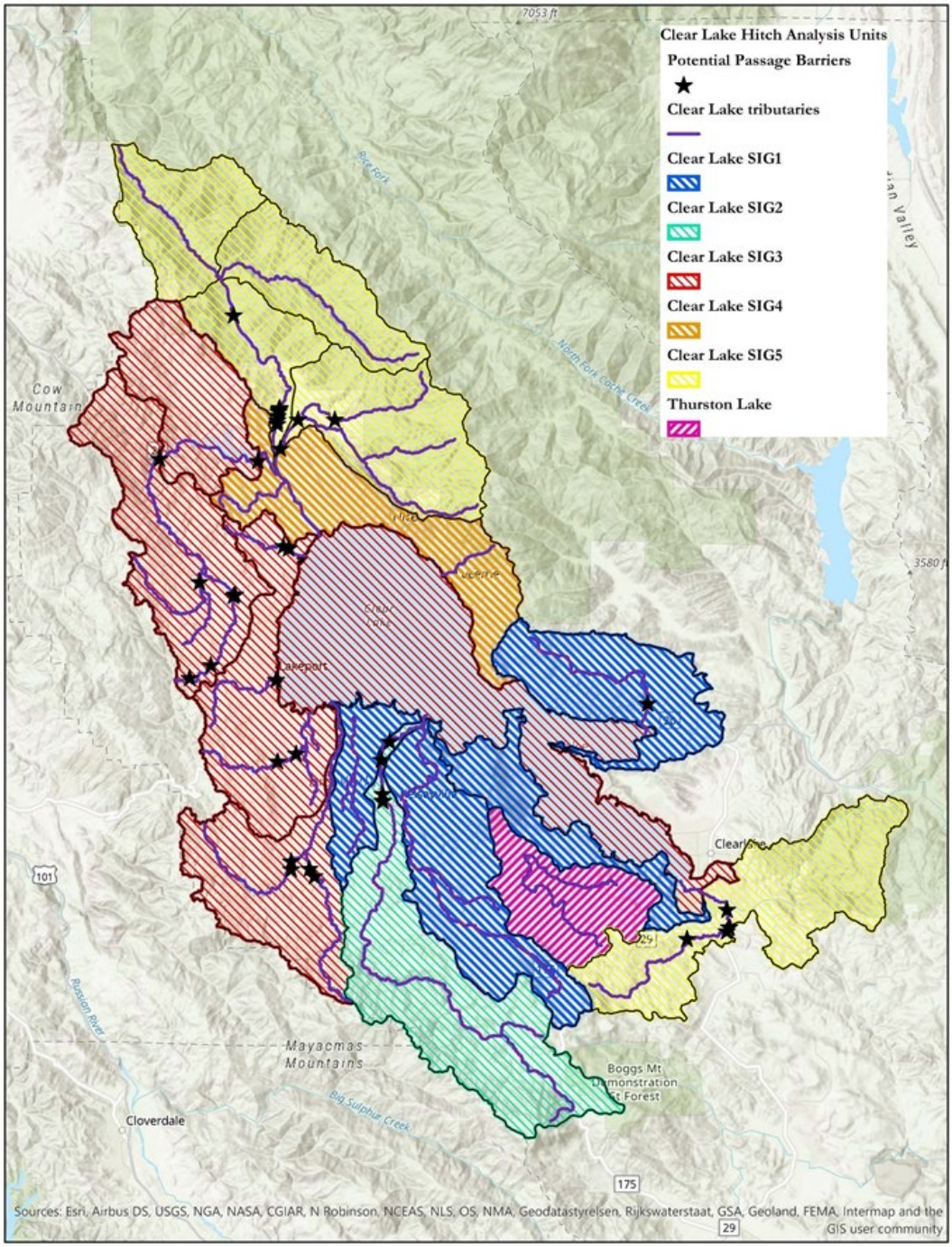

Figure 5.3 Passage barriers within each analysis unit

Tributary Water Quantity: The amount of water within a primary natal habitat stream is likely influenced by the presence of surrounding urban development and agricultural production (see Figures 4.2 and 4.4 above). The greatest concentration of agricultural production is within SIG 1, with lower levels of production in each of the other analysis units. The greatest concentration of urban development is within SIG's 2 and 3, and there is an intermediate amount in SIG's 1, 4, and 5. Therefore, for the purposes of this analysis, SIG's 1, 2, and 3 are considered a low condition due to the high concentration of water users, and SIG's 4 and 5 are a moderate condition since water reliance is not as intense. Coincidentally, SIG's 1, 2, and 3 happen to fall within the Big Valley groundwater basin, which has been given a medium priority under SGMA due to overdraft.

Wetland/Tule Habitat: Remaining wetland/tule habitat is found either within each SIG or, as in the case for SIG 5, is found in the SIG between SIG 5 and the lake. Because the amount of wetland/tule habitat has been greatly reduced from past conditions and the presence of non-native fish within this habitat type has increased both predation pressure and competition, we consider wetland/tule habitat to be at a low condition for all analysis units. It is assumed that the loss of rearing habitat (both physical loss and the introduction of non-native fish that exclude the hitch via predation or competition) is one of the primary factors limiting population growth.

Lake Water Quality: The current water quality condition for Clear Lake is considered moderate. Although the lake has been degraded and in some years conditions should be considered low, it is not thought to have a population level effect on the subspecies every year and therefore, is typically at a moderate condition.

Table 5.4a Demographic factors and habitat elements used to create condition categories in Table 5.5a below

	Demographic Factors		**Tributary Habitat Elements**		**Lake Habitat Elements**	
Condition Category	**Reproduction**	**Recruitment (see Table 5.4b)**	**Connectivity**	**Tributary Water Quantity**	**Wetland/ Tule Habitat**	**Lake Water Quality**
High	Reproduction documented each year	Overall recruitment total from recruitment analysis is high	Free passage under all flow conditions; no/few barriers	Water is retained within the tributaries throughout the spawning season	Extensive wetland habitat is available for rearing	Lake water is well oxygenated and uncontaminated
Moderate	Reproduction documented frequently, but not each year	Overall recruitment total from recruitment analysis is moderate	--	Water is retained within the tributaries throughout a large portion of the spawning season	Some wetland habitat is available for rearing	Lake water is oxygenated most of the time, hypoxic conditions do occur periodically. Some contaminants are present, but not at lethal levels
Low	Reproduction documented infrequently	Overall recruitment total from recruitment analysis is low	Free passage only under specific flow conditions; many or large concentration of barriers	Water is retained within the tributaries throughout just a small portion of the spawning season	Limited wetland habitat is available for rearing	Lake water is not well oxygenated and hypoxic conditions occur frequently. Contaminants are present, sometimes at lethal levels
Ø	No reproduction	No recruitment	No passage under any flow conditions	Water is not retained within the tributaries during any portion of the spawning season	No wetland habitat is available for rearing	Lake water quality is uninhabitable

Table 5.4b Recruitment analysis used to create recruitment condition category in Table 5.4a above. The otolith analysis is weighted double when calculating the overall condition

Condition Category	Recruitment – Wetland Habitat	Recruitment – Otolith Analysis (2X)
High	--	Otolith analysis shows SIG is a primary contributor to population recruitment (>20%).
Moderate	Remnant wetland habitat occurs within the SIG	Otolith analysis shows SIG contributes to population recruitment, but is not the primary source (<20% and >10%).
Low	Very little remnant habitat occurs within the SIG	Otolith analysis shows SIG has very little contribution to population recruitment (<10%)
Ø	No wetland habitat within the SIG	No recruitment, no individuals assigned to SIG

Determining Overall Analysis Unit Condition

The overall condition for each analysis unit is calculated by summing the condition of each of the demographic factors and habitat elements within that unit. A high condition for any demographic factor or habitat element (factor/element) is worth a score of 3, moderate is worth 2, and a low condition is worth 1. Because there are six factors/elements to analyze, an analysis unit that has all factors/elements in a high condition would have a total score of 18. Likewise, an analysis unit with all six factors/elements in moderate condition would have a total of 12 and one with all factors/elements in low condition would have a total of 6. We took the difference between the lowest and highest possible overall condition scores (6 and 18) and divided this into three equal intervals representing the breadth of possible scores. A score of 9 or less means the analysis unit is in overall low condition, a score of 15 or greater means the unit is in overall high condition, and scores between 10 and 14 mean the unit is in overall moderate condition.

Determining Population Condition

The overall condition of a particular factor/element for the entire Clear Lake population is calculated by summing the condition of that particular factor for each analysis unit, which was determined using the evaluation described above. Similar to the analysis unit evaluation, conditions of high, moderate, and low are scored as 3, 2, and 1, respectively. However, unlike the analysis unit evaluation, there are only five SIG's that are being evaluated, therefore, a factor/element in high condition for each of the analysis units would have a total score of 15. Likewise, a factor/element with all five SIG's in moderate condition would have a total of 10 and one with all SIG's in low condition would have a total of 5. We took the difference between the lowest and highest possible overall condition scores (5 and 15) and divided this into three intervals representing the breadth of possible scores. A score of 8 or less means the factor/element is in overall low condition, a score of 13 or greater means the factor/element is in overall high condition, and scores between 9 and 12 mean the factor/element is in overall moderate condition.

The overall condition of the Clear Lake population is determined by using the same scoring process that was used to determine the condition of each analysis unit, which is described above. All six factors/elements have a score ranging from 1 to 3 based on the condition of that factor/element (high condition = 3, moderate condition = 2, and low condition = 1). The condition of all

factors/elements are summed to give an overall population score between 6 and 18. A score of 9 or less means the population is in overall low condition, a score of 15 or greater means the population is in overall high condition, and scores between 10 and 14 mean the population is in overall moderate condition.

5.4 Current Population Resiliency

The Clear Lake hitch currently has two populations throughout its range, one occupying Clear Lake and its tributaries, and the other Thurston Lake and its tributary. Thurston Lake and Thurston Creek are both within the same HUC 12 unit, which is its own analysis unit and is considered to be at a high level of resiliency due to the robust population that currently resides there. The Clear Lake population occupies numerous HUC 12 units, which have been further grouped into one of five SIG's based on natal origin strontium signatures.

Using the methods summarized in Section 5.3 and Tables 5.4a and 5.4b, and as seen in Table 5.5a, the current condition of wetland/tule habitat within the Clear Lake population is at a low condition in each of the five units. Similarly, the current condition of lake water quality is at a moderate condition for all five SIG units. For reproduction, SIG's 2 and 3 are currently at a high condition because they have had consistent spawning observations each survey year. Reproduction for SIG's 1 and 5 are currently at a moderate condition due to somewhat frequent, but still inconsistent, annual spawning observations (see Tables 5.1 and 5.2 above). The portion of the watershed associated with SIG 4 is not typically included in observational surveys, so the current condition of recruitment for SIG 4, moderate, is also being used for reproduction. As explained above, the current recruitment condition for SIG 3 is high, moderate for SIG's 2 and 4, and low for SIG's 1 and 5. For connectivity, SIG's 1 and 4 are currently at a high condition, and SIG's 2, 3, and 5 are at a low condition. The current condition for tributary water quantity is low for SIG's 1, 2, and 3, and moderate for SIG's 4 and 5. Currently, the Clear Lake population has four analysis units at a moderate resiliency (SIG's 1–4), and one unit at a low resiliency (SIG 5), for an overall Clear Lake population resiliency of moderate. The Thurston Lake population is currently in high condition (see Table 5.6).

Table 5.5a Current condition for each of the Clear Lake population analysis units and the overall current condition of the Clear Lake population. See Table 5.4a for a description of condition categories. See Table 5.5b for the detailed current recruitment condition analysis.

Clear Lake Population Analysis Unit (AU)	Demographic Factors		Habitat Elements				Current Condition
	Reproduction	Recruitment (see Table 5.5b)	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Cole Creek (SIG1)	Moderate	Low	High	Low	Low	Moderate	Moderate
Kelsey Creek (SIG2)	High	Moderate	Low	Low	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	High	High	Low	Low	Low	Moderate	Moderate
Rodman Slough (SIG4)	Moderate	Moderate	High	Moderate	Low	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Moderate	Low	Low	Moderate	Low	Moderate	Low
Overall Condition	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate

Table 5.5b Current recruitment condition analysis for the Clear Lake population of Clear Lake hitch. See Table 5.4b for a description of the recruitment condition categories.

Clear Lake Population Analysis Unit (AU)	Demographic Factor - Recruitment		Overall Current Recruitment Condition
	Wetland Habitat	Otolith Analysis	
Cole Creek (SIG1)	Moderate	Low	Low
Kelsey Creek (SIG2)	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	Moderate	High	High
Rodman Slough (SIG4)	Moderate	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Low

Table 5.6 Current resiliency for each of the Clear Lake hitch populations.

Population	Demographic Factors		Habitat Elements				Current Condition
	Reproduction	Recruitment	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Thurston Lake	--	--	--	--	--	--	High
Clear Lake	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate

5.5 Current Species Representation

The Clear Lake hitch currently has a low level of representation. Although the subspecies currently has different spawning strategies they can utilize under variable environmental conditions, the subspecies occupies a very narrow range with similar habitat characteristics.

5.6 Current Species Redundancy

The Clear Lake hitch currently has a moderate level of redundancy. Although the subspecies currently has two separate populations (Thurston Lake and Clear Lake) it is possible a catastrophic event could still impact the entire range of the species. The hitch also expresses some within population redundancy by being able to utilize different habitats for reproduction and through the number of available tributary streams within the Clear Lake population.

5.7 Summary of Current Condition

We used the best available information to determine the current condition of the Clear Lake hitch. Our goal was to describe the viability of the subspecies in a manner that will address the needs of the hitch in terms of resiliency, representation, and redundancy. When considering the current condition of the Clear Lake hitch, we considered the following factors influencing the subspecies:

1. The loss spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams. The lack of consistent tributary flow seen in the Clear Lake watershed is due to the effects of past instream gravel mining, deforestation, and grazing practices, existing flood control project infrastructure, fire activity, and water utilization for agricultural and urban uses. Passage barriers in the watershed include the lack

of adequate tributary flow and physical barriers such as dams, diversions, roadways, and crossings;

2. The conversion and loss of wetland/tule habitat for agricultural production and urban development;

3. Reductions in lake water quality due to the loss of wetland/tule habitat surrounding the lake, contamination from past mercury mining along the lake's shore and pesticide use for agricultural and urban uses, the input of sediment and nutrients from degraded tributary streams, and nutrient inputs from surrounding urban and agricultural development. Increased nutrient and sediment inputs have contributed to periodic cyanobacteria blooms, which further reduce water quality;

4. The past introduction and establishment of non-native fish species;

5. Drought conditions within the Clear Lake watershed further reducing tributary flow during the spawning season; and

6. The implementation of current regulatory mechanisms (i.e., CESA, Lake County's Clear Lake Shoreline Ordinance) and management actions (i.e., Lake County's Aggregate Resources Management Plan, other miscellaneous restoration actions occurring throughout the watershed).

The various past and current negative influencing factors detailed above have significantly reduced the current abundance of hitch, primarily due to reductions in reproductive success, recruitment, and survival. These influences were used, in addition to implemented management actions, to assess the current condition of the Clear Lake hitch in terms of the 3 Rs. Currently, the Clear Lake hitch has one population at a high resiliency (Thurston Lake) and one at a moderate resiliency (Clear Lake). The Clear Lake hitch currently has a low level of representation; however, the subspecies has never had a high level of representation due to its very narrow range with similar habitat characteristics. The Clear Lake hitch is currently at a moderate level of redundancy. Both the Thurston and Clear Lake populations are currently extant, and each likely expresses within population redundancy in spawning habitat types and/or the number of available tributary streams.

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CHAPTER 6: FUTURE CONDITION

6.1 Introduction

We have considered what the Clear Lake hitch needs for long term viability (Chapter 3), evaluated the past, current, and future factors that are influencing those needs (Chapter 4), and we determined the current condition of those needs (Chapter 5). We now will analyze the subspecies' future condition by considering how those past and current influencing factors described in Chapter 4 will continue to act on the subspecies into the future, and how those influencing factors will impact the future condition of the Clear Lake hitch's needs (i.e., demographic factors and habitat elements). We apply our future projections to the concepts of resiliency, representation, and redundancy to describe the future viability of the Clear Lake hitch.

Although the Clear Lake hitch population has declined significantly in overall observed abundance (see Sections 5.1 and 5.2), it currently occupies most of its historical range. There are currently two separate populations of hitch, one that resides in Clear Lake and its tributaries, and one that occupies Thurston Lake and its tributary. Historically, the hitch spawning run would fill the surrounding tributary streams, producing an abundance of hitch that the local tribes relied on for sustenance. However, as the watershed underwent European settlement and the various activities described in Chapter 4 modified the watershed, the number of tributary streams available to the subspecies for reproduction during the spawning season decreased. In addition, the amount of available wetland habitat decreased from the reclamation and conversion of large wetland tracts surrounding the lake. These impacts to the watershed reduced reproductive and recruitment success for the subspecies, and caused an overall population decline.

The different combinations of influencing factors, both negative and positive (i.e., regulatory mechanisms and management actions), discussed in Chapter 4 that will continue to act on the subspecies into the future could result in varying changes to each of the Clear Lake hitch populations throughout its range. A reduction or increase in the number of available natal habitat types and tributary streams or impacts to lake water quality can reduce or increase that population's resiliency. Any reduction or increase in resiliency will further reduce or increase the level of redundancy and representation the subspecies expresses. However, neither redundancy nor representation should ever be considered at a high level because of the hitch's narrow range and low variability of habitat characteristics across the species' geographical range. As a consequence of those influencing factors acting on the subspecies and the subspecies' current condition (see Chapter 5), the future viability of the Clear Lake hitch now primarily depends on ensuring successful reproduction and recruitment to maintain or increase overall population abundance. This can be accomplished by preventing further destruction of natal and rearing habitats, maintaining or improving the water quality within Clear Lake, and potentially, the restoration of tributary streams so they can retain water throughout the spawning season.

Table 5.3 above describes those influencing factors we carried forward for the future condition analysis. These influencing factors will be used, in addition to implemented management actions, to assess the possible future condition of each Clear Lake hitch under three different scenarios. The future resiliency of each population will help describe the level of redundancy and representation the subspecies will express in the future, under that specific scenario. However, neither redundancy nor representation could ever be considered at a high level under any scenario due to the hitch's narrow range and low variability of habitat characteristics across the subspecies' geographical range.

6.1.1 Summary of Methods

Because we have significant uncertainty regarding if, when, where, and/or to what extent agricultural production, urban development, restoration actions, or climate effects may occur, we have forecast the possible viability of the Clear Lake hitch in terms of resiliency, representation, and redundancy under three plausible future scenarios. We chose to forecast the future scenarios for Clear Lake hitch viability over the next 50 years because it is within the range of the available climate change model projections for the North Coast Region, where Clear Lake is located (Grantham 2018; Pierce *et al.* 2018). These projections are given over two different time periods, one out 50 years (2040-2069) and one out to the end of the century (2070-2099). We chose the shorter timeframe because the two emissions scenarios used in the climate models, RCP 4.5 and RCP 8.5, have similar precipitation and temperature projections into the mid-century (2040-2069). Beyond this time period, both temperature and precipitation projections begin to diverge. Because we are uncertain what emissions trajectory we will follow into the future, and that uncertainty increases with time, we are being conservative and are using the shorter time period for this analysis. Because the rate of urban development has slowed in the last decade, we do not anticipate a significant amount of urban growth into the future. The timeframe for the current Lake County General Plan is 20 years and only projects growth out to 2028; however, we still do not expect growth to increase much after 2028. Although the amount of agricultural development increased substantially leading up to the 21st century, over the last 10 years or so the acreage of fruit, nut, field, seed, and vegetable crops in Lake County only slightly increased. Therefore, we do not anticipate a substantial increase in the amount of agricultural production into the future and do not have a specific timeframe to project the rate agricultural production into the future. It should be noted that the presence of agricultural production in the watershed will continue to result in sediment and nutrients entering the lake into the future.

Scenario 1 evaluates the condition of the Clear Lake hitch if there is a similar or slight increase in the amount of being water extracted from the watershed and the number of restoration actions being performed throughout the watershed from what exists today. It also takes into account climate change and what effects it may have on those influencing factors already acting on the subspecies. The other scenarios will evaluate the response of the subspecies to different changes in each of those influencing factors. For each scenario we describe the factors influencing viability that would occur in each analysis unit and population, and the subspecies' response. Since the entire Thurston Lake population is completely within the Thurston Lake HUC 12, we will continue to evaluate that population using just the one analysis unit when analyzing future scenarios.

We examine the resiliency, representation, and redundancy of the Clear Lake hitch under each of these three plausible scenarios. The resiliency of a Clear Lake hitch population depends on future environmental conditions and the availability of spawning and rearing habitat within that population. We expect each population to experience changes to these aspects of their habitat in different ways under the different scenarios. We projected the expected future resiliency of each population based on the events that may occur under each scenario and then projected an overall condition for the subspecies. For these projections, populations in high condition are expected to have high resiliency at that time period; i.e., there are multiple tributaries available throughout the spawning season and the different natal habitats are present and can be used for reproduction, individuals within a population are reproducing successfully and actively recruiting, and the amount and quality of spawning and rearing habitat is sufficient to allow for varying population densities.

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Populations in high condition are expected to persist into the future, beyond 50 years, and have the ability to withstand stochastic events that may occur. Populations in moderate condition are less resilient than those in high condition, but are expected to persist beyond 50 years. Populations in moderate condition may contain fewer natal and spawning habitats, and therefore, will contribute less to reproduction and recruitment than those populations in high condition. Finally, those populations in low condition have low resiliency and may not be able to withstand stochastic events. As a result, populations in low condition are less likely to persist for 50 years; however, a population in a low condition does not automatically mean the population cannot support any reproduction or recruitment, it just means those demographic factors are greatly reduced.

6.2 Scenario 1

Under Scenario 1, those factors that are having an influence on each of the Clear Lake hitch populations continue at current rates, or slightly increase. The effects of climate change, specifically increased aridity, are already occurring throughout the watershed, although the effects of increased aridity are not apparent every year. Future drought conditions are projected to increase in both the number of years drought conditions persist and the intensity of drought. Due to the increased incidence of aridity, and because future climate projections show the timing of precipitation will change, some years the number of spawning tributaries available to the subspecies over the spawning season will decrease. Increased fire and flooding incidence will increase the amount of erosion occurring in the tributary streams, decreasing lake water quality. As conditions worsen in the tributary streams, the subspecies will have to increasingly rely on spawning in the lake or the mouths of streams. Because the Clear Lake hitch is a state listed species, direct take will continue to be limited. Due to Lake County's shoreline ordinance, existing wetland/tule habitats surrounding the lake will continue to persist. Under Scenario 1, restoration projects (contaminant remediation, tributary function, barrier removal) continue to be implemented at a small scale throughout the watershed. Scenario 1 assumes the benefits of the Middle Creek Project have not been fully met (i.e., has not yet been fully constructed; see Section 4.9 Regulatory Mechanisms and Management Actions for a full description of benefits associated with the Middle Creek Project). A detailed analysis of each Clear Lake population analysis unit is shown in Tables 6.1a and 6.1b. The future condition of each Clear Lake hitch population under Scenario 1 is shown in Table 6.2.

6.2.1 Resiliency

<u>Thurston Lake Population</u>

Thurston Lake – Under Scenario 1, the resiliency of the Thurston Lake population will decline from high to a moderate level due to effects from climate change. Climate change will impact this population by reducing the availability of spawning habitats in some years and by reducing lake water quality. The one tributary stream to the lake, Thurston Creek, may not have continual flow to accommodate spawning every year.

<u>Clear Lake Population</u>

SIG 1 (Cole Creek) – In Scenario 1, SIG 1 experiences an increase in aridity during some years due to climate change. The increase in aridity would result in reduced spawning tributary availability during that year and a slight potential reduction in natal habitat variety. Since this analysis unit is within the Big Valley groundwater basin, the implementation of sustainable groundwater use through SGMA may increase the amount of water retained within the tributary creeks, reducing the effects of arid conditions during some years due to climate change. Under this scenario, SIG 1 would maintain a moderate resiliency.

SIG 2 (Kelsey Creek) – This analysis unit will also experience an increase in aridity during some years due to climate change. Similar to SIG 1, the increase in aridity would result in a potential reduction in natal habitat variety and reduced spawning tributary availability during those years. Because SIG 2 is in the Big Valley groundwater basin, implementation of SGMA may increase the amount of water retained within the tributary creeks, reducing the effects of climate change. Under Scenario 1, this analysis unit would maintain a moderate resiliency.

SIG 3 (Adobe Creek and Clear Lake) – SIG 3, which includes both Adobe Creek and Clear Lake, will also experience an increase in aridity during some years due to climate change under Scenario 1. Similar to SIG's 1 and 2, the increase in aridity would reduce spawning tributary availability, especially since this SIG will likely continue to have a high concentration of passage barriers. During drought years, there will likely be a reduction in the number of natal habitats the subspecies can utilize since the tributary streams may not be fully available. Because Adobe Creek is in the Big Valley groundwater basin, implementation of SGMA may increase the amount of water retained within the tributary creeks, reducing the effects of climate change. This analysis unit would maintain a moderate resiliency under Scenario 1.

SIG 4 (Rodman Slough) – This analysis unit will also experience an increase in aridity during some years due to climate change, which would reduce spawning tributary availability during those years. However, because a large portion of spawning habitat within this unit is contained within the lake, impacts due to climate change will be less than the other SIG's. Under Scenario 1, SIG 4 would maintain a moderate resiliency.

SIG 5 (Middle, Clover, and Seigler Canyon Creeks) – Similar to SIG's 1 and 2, SIG 5 will experience increased aridity during some years due to climate change under Scenario 1. Also comparable to those SIG's, the effects of climate change will reduce tributary availability over the spawning season and natal habitat variety. Unlike SIG's 1 and 2, SIG 5 is not included in the Big Valley groundwater basin and any benefits from SGMA will not apply to this analysis unit; however, overdraft is not projected to be as much of an issue in this unit. Therefore, SIG 5 would maintain a low resiliency under Scenario 1.

Table 6.1a Future condition for each of the Clear Lake population analysis units and the overall future condition of the Clear Lake hitch under Scenario 1. See Table 6.1b for the detailed future recruitment analysis under Scenario 1.

Clear Lake Population Analysis Unit (AU)	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment (see Table 6.1b)	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Cole Creek (SIG1)	Moderate	Low	High	Low	Low	Moderate	Moderate
Kelsey Creek (SIG2)	High	Moderate	Low	Low	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	High	High	Low	Low	Low	Moderate	Moderate
Rodman Slough (SIG4)	Moderate	Moderate	High	Moderate	Low	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Moderate	Low	Low	Moderate	Low	Moderate	Low
Overall Condition	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate

Table 6.1b Future recruitment condition analysis for the Clear Lake population of Clear Lake hitch under Scenario 1.

Clear Lake Population Analysis Unit (AU)	Demographic Factor - Recruitment		Overall Future Recruitment Condition
	Wetland Habitat	Otolith Analysis	
Cole Creek (SIG1)	Moderate	Low	Low
Kelsey Creek (SIG2)	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	Moderate	High	High
Rodman Slough (SIG4)	Moderate	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Low

Overall Clear Lake Population – Under Scenario 1, the Clear Lake population maintains a moderate level of resiliency. The effects of climate change, specifically increased aridity, may reduce or eliminate stream based spawning in some years; however, future climate change projections do not predict increased aridity every year and the subspecies will still have the ability to spawn in other lake based habitats when drought conditions do occur. In addition, small-scale restoration projects throughout the watershed will increase the amount of available spawning habitat available to the hitch when conditions do allow for stream based spawning.

Table 6.2 Future resiliency for each of the Clear Lake hitch populations under Scenario 1

Population	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Thurston Lake	--	--	--	--	--	--	Moderate
Clear Lake	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate

Scenario 1 projects the condition of each Clear Lake hitch analysis unit if the current risks continue on the same, or a very similar, trajectory they are on now. Overall, four of the five Clear Lake population analysis units would be at a moderate condition and one would be at a low condition. The Thurston Lake analysis unit, and population overall, would be at a moderate condition

Over the next 50 years, this scenario is most likely to occur since we expect climate change to continue (thereby increasing the likelihood of aridity) and the amount of water use within the watershed will only slightly increase due to urban development and agricultural production. We also expect groundwater resources will slightly improve in the Big Valley groundwater basin due to the implementation of SGMA, and we expect small scale restoration projects to continue throughout the watershed.

6.2.2 Representation

The Clear Lake hitch currently has a low level of representation and that is unlikely to change under Scenario 1. Under this scenario, the subspecies will continue to have different spawning strategies to utilize under different environmental conditions.

6.2.3 Redundancy

Under Scenario 1, the Clear Lake hitch will likely continue to maintain its current moderate level of redundancy, as both populations are expected to be maintained and the variety of habitats that can currently be utilized for reproduction will continue to be available to each hitch population. However, because the resiliency of the Thurston Lake population is expected to decrease due to an increased incidence of drought, redundancy will decrease slightly.

6.3 Scenario 2

Scenario 2 is a best case scenario for the Clear Lake hitch, where all of the analysis units within the Clear Lake population either retain or improve their current condition due to restoration and enhancement activities throughout the watershed. Similar to Scenario 1, those factors that are currently having a negative influence on each of the Clear Lake hitch populations continue at current rates, or slightly increase. Under this scenario, the effects of climate change affect the entire watershed, although they may not occur annually. Drought conditions are projected to increase and some years the number of spawning tributaries available to the subspecies over the spawning season will decrease. Erosion within the tributary streams will continue to be an issue due to increased incidence of fire and flooding, and as a consequence the water quality in the lake will decrease. However, restoration actions will also increase throughout the watershed, including the construction of the Middle Creek Project. The restoration of tributary streams will improve water retention throughout the spawning season, the removal of passage barriers will increase the amount of tributary habitat the subspecies can use for spawning, and construction of the Middle Creek Project will increase the amount of available rearing habitat, improving that habitat element for the Clear Lake population from low to moderate condition. These activities will all increase reproductive success and increase the likelihood of recruitment within Clear Lake. The restoration of tributary streams and the creation of wetland habitats surrounding the lake from the Middle Creek Project will improve the water quality of Clear Lake, but not enough to increase it from a moderate to a high condition because mercury contamination and nutrient input are not likely to cease. Like Scenario 1, the direct take of hitch will continue to be limited by CESA, and the existing wetland/tule habitats surrounding the lake will continue to persist due to county ordinances. A detailed analysis of each Clear Lake population analysis unit is shown in Tables 6.3a and 6.3b. The future condition of each Clear Lake hitch population under Scenario 2 is shown in Table 6.4.

6.3.1 Resiliency

<u>Thurston Lake Population</u>

Thurston Lake – Like Scenario 1, the resiliency of the Thurston Lake population will decline to a moderate level due to effects from climate change under Scenario 2. Climate change will impact this population by reducing the availability of spawning habitats in some years. The one tributary stream to the lake, Thurston Creek, may not have continual flow to accommodate spawning every year and the water quality within the lake will likely decrease. Even though restoration projects are occurring throughout the watershed under this scenario, those efforts are not directed to the Thurston Lake sub-watershed.

<u>Clear Lake Population</u>

SIG 1 (Cole Creek) – In Scenario 2, SIG 1 experiences an increase in aridity during some years due to climate change. The increase in aridity could reduce tributary availability and natal habitat variety; however, due to restoration actions within the watershed, the tributary creeks will be able to retain water until later in the season, and miles of additional tributary habitat will become available with the

removal of passage barriers. Those factors, along with the increase of wetland habitat for rearing, will increase reproductive success and recruitment within SIG 1 under Scenario 2. Although the condition of most demographic factors and habitat elements increase under this scenario, resiliency would be maintained at a moderate level.

SIG 2 (Kelsey Creek) – Analysis unit SIG 2 experiences an increase in aridity during some years due to climate change. Similar to SIG 1, the increase in aridity would reduce natal habitat variety and tributary availability, but restoration actions throughout the watershed would help in countering those negative effects and would improve stream function. The removal of passage barriers within this unit increases the amount of tributary habitat available to the subspecies for spawning. Under Scenario 2, the resiliency of SIG 2 will be maintained at moderate.

SIG 3 (Adobe Creek and Clear Lake) – The resiliency of the SIG 3 analysis unit will be maintained at a moderate level under Scenario 2. Even though the effects of climate change are still projected to occur, the restoration of spawning and rearing habitat will improve the tributary water quantity and wetland/tule habitat elements, and the removal of passage barriers will increase connectivity.

SIG 4 (Rodman Slough) – Conditions in SIG 4 under Scenario 2 will primarily stay the same, except for an increase of wetland/tule habitat due to restoration projects, which will increase recruitment. Although tributary restoration improved water quantity conditions in SIG's 1–3 under this scenario, this unit is already currently at a moderate condition and effects from climate change make it unlikely for any high condition to occur within the watershed. Under Scenario 2, SIG 4 would maintain a moderate resiliency.

SIG 5 (Middle, Clover, and Seigler Canyon Creeks) – Under Scenario 1 the Middle Creek Project is constructed and this analysis unit will receive the bulk of the benefit from it, primarily through an increase in habitat that supports successful reproduction and population recruitment. Like all of the analysis units in this scenario, climate change will effect SIG 5 through increased incidence of drought, but restoration actions will help counter those effects. The resiliency of SIG 5 will increase to a moderate condition under Scenario 2.

Table 6.3a Future condition for each of the Clear Lake population analysis units and the overall future condition of the Clear Lake hitch under Scenario 2. See Table 6.3b for the detailed future recruitment analysis under Scenario 2.

Clear Lake Population Analysis Unit (AU)	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment (see Table 6.3b)	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Cole Creek (SIG1)	High	Moderate	High	Moderate	Moderate	Moderate	Moderate
Kelsey Creek (SIG2)	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	High	High	Moderate	Moderate	Moderate	Moderate	Moderate
Rodman Slough (SIG4)	Moderate	High	High	Moderate	Moderate	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Overall Condition	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Table 6.3b Future recruitment condition analysis for the Clear Lake population of Clear Lake hitch under Scenario 2.

Clear Lake Population Analysis Unit (AU)	Demographic Factor - Recruitment		Overall Future Recruitment Condition
	Wetland Habitat	Otolith Analysis	
Cole Creek (SIG1)	High	Moderate	Moderate
Kelsey Creek (SIG2)	Low	Moderate	Moderate
Clear Lake, Adobe Creek (SIG3)	High	High	High
Rodman Slough (SIG4)	High	High	High
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	High	Moderate	Moderate

Overall Clear Lake Population – Under Scenario 2, the Clear Lake population maintains a moderate level of resiliency, although a majority of factors/elements increase in condition due to the implementation of restoration efforts throughout the watershed. The effects of climate change, specifically increased aridity, may reduce or eliminate stream based spawning in some years; however, future climate change projections do not predict increased aridity every year and the subspecies will still have the ability to spawn in other lake based habitats when drought conditions do occur.

Table 6.4 Future resiliency for each of the Clear Lake hitch populations under Scenario 2

Population	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Thurston Lake	--	--	--	--	--	--	Moderate
Clear Lake	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Scenario 2 provides an idea of the Clear Lake hitch's best possible condition over the next 50 years. This scenario presumes all of the analysis units within the Clear Lake population are able to maintain or improve their current condition. Because most restoration activities are likely to be concentrated on tributaries to Clear Lake and the lake itself, and climate change impacts will be felt throughout the watershed, the resiliency of Thurston Lake will decrease from high to moderate. Under Scenario 2, all five analysis units within the Clear Lake population would be at a moderate condition.

Over the next 50 years, this scenario is not the most likely to occur because large scale restoration projects like the Middle Creek Project and numerous small scale restoration projects spread throughout the watershed will require a lot of money and coordination. It is possible a small subset of restoration projects could occur over the next 50 years, potentially even the Middle Creek Project; however, the wide scale restoration of the entire watershed as described in this scenario is not likely to be completed within the 50 year timeframe.

6.3.2 Representation

Under Scenario 2, the Clear Lake hitch will continue to have a low level of representation. Although conditions will improve throughout portions of the watershed, the subspecies will still be restricted to the same watershed, will continue to occupy the same ecological niche, and will continue to have the current spawning strategies available in the future. Therefore, the level of representation will not change under this scenario.

6.3.3 Redundancy

The Clear Lake hitch will likely continue to maintain its current moderate level of redundancy under Scenario 2, even with improved conditions throughout most of the watershed. Because the subspecies occurs within a narrow range, and the entire subspecies could be susceptible to a potential catastrophic event, the hitch will never be at a high level of redundancy. Under this scenario, both populations and the different natal habitat types within each population will continue to be maintained.

6.4 Scenario 3

Under Scenario 3, some of the risks we forecasted would continue to occur, and some that are predicted to stay constant may increase. In this scenario, climate change results in more arid conditions throughout the subspecies' range and impacts from increased fire and flooding will increase erosion occurring in the tributary streams, further decreasing water quality within the lake to a low condition. As conditions worsen in the tributary streams, the subspecies will have to increasingly rely on spawning in the lake or in the mouths of streams. In addition, under this scenario agricultural production slightly increases in areas currently not prioritized by SGMA, no or very few small scale restoration projects have been implemented, the Middle Creek Project has not been constructed, and no passage barriers have been removed. Under Scenario 3, Lake County's shoreline ordinance will continue to limit tule habitat loss and take of individuals will be limited by CESA. A detailed analysis of each Clear Lake population analysis unit is shown in Tables 6.5a and 6.5b. The future condition of each Clear Lake hitch population under Scenario 3 is shown in Table 6.6.

6.4.1 Resiliency

<u>Thurston Lake Population</u>

Thurston Lake – Similar to Scenarios 1 and 2, the resiliency of the Thurston Lake population in Scenario 3 will decline to a moderate level due to effects from climate change. Climate change will impact this population by reducing the availability of spawning habitats in some years. The one tributary stream to the lake, Thurston Creek, may not have continual flow to accommodate spawning every year and the water quality within the lake will likely decrease.

<u>Clear Lake Population</u>

SIG 1 (Cole Creek) – In Scenario 3, SIG 1 experiences an increase in aridity during some years due to climate change. The increase in aridity will reduce tributary availability and natal habitat variety, reducing reproduction and connectivity within the analysis unit. Under this scenario, the condition of SIG 1 would decline to low resiliency.

SIG 2 (Kelsey Creek) – SIG 2 experiences an increase in aridity during some years due to climate change in this scenario. Similar to SIG 1, the increase in aridity would reduce natal habitat variety

and tributary availability, reducing both reproduction and recruitment to a moderate and low level, respectively. In Scenario 3, the resiliency of SIG 2 will decrease to low.

SIG 3 (Adobe Creek and Clear Lake) – The resiliency of the SIG 3 analysis unit will decrease to a low condition under Scenario 3 for the same reasons SIG 2 declined. Although reproduction and recruitment decline under this scenario, they only decline to a moderate condition. This is due to the presence of the lake within this unit and the increasing reliance on the lake for spawning during drought conditions.

SIG 4 (Rodman Slough) – Conditions in SIG 4 under Scenario 3 will decrease to a low condition. The increase in aridity due to climate change will reduce flow conditions within the tributary streams, reducing connectivity throughout the watershed. Because this unit includes a backwater-like area of the lake, the condition of reproduction and recruitment is maintained at moderate.

SIG 5 (Middle, Clover, and Seigler Canyon Creeks) – Under Scenario 3, the condition of the SIG 5 analysis unit is maintained at low, with reductions in the conditions of some factors/elements. Effects from climate change and a slight increase in agricultural production will reduce tributary availability during the spawning season and ultimately, reproduction.

Table 6.5a Future condition for each of the Clear Lake population analysis units and the overall future condition of the Clear Lake hitch under Scenario 3. See Table 6.5b for the detailed future recruitment analysis under Scenario 3.

Clear Lake Population Analysis Unit (AU)	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment (see Table 6.5b)	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Cole Creek (SIG1)	Low	Low	Moderate	Low	Low	Low	Low
Kelsey Creek (SIG2)	Moderate	Low	Low	Low	Low	Low	Low
Clear Lake, Adobe Creek (SIG3)	Moderate	Moderate	Low	Low	Low	Low	Low
Rodman Slough (SIG4)	Moderate	Moderate	Moderate	Low	Low	Low	Low
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Low	Low	Low	Low	Low
Overall Condition	Low	Low	Low	Low	Low	Low	Low

Table 6.5b Future recruitment condition analysis for the Clear Lake population of Clear Lake hitch under Scenario 3.

Clear Lake Population Analysis Unit (AU)	Demographic Factor - Recruitment		Overall Recruitment Condition
	Wetland Habitat	Otolith Analysis	
Cole Creek (SIG1)	Low	Low	Low
Kelsey Creek (SIG2)	Low	Low	Low
Clear Lake, Adobe Creek (SIG3)	Low	Moderate	Moderate
Rodman Slough (SIG4)	Moderate	Moderate	Moderate
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Low

Overall Clear Lake Population – Under Scenario 3, the Clear Lake population declines to a low level of resiliency. The effects of climate change may reduce or eliminate stream based spawning in some years and will likely increase tributary erosion due to increased incidence of fire and flooding, further reducing lake water quality. Increased reliance on water resources for agricultural purposes further reduce water the amount of water retained within tributary streams, especially during drought conditions.

Table 6.6 Future resiliency for each of the Clear Lake hitch populations under Scenario 3.

Population	Demographic Factors		Habitat Elements				Future Condition
	Reproduction	Recruitment	Connectivity	Tributary Water Quantity	Wetland/ Tule Habitat	Lake Water Quality	
Thurston Lake	--	--	--	--	--	--	Moderate
Clear Lake	Low	Low	Low	Low	Low	Low	Low

Scenario 3 provides an idea of the Clear Lake hitch's condition over the next 50 years when the effects of agricultural production slightly increase in areas where production is not currently concentrated, effects from climate change impact the entire watershed, and little to no restoration actions occur in the watershed. Overall, Thurston Lake would decline to a moderate condition and the Clear Lake population would decline to a low condition. Within the Clear Lake population, SIG's 1-4 would all decline to a low condition and SIG 5 would be maintained at a low condition.

Over the next 50 years, this scenario could occur, but is not the most likely. Effects due to climate change are projected to continue and the amount of water use within the watershed will only slightly increase due to urban development and agricultural production within the Clear Lake area over time. With the implementation of SGMA, analysis units within the Big Valley groundwater basin may not experience any increase in agriculture; however, this may not limit agricultural expansion into the other groundwater basins within the range. Because various restoration projects have been periodically implemented throughout the watershed, the lack of restoration described under this scenario is not likely to occur, but is possible.

6.4.2 Representation

Clear Lake hitch representation under Scenario 3 will continue to be at a low level. Because of deteriorated conditions throughout the watershed, the subspecies may not have all spawning strategies to utilize in any given year.

6.4.3 Redundancy

Under Scenario 3, the level of redundancy for the Clear Lake hitch will likely decrease to low. Although both populations will still be extant, the Thurston Lake population will decline to moderate resiliency and the Clear Lake population will decline to low resiliency due to the deteriorated condition of the watershed under this scenario. In addition, each of the different natal habitats available to each of the populations may no longer be available or may have only limited availability in the future. The availability of tributary streams for the Clear Lake population in particular are likely to decrease. Under this scenario, the Clear Lake hitch would be particularly susceptible to a potential catastrophic event.

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6.5 Summary of Future Condition

We used the best available information to forecast the likely future condition of the Clear Lake hitch. Our goal was to describe the viability of the subspecies in a manner that will address the needs of the subspecies in terms of resiliency, representation, and redundancy. We considered the possible future condition of the subspecies under three different potential scenarios, using the following current and future influencing factors consistently throughout each scenario:

1. The loss spawning habitat due to past watershed modifications that have blocked access to or altered the flow regime of tributary streams. The lack of consistent tributary flow will continue due to the effects of past instream gravel mining, deforestation, and grazing practices, existing flood control project infrastructure, fire activity, and water utilization for agricultural and urban uses. We do not expect the rate of agricultural production or urban development to increase substantially into the future. Furthermore, future climate change is projected to further exacerbate the degradation and inaccessibility of tributary streams by increasing the incidence of fire activity, flood events, and aridity. Various passage barriers, both physical barriers and lack of flow, will continue to persist in the watershed;

2. The loss of wetland/tule habitat. The current remaining wetland/tule habitat surrounding the lake will persist into the future, primarily due to the implementation of Lake County's shoreline ordinance;

3. Continued reductions in lake water quality due to the past loss of wetland/tule habitat surrounding the lake, contamination from past mercury mining along the lake's shore and pesticide use for agricultural and urban uses, the input of sediment and nutrients from degraded tributary streams, and nutrient inputs from surrounding urban and agricultural development. Like mentioned above, we do not project agricultural production or urban development to increase substantially into the future. Increased nutrient and sediment inputs continue to contribute to periodic cyanobacteria blooms, further reducing water quality. Periodic fish kills continue to occur;

4. Non-native fish species are still established within the lake from past introductions; and

5. Drought incidence and intensity increase due to climate change, reducing tributary flow during the spawning season in some years; and

6. The implementation of current regulatory mechanisms (i.e., CESA, Lake County's Clear Lake Shoreline Ordinance) and management actions (i.e., Lake County's Aggregate Resources Management Plan, other miscellaneous restoration actions occurring throughout the watershed).

These influencing factors were used to assess the possible future condition of the Clear Lake hitch under three different scenarios, in terms of the 3 Rs. These influencing factors are likely to continue to both negatively and positively affect the Clear Lake hitch, primarily due to reductions or increases in reproductive success, recruitment, and survival. A summary of our analysis under each of the three different potential future scenarios are as follows (see Figures 6.7 and 6.8):

Scenario 1, those factors that are currently having an influence on each of the Clear Lake hitch populations continue at current rates, or may slightly increase, for all of the influencing

factors. Under Scenario 1, we project both Clear Lake hitch populations would be at moderate condition.

Scenario 2, those factors that are currently having a negative influence on each of the Clear Lake hitch populations continue at current rates, or slightly increase. Scenario 2 is the best case scenario for the Clear Lake hitch because all of the analysis units within the Clear Lake population either retain or improve their current condition due to restoration and enhancement activities being implemented throughout the watershed. Under Scenario 2, we project both Clear Lake hitch populations would be at a moderate condition.

Scenario 3: Under Scenario 3, some of the risks would continue to occur at their current rates, and some that are predicted to stay constant may increase. In Scenario 3 we project the Thurston Lake population would decline to a moderate condition and the Clear Lake population would decline to a low condition.

Table 6.7 Summary of Clear Lake population analysis unit resiliency under current conditions and under each future scenario

Clear Lake Population Analysis Unit (AU)	Current Condition	Scenario 1 Future Condition	Scenario 2 Future Condition	Scenario 3 Future Condition
Cole Creek (SIG1)	Moderate	Moderate	Moderate	Low
Kelsey Creek (SIG2)	Moderate	Moderate	Moderate	Low
Clear Lake, Adobe Creek (SIG3)	Moderate	Moderate	Moderate	Low
Rodman Slough (SIG4)	Moderate	Moderate	Moderate	Low
Middle Creek, Clover Creek, Seigler Canyon Creek (SIG5)	Low	Low	Moderate	Low

Table 6.8 Summary of Clear Lake hitch population resiliency under current conditions and each of the future scenarios.

Population	Current Condition	Scenario 1 Condition	Scenario 2 Condition	Scenario 3 Condition
Thurston Lake	High	Moderate	Moderate	Moderate
Clear Lake	Moderate	Moderate	Moderate	Low

Over the next 50 years, we believe Scenario 1 is the most likely to occur and Scenario 2 is the least likely to occur. We believe Scenario 1 is the most likely since we expect climate change is likely to continue (thereby increasing the likelihood of aridity, fire incidence, and flood incidence), future drought conditions are likely to increase, CESA will continue to limit direct take, the Lake County shoreline ordinance will continue to maintain the existing amount of available wetland/tule habitat surrounding the lake, and current small scale restoration projects will continue to be implemented into the future. Under this scenario, the Clear Lake hitch will continue to maintain its current low and moderate level of representation and redundancy, respectively.

Scenario 2 is not the most likely to occur because large scale restoration projects like the Middle Creek Project and numerous small scale restoration projects spread throughout the watershed will require extensive funding and coordination. It is possible a small subset of restoration projects will occur over the next 50 years, potentially even the Middle Creek Project; however, the wide scale restoration of the entire watershed as described in this scenario is not likely to occur. It is probable Scenario 3 could occur, but it is not the most likely when compared to Scenario 1. This is primarily because various restoration projects have been implemented throughout the watershed and the lack of restoration described under this scenario is not likely occur.

The Clear Lake hitch faces a variety of risks from habitat loss, degradation, and modification, increased predation and competition from the introduction of non-native fish, drought, and climate change. These risks, and the level in which they act upon the Clear Lake watershed, play a large role in the future viability of the Clear Lake hitch. If populations lose resiliency, the subspecies overall will have a further reduced level of representation and redundancy, which increases their risk of extirpation.

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COMMENTS OF PETER WINDREM, PRESIDENT OF THE CHI COUNCIL FOR THE CLEAR LAKE HITCH, ON THE SPECIES STATUS ASSESSMENT FOR THE CLEAR LAKE HITCH (*Lavinia exilicauda chi)* Version 1.0

Dated March 10, 2020

THURSTON LAKE IS NOT A DISTINCT POPULATION OF CLEAR LAKE HITCH

<u>Comments on Executive Summary and comparable sections</u>

This Species Status Assessment for the Clear Lake Hitch *(Lavinia exilicauda chi)* Version 1.0 creates the erroneous impression that the hitch in Thurston Lake is as significant as the hitch in Clear Lake. The document contains factually incorrect statements such as, "Currently, the subspecies is thought to be extirpated from the Blue Lakes, but still resides in Clear and Thurston Lakes throughout the year *until the spring when reproductive adults migrate into tributary streams to spawn. . . . . Although all of the described waterbodies were hydrologically connected in the past*, Thurston Lake and its tributary Thurston Creek are currently isolated from the other waterways." (Italics added)(Exec. Summary, ii)

There is no physical connection between Thurston Lake and Clear Lake. Thurston Lake is essentially a 255-acre pond with no outlet. (Exhibit A) It is located eight-tenths (.8) of a mile away from Clear Lake. (Exhibit B) A mountain ridge separates Thurston Lake from Clear Lake. Thurston Lake's elevation is 1,420 feet and the mountain ridgetop elevation is 1,800 feet, a rise of nearly 400 feet in elevation. (Exhibit C) The ridge is the result of volcanic activity that occurred about 440,000 years ago that separated Thurston Lake from Clear Lake. (Exhibit D: Enderlin, Dean A., P.G., Guide to Clear Lake Geology -- Field Trip Guide for Teachers, May 2007, pp. 18-19) There is no conceivable way for hitch to have gotten into Thurston Lake other than by being physically introduced by humans.

On March 4, 2020, I conducted a telephone interview of a local resident, Rob Suenram. I have known Rob personally for over 40 years. He was my wife's classmate in Kelseyville schools from kindergarten through high school. He is a highly regarded in our community. Rob told me that, when he was a small boy, he lived with his family at Thurston Lake. His mother grew up in Jago Bay on Clear Lake that is just over the ridge from Thurston Lake. Throughout his high school years (1967-1971), Rob and his brothers trapped animals around Thurston Lake and fished in its waters. He said there were bass, perch and suckers in Thurston Lake, but no hitch. The fish in the lake had been introduced by early owners of the property around Thurston Lake. He said that, more recently, a man known locally as "Smitty" lived in a house on the lake and introduced minnows into the lake. Rob believes those minnows most likely were the source of the hitch in the lake today.

It is misleading and detracts from the seriousness of the document to treat the hitch in Thurston Lake as comparable to the hitch in Clear Lake. Whether or not hitch survive in Thurston Lake is insignificant when compared to whether or not hitch survive in Clear Lake. Clear Lake is the natural home for the hitch; Thurston Lake nothing more than a large pond into which hitch were introduced less than 50 years ago.

THE INTRODUCTION OF THE NON-NATIVE FLORIDA STRAIN OF BLACK BASS INTO CLEAR LAKE AND ITS PREDATION OF THE CLEAR LAKE HITCH MUST BE ACKNOWLEDGED

Comments on Section 4.5 Predation and Competition

Nowhere in Section 4.5, Predation and Competition, nor anywhere else in the document, is there any mention of the non-native Florida-strain of black bass introduced into Clear Lake between 1969 and 1971. No predator has more direct impact on the Clear Lake hitch that this strain of bass.

The Florida-strain was introduced into Clear Lake by the California Department of Fish and Game. (Thompson, L.C., et al., The native and introduced fishes of Clear Lake: a review of the past to assist with decisions of the future. California Fish and Game 99(1):15) The purpose of the introduction was to create trophy size bass and thereby enhance the bass fishery for recreational and economic purposes. (Exhibit E: State of California, Department of Fish and Wildlife [CDFW], Trophy Black Bass Program, brochure / DFW 7378 / Rev. 04-17; CDFW website: wildlife.ca.gov/Fishing/Inland/Black-bass)

California Fish & Game fisheries biologist Richard Macedo wrote in his article "Swimming Upstream Without a Hitch" published in the January-February 1994 edition of Outdoor California:

> "Clear Lake hitch are an important component to the food chain in the Clear Lake basin. Without them, many fish, birds and mammals would not have adequate forage. While examining Clear Lake's record bass, a 17.5-pound monster, I discovered a large hitch in its stomach. Many large bass specifically target hitch as prey.
>
> "Bass anglers who frequent Clear Lake recognize this relationship and have attempted to trick bass with a technique as "ripping." The ripping technique involves the use of a large rapala, or other fish-like lure. After casting in a desirable location, the angler retrieves the lure by alternately jerking on the rod and quickly retrieving the line. This technique has proven effective for many anglers targeting bass in Clear Lake. What some anglers may not realize is that they are mimicking the actions of hitch."

A lure made to look like a hitch is used by bass fishermen in the early spring when hitch are gathered in the vicinity of the mouths of the creeks in preparation for spawning upstream. Attached is a photograph of a fishing lure called a "swimbait" that is made to look like a hitch. (Exhibit f)

BASSMASTER is the sponsor of major bass fishing tournaments throughout the United States. In March of 2010, BASSMASTER sponsored a tournament on Clear Lake called the 2010 Golden State Shootout. The winning prize for the fisherman who brought in the heaviest total weight of a specified number of bass was $100,000. On March 10, 2020, Joel Shangle, a reporter for BASSMASTER, wrote an article about the tournament fishing on Clear Lake captioned "Clear Lake bait beasts: swimbaits". (bassmaster.com/node/39301) In the article he describes the swimbaits and how they are used to catch the largest bass on Clear Lake. Following is his description of why the bait works:

> "Clear Lake's biggest fish, clearly, are swimbait biters.
>
> . . . . .

“Because it's designed to imitate a slowly moving baitfish, a swimbait requires either a glacially slow retrieve, or a deadstick retrieve where you leave the bait suspended in the water for several seconds at a time before slowly starting up the retrieve again.

. . . . . .

“Why the bait works

“ESPN photographer James Overstreet took a photo perfectly illustrating why the swimbait is such an effective bait on Clear Lake. In it, a Western grebe holds a 9-inch hitch in its mouth, one of the primary sources of nourishment for the lake's jumbo-class largemouth.

“The Clear Lake hitch, a sub-species of the minnow family found only in Clear Lake, runs 9 to 14 inches at maturity, has a modestly elongated, slightly oval body, and begins its spawning run in late winter, continuing into early summer.

“In other words, the lake's largemouth were cued into the hitch all week and will be for several months. All the 7-, 9- and 12-inch swimbaits on the Elite pros' decks were simply matching the hitch, including Velvick's hitch-colored BV 3D.

“’I got to my spot on Day One and saw them chasing hitch, and I got pretty happy," Velvick said. "I knew right then it was going to be on."

. . . . . .

Bryon Velvick won the 2010 Golden State Shootout Tournament with 98 pounds and 6 oz of fish and first prize of $100,000.

On March 4, 2020, Tom Smythe submitted the following comments to you with which I concur entirely:

“I am concerned that it [the Species Status Assessment for the Clear Lake Hitch] downplays the impact of predation on the hitch populations. Terry Knight, local fishing guide has noted the following:

“Nearly all the trophy sized bass that have had their stomach contents observed have included hitch in their stomachs.

“One of the most popular fishing lures for bass is designed to look like and mimic the swimming characteristics of the Clear Lake hitch.

“During the Clear Lake hitch spawning period (February-April), bass fisherman congregate at the mouths of the streams where hitch are schooling prior to migrating upstream to spawn, as the bass are also schooling and reportedly feasting of CLH. One report he relayed to us is that fisherman observed bass decimate a school of hitch in a matter of minutes at the mouth of one of the creeks.

“Much credence is given to a single fish shocking survey in May that there are no hitch in the bass stomachs. [Section 4.5 Predation and Competition, paragraph 4] From what I have read and understand, in May the CLH are primarily pelagic and not in the near shore areas.

Examination of bass stomach contents in March may be enlightening, however, fish shocking at the mouths of streams where adult hitch are present could have a detrimental impact on their spawning ability and is probably inadvisable.

"Granted, control of introduced fish populations is essentially impossible once the species is established is essentially impossible, however, measures such as restoration of delta systems (essentially all stream mouths have been channelized) and wetland restoration near the stream mouths are possible, and if predation is not a factor, are in danger of having a lower priority. Restoration of deltaic systems at the stream mouths would disperse CLH populations at the start of spawning runs (and when fry return to the lake) and theoretically disperse predators, such as bass, improving the chances of survival of the CLH. The benefits of wetlands providing shelter is already discussed."

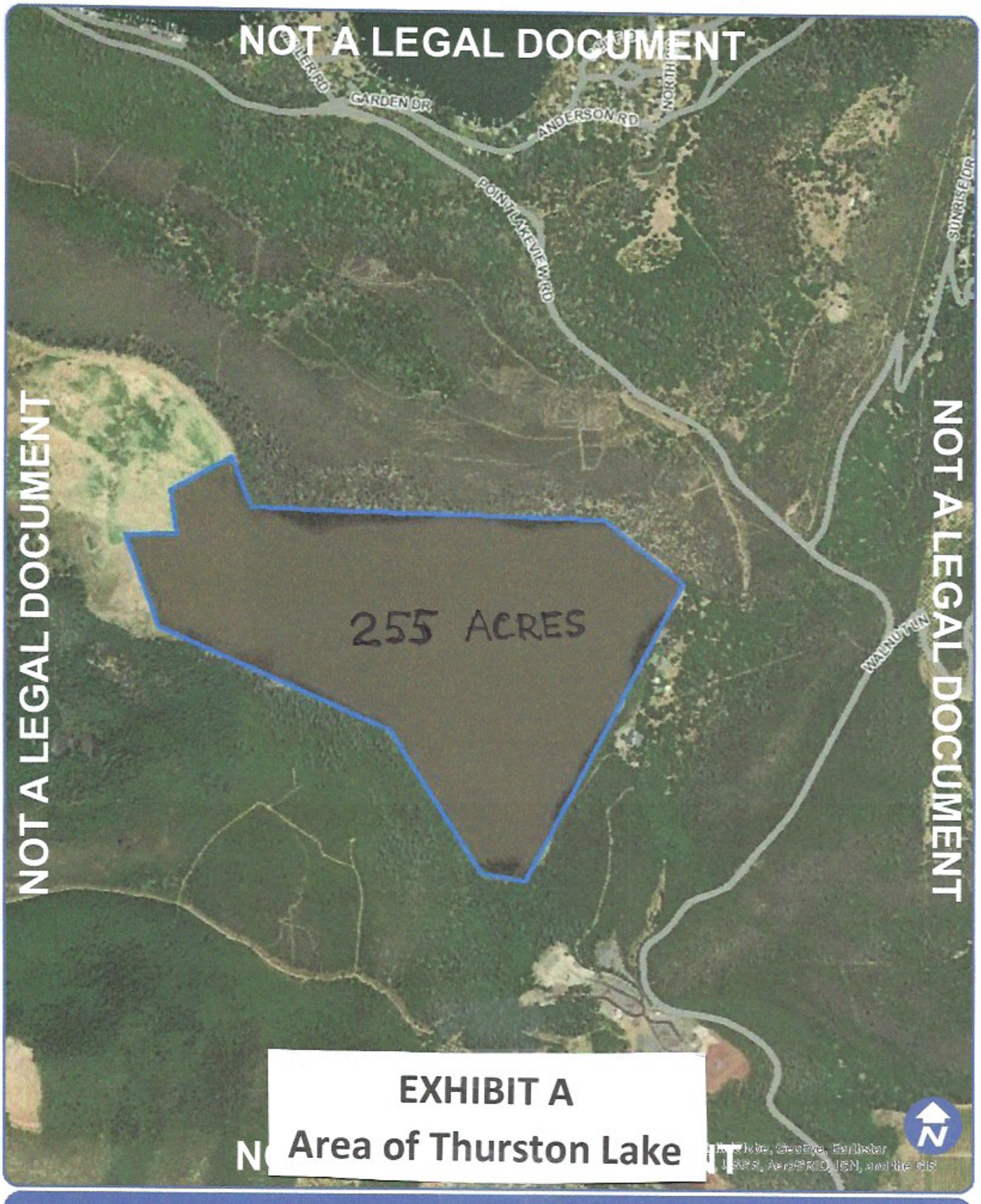
Conclusion:

This SSA (pages 40-42) lists every other non-native species of fish introduced into Clear Lake, but not the Florida-strain of black bass introduced by the California Department of Fish and Wildlife between 1969 and 1971. This species of bass was introduced to create a trophy size game fish. A principal source of food for these bass is the Clear Lake hitch and especially in the springtime when the hitch are schooling near the mouths of streams to begin their ascent to their spawning grounds. The bass congregate in those locations to feed on adult hitch. These facts should be included in this Species Status Assessment for the Clear Lake Hitch.

EXHIBITS A to D

Attached are Exhibits A to D to COMMENTS OF PETER WINDREM, PRESIDENT OF THE CHI COUNCIL FOR THE CLEAR LAKE HITCH, SUBMITTED ON THE USFWS SPECIES STATUS ASSESSMENT FOR THE CLEAR LAKE HITCH (*Lavinia exilicauda chi)* Version 1.0

(EXHIBITS E & F are attached separately.)



Lake County, CA

Area of Thurston Lake

Web AppBuilder for ArcGIS

mi 0 0.25 0.5

All parcel boundaries are approximate. Discrepancies in acreage, shape and location are common.
This map is not the legal survey document to be used in single site determinations. Consult your deed for a legal parcel description.

Print Date: 3/10/2020

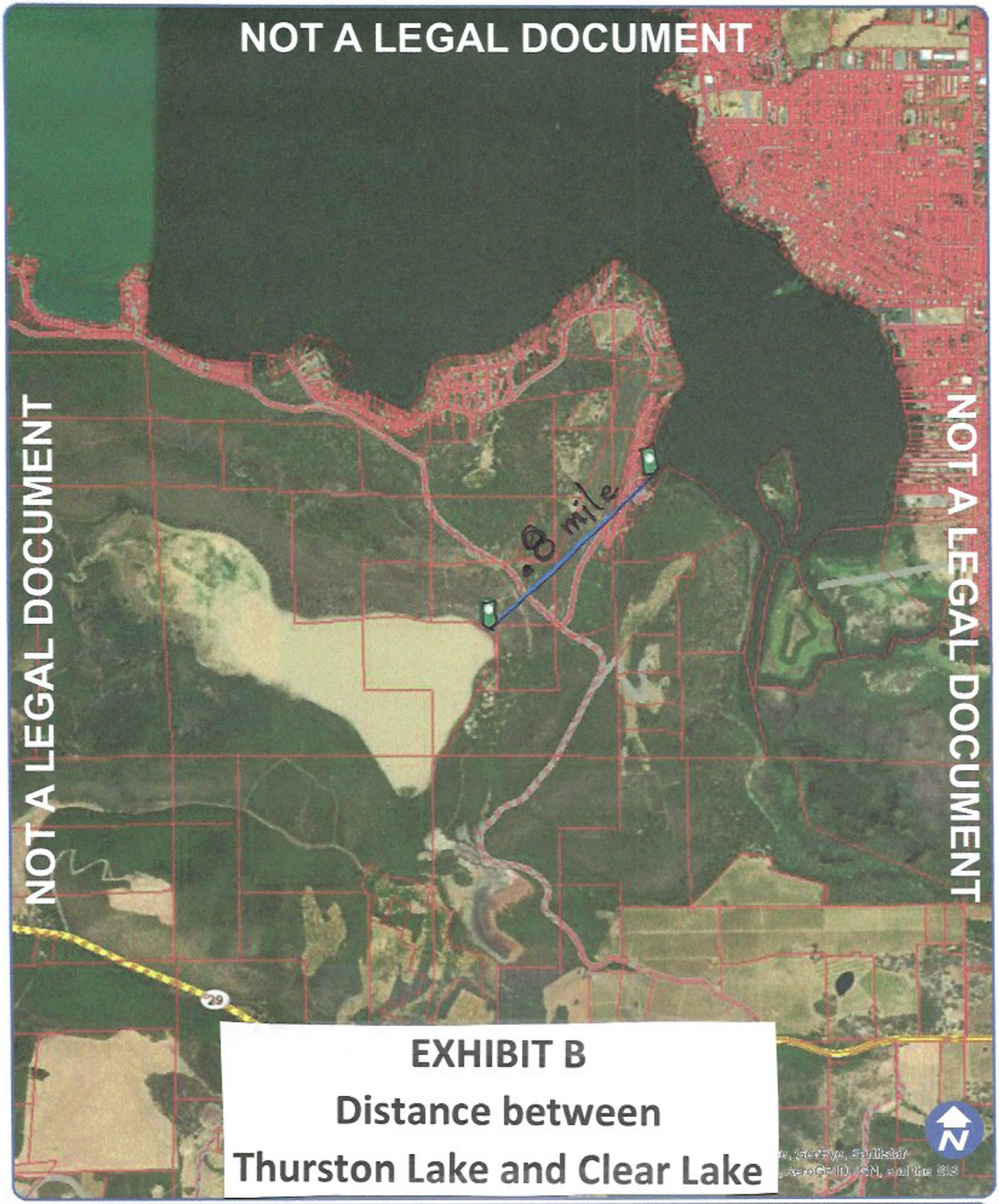


EXHIBIT B
Distance between Thurston Lake and Clear Lake

Lake County, CA

Thurston Lake to Clear Lake

Web AppBuilder for ArcGIS

mi 0 0.55 1.1

All parcel boundaries are approximate. Discrepancies in acreage, shape and location are common.
This map is not the legal survey document to be used in single site determinations. Consult your deed for a legal parcel description.

Print Date: 3/13/2020

EXHIBIT C

Elevations of Thurston Lake, Point Lakeview Road & Clear Lake

Lake County, CA

Thurston Lake to Clear Lake

Web AppBuilder for ArcGIS

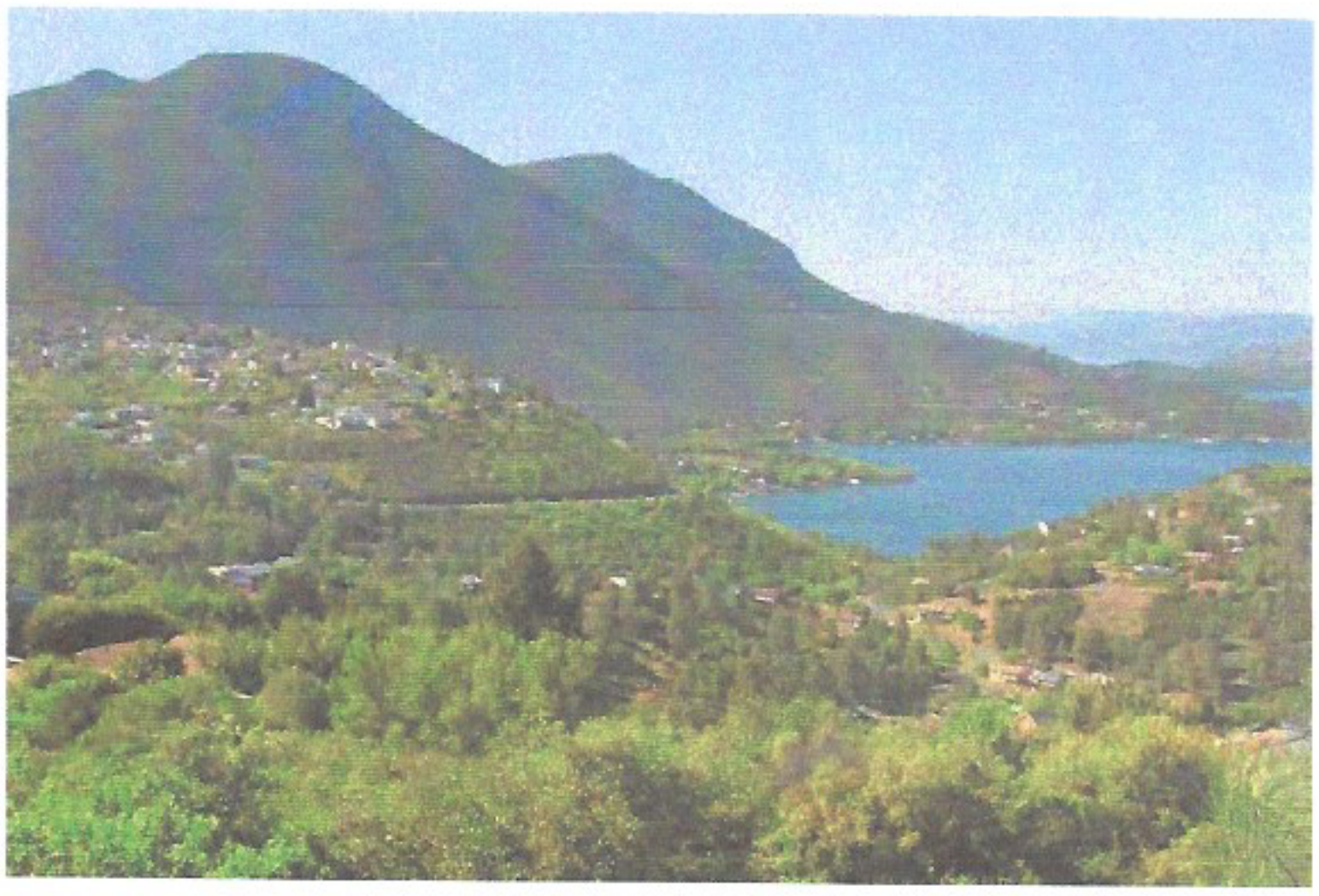
mi 0 0.25 0.5

All parcel boundaries are approximate. Discrepancies in acreage, shape and location are common.
This map is not the legal survey document to be used in single site determinations. Consult your deed for a legal parcel description.

Print Date: 3/10/2020

CLEAR LAKE GEOLOGY

FIELD TRIP GUIDE FOR TEACHERS



MAY 2007

BY

DEAN A. ENDERLIN, P.G.

Prepared under the direction of the
LAKE Science Collaborative
Lake County, California

EXHIBIT D

Introduction

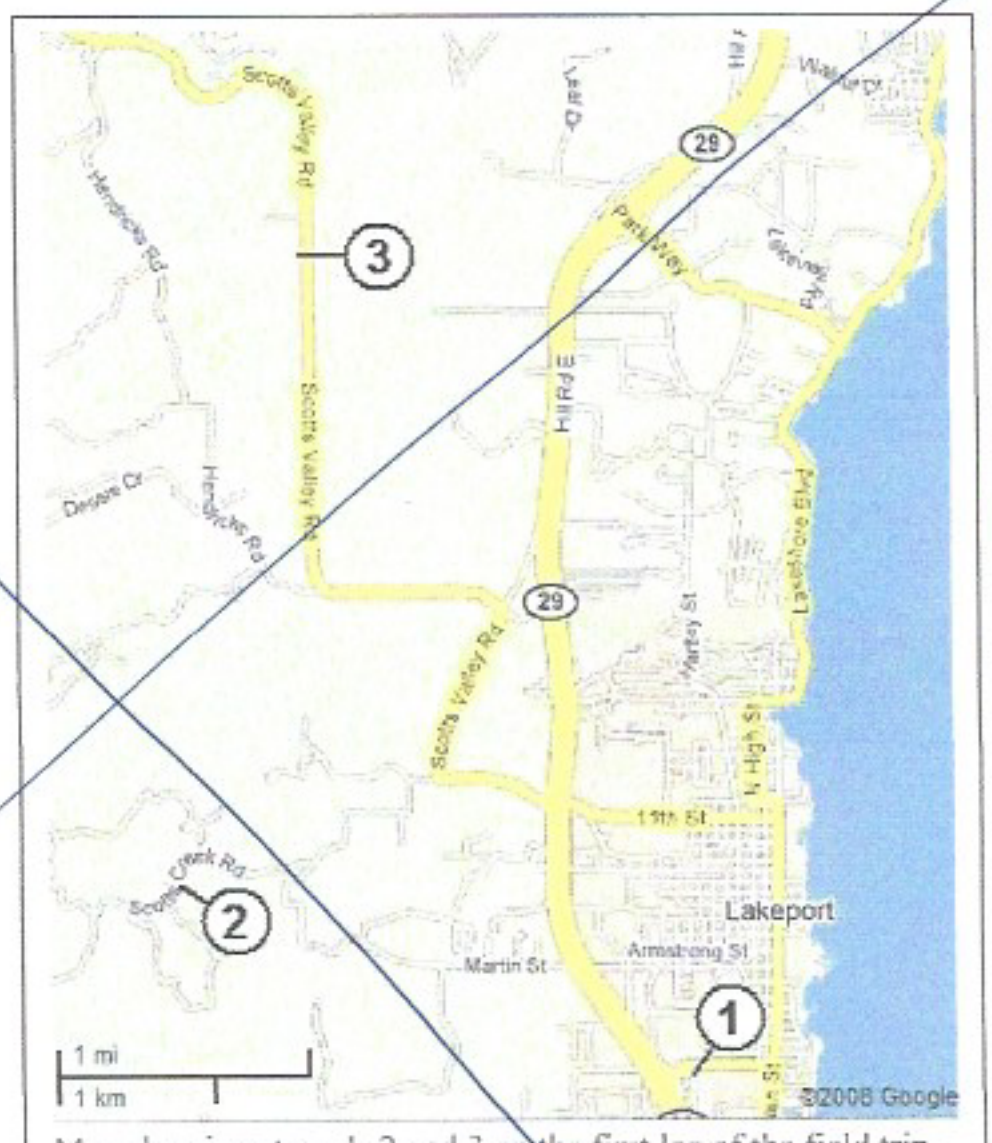
This field trip guide follows the route taken during a field trip on May 5, 2007, sponsored by the LAKE Science Collaborative. It is designed and intended for teachers of grades 4 to 6, with an emphasis on earth science topics. Each stop highlights local geological points of interest that can be integrated into the teaching curriculum for these grades.

We are fortunate to be in a region where the underlying geology is boldly expressed, and where a variety of geological features (many relating the Science Content Standards for California Public Schools) can be visited in a one-day field trip. There are seven stops on this field trip. For convenience, many geological terms appear in **bold** print wherever they first appear in the guide.

The field trip begins at the George Hoberg Visitor Center, located in Lakeport, southeast of the intersection of State Highway 29 and Lakeport Boulevard. For those equipped with GPS equipment, latitude and longitude (NAD-27) are provided for each stop.

1) George Hoberg Visitor Center Overlook

Lat.: N 39.03414
Long.: W 122.92062
Trip Odometer: 0.0 miles (reset)
Parking lot at the Visitor Center



Map showing stops 1, 2 and 3 on the first leg of the field trip.

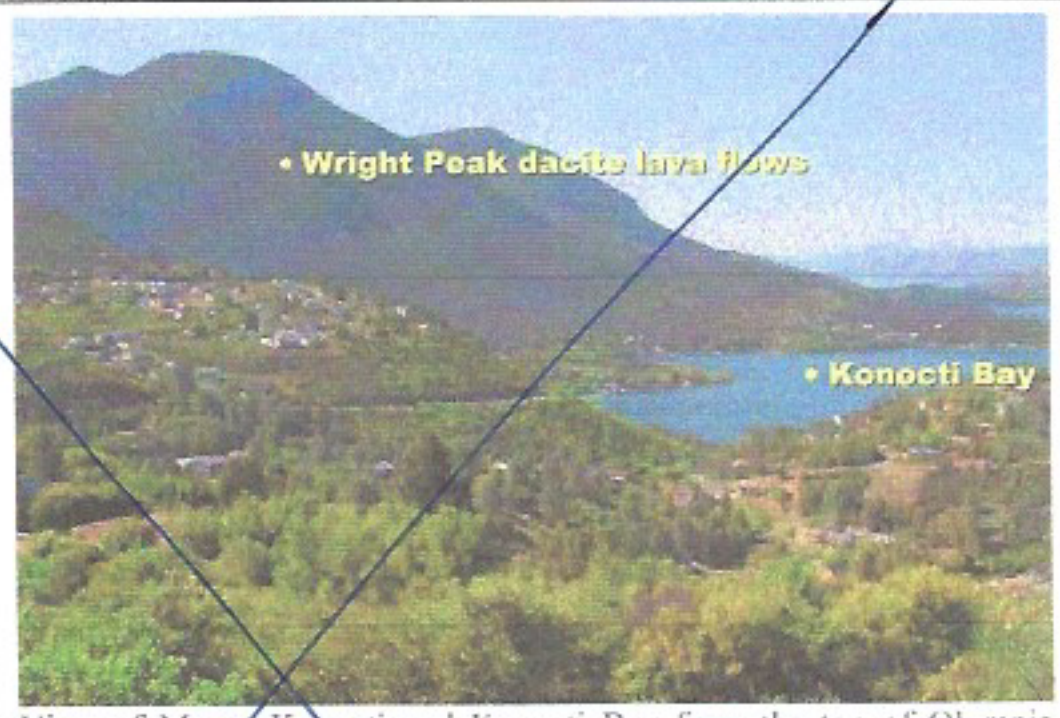
The Hoberg Visitor Center offers a fine vista from which to see the Clear Lake basin and its surroundings, so it is an excellent launching point for the field trip. It is here that we can review some of the basics of the geology in our area, before moving on to view some specific examples.

Lake County geology can be divided into two assemblages of rocks: 1) The basement rocks, which go back to a time when our area was in the deep ocean; and 2) The overlying rocks, which include volcanic deposits and lake beds, which are much younger than the basement.

First, let's talk about the basement rocks. **Plate tectonics** played (and continues to play) a key role in the development of our Lake County landscape. The **crust** of the earth is formed by a series of **plates**, which are continually shifting as a consequence of deep convection in the **mantle**. Each earth plate moves differently, depending on what forces are acting on it (and they don't always keep moving in the same direction). Far back in geologic

local term for the crescent-shaped landforms that were created by the last lava that flowed from the top of the peak. This particular lava flow is called the Dacite of Wright Peak. It is about 350,000 years old. As we discussed earlier, Mount Konocti is a **composite** or **stratovolcano**. Volcanoes of this type are formed from many generations of eruptions. That's why there are so many different types of volcanic rock with so many different ages on each of the mountain's peaks.

The views of Konocti Bay and parts of the western shoreline of Clear Lake are also great from this spot. Notice the scallop-shaped shoreline, created by the maar eruptions.



View of Mount Konocti and Konocti Bay from the top of Olympia Drive

Several splays of the Konocti Bay Fault Zone pass into Konocti Bay in the area we see from here. In spots, gas bubbles rise up in the lake water along these fault lines. The most spectacular of these "gas springs" is on the other side of Buckingham Peninsula, out in the lake near Horseshoe Bay. The gas is actually a mixture of a number of volcanic gases and gases that formed from decaying organic matter. Carbon dioxide is the most common component in the springs. It is heavier than air, which is why it has caused safety concerns near some of the springs in Soda Bay.

Earth Science Standards to Consider:

Grade 4:

- Shaping of the landscape due to earthquakes and volcanic eruptions.

Grade 6:

- Earthquakes, epicenters, and plate tectonics.
- Type of building construction in seismically active areas.

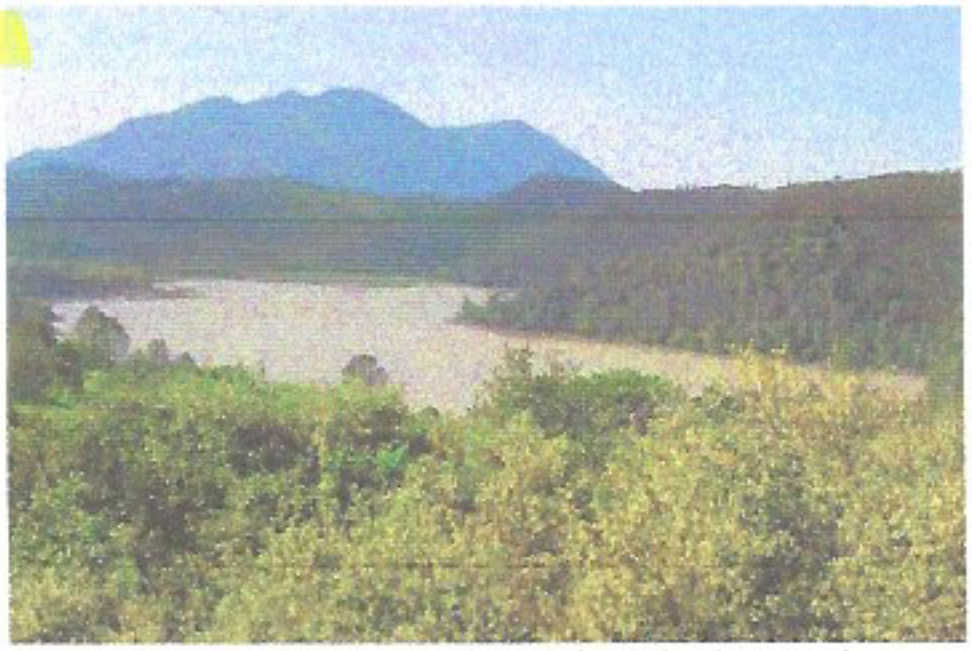
This concludes the main field trip. From Riviera Hills Country Club, an interesting scenic loop can be taken by continuing along the lakeshore via Point Lakeview Road. To do this, continue southward on Fairway Drive 0.6 miles to the intersection with Point Lakeview Road. Turn right onto Point Lakeview Road. Continue 4.3 miles to a wide shoulder turnout overlooking Thurston Lake.

Thurston Lake Overview

Lat.: N 38.92389

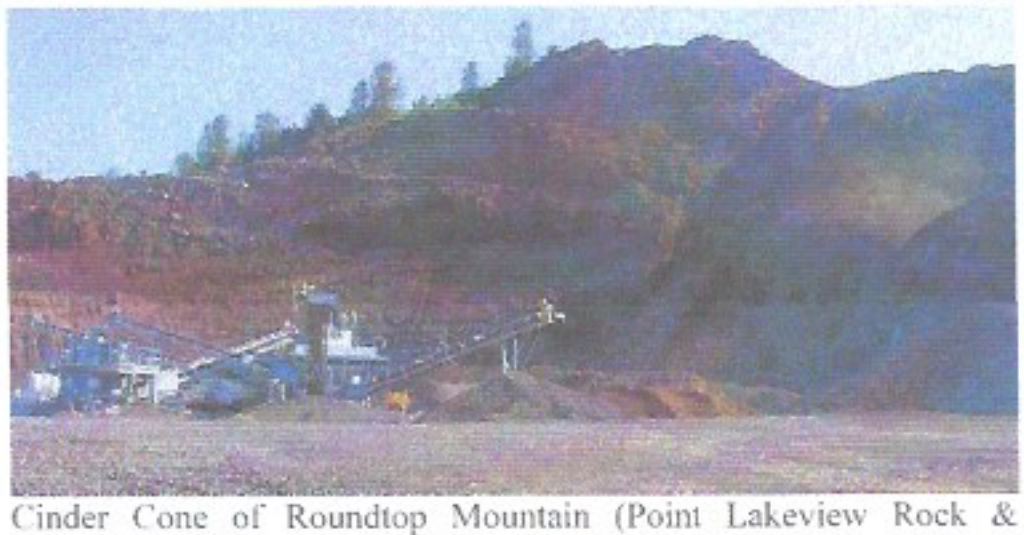
Long.: W 122.66067

The road here passes over the Dacite of Wheeler Point (about 400,000 years old) and the Dacite of Thurston Lake (about 440,000 years old). These volcanic deposits form a ridge that


Thurston Lake, as seen from Point Lakeview Road.

isolated the Thurston Lake drainage from the rest of the Clear Lake basin. The bottom of Thurston Lake is considerably higher in elevation than Clear Lake level, so the two aren't directly connected. Seasonal runoff into Thurston Lake does recharge groundwater, however, which eventually enters Clear Lake as springs in the vicinity of Jago Bay. The water in Thurston Lake is remarkably murky (**turbid**), because it is fed by clayey runoff from Manning Flat on the ridge to the southwest. This is a man-made effect. Manning Flat was originally a valley with no natural outlet (called a **closed basin**). Water would have originally accumulated in the basin as seasonal lakes (**vernal pools**). In an effort to drain the valley, land owners attempted (and eventually succeeded) in cutting a channel through the ridge that separates Manning Flat from the Thurston Lake watershed. Since then, the fine-grained sediments in the Manning Flat basin have eroded rapidly, creating a deeply **incised channel** that is actively cutting through the soils in the flat and is threatening State Highway 29. As a prank, the channel was once posted with a sign, reading "Guy's Fault," but the channel has nothing to do with faulting. It is purely erosional, but its path across the flat may have followed portions of old roadways and a race track that was once used there.

Continuing 0.4 miles southward on Point Lakeview Road, we pass Point Lakeview Rock and Redimix. The quarry is on the right side of the road, and has been producing decorative "cinder" rock at this location for many years. This is some of the youngest volcanic rock in the Clear Lake Volcanics. It is probably no more that 40,000 years old. The red rock is **basalt**. Basalt is usually black or dark gray in color. The red pigment is caused when water mixes with the magma as it is erupting. If the conditions are right, the oxygen in the water reacts with iron in the basalt to produce iron oxides, which are red. Most of this rock is full of trapped gas bubbles (called **vesicles**). When basalt is **vesicular** like this, it is also known as **scoria**. During the eruption, the larger chunks of molten basalt would sometimes spin as they flew through the air, giving them a distinctive football-like shape. These are sometimes referred to as volcanic **spindle bombs**. The thick accumulations of these bombs creates a steep-sided cone-shaped volcanic peak, called a **cinder**


Cinder Cone of Roundtop Mountain (Point Lakeview Rock & Redimix quarry).

EXHIBITS E & F

Attached are Exhibits E and F to COMMENTS OF PETER WINDREM, PRESIDENT OF THE CHI COUNCIL FOR THE CLEAR LAKE HITCH, SUBMITTED ON THE USFWS SPECIES STATUS ASSESSMENT FOR THE CLEAR LAKE HITCH (*Lavinia exilicauda chi)* Version 1.0

EXHIBIT E

CONSERVATION AND MANAGEMENT ACT

Recognizing the value of California's black bass fishery, the California Legislature adopted the Black Bass Conservation and Management Act of 1980 that states:

"It is the policy of the state to preserve and enhance black bass resources and to manage black bass populations to provide satisfactory recreational opportunities to the public."

The Act also includes a provision that the Department of Fish and Wildlife's black bass management program include management for trophy-sized black bass in some waters. To help fulfill that policy the Trophy Black Bass program was adopted by the Fish and Game Commission in February, 1993. The purpose of the Program is to provide a reasonable opportunity for an angler to catch a trophy-sized black bass at designated waters.

TROPHY BASS AND WATERS

In the Trophy Black Bass Program policy, trophy-sized black bass are recognized by the following minimum weight standards:

Largemouth Bass	*Micropterus salmoides*	10 lb
Smallmouth Bass	*Micropterus dolomieu*	6 lb
Spotted/Alabama Bass	*Micropterus punctulatus/henshalli*	6 lb

As part of the program, the Department is charged to:

1. Identify and submit to the Commission certain waters within the state to be designated as trophy-sized black bass waters based on the following criteria:

A. Angler access:

i. Open for public angling with unrestricted access, or

ii. Open for public angling with controlled access consistent with Commission policy.

B. Historically or biologically demonstrated the capability of producing, with appropriate angling regulations or other fishery management actions, catch by anglers in most years of fish meeting the above trophy-sized black bass standards.

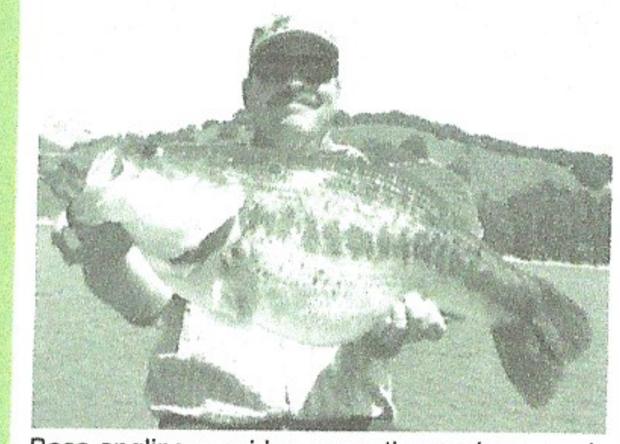
2. Manage at least one water in each of the Department's six management regions as a Trophy Black Bass Water.

3. Develop a management plan for each designated water. The plan shall include a description and evaluation of the fishery, an assessment of environmental factors conducive to or limiting trophy black bass management, recommendations for management actions needed to increase abundance of trophy black bass, and an assessment of personnel and fiscal resources needed to carry out the intent of the program.

4. Establish a Trophy Black Bass Recognition Program. In February 1994, the Commission designated Trinity, Oroville, Clear, Isabella, and Castaic lakes as trophy black bass waters. Trophy black bass management plans were developed for these waters as part of the program.

CDFW - F B
Inland Fisheries Assessment and Monitoring
980 Riverside, Suite 100
West Sacramento, CA 95605

California Trophy Black Bass Program



Bass angling provides recreation and economic value to the state of California. For several years, California has been the center of attention for producing trophy-sized black bass. In a list of the top 25 largest Largemouth Bass caught in the U.S., 20 of the bass are from California waters. Nationwide attention to California's Largemouth Bass fisheries began with the success of Florida Largemouth Bass introductions. Numerous catches of Largemouth Bass over 10 pounds were reported following the introductions and in 1972, the first Largemouth Bass over 20 pounds from California was caught at Lake Miramar. In addition to trophy-sized Largemouth Bass, the introduction of Alabama Bass in 1976 and subsequent introductions to other California waters has produced trophy-sized and state and world record catches from California waters.

Natural Resources Agency
Department of Fish and Wildlife

Trophy Black Bass Angler Recognition Program

RECOGNITION PROGRAM

As part of the Trophy Black Bass program the Department keeps records of anglers who catch a trophy size bass and submit a recognition form to the Department. Successful anglers can complete and mail the Trophy Black Bass Recognition Program application form included with this leaflet. Verified catches are entered into Department databases and provide information on trophy fish catches to managers. Anglers will receive a certificate documenting their catch and if the fish is released back to the water, an attractive California Trophy Black Bass Program Catch and Release hat/ lapel pin.

Direct inquiries or the Trophy Black Bass Verification form to: California Department of Fish and Wildlife, Fisheries Branch, Attention: Inland Fisheries Assessment and Monitoring, 980 Riverside Pkwy, Suite 100 West Sacramento, Ca. 95605

www.wildlife.ca.gov

(916) 375-5484

PLEASE PRINT

California Trophy Black Bass Recognition Program Angler Verification Form

Mr./Ms. _____ First Name ____ M.Initial _____ Last Name

_____ Mailing Address

_____ City ____ State _____ Zip ( ) _____ Area Code Daytime Phone

Optional: E-mail Address: _____

I hereby certify that I caught a trophy _____ (use fish name listed below) from _____ (name of water) in _____ (name of county) on _____ (date caught).

The fish weighed _____ lbs. _____ oz. The fish measured _____ inches (nose to end of tail fin) and _____ inches in girth (measured around largest part of body) AND was weighed and/or measured in the presence of other witnesses, whose names and addresses are:

Witness #1 _____

Witness #2 _____

The fish was ☐ kept ☐ released. The gear used to catch this fish was ☐ bait ☐ lure ☐ fly. The fish was caught from ☐ shore ☐ boat ☐ wading.

Enclosed Supporting Documentation: ☐ photograph ☐ news item ☐ weight slip Remarks: _____

Signature of Applicant: _____ Date of Application: _____

Largemouth Bass
Micropterussalmoides

Smallmouth Bass
Micropterus dolomieu

Spotted/Alabama Bass
Micropterus punctulatus/henshalli

Largemouth Bass, *Micropterus salmoides*, were first introduced into California from Quincy, Illinois, into Lake Cuyamaca (San Diego County) in 1891, and are now found throughout California. Two subspecies are recognized, the northern subspecies *M. salmoides*, and the Florida subspecies *M. s. Floridanus*. The first introduction of Florida Largemouth Bass was made in 1959 into southern California. The value of Florida Largemouth Bass has been demonstrated by increased catches of trophy-sized fish and nationwide public attention. Many bass greater than 10 pounds have been caught from California waters including a 22.01 pound bass caught and released by Robert Crupi from Castaic Lake, Los Angeles County, in 1991.

Spotted Bass, *Micropterus punctulatus*, and **Alabama Bass** *M. henshalli* have been introduced into California. Although they are colored similar to Largemouth Bass, they are easily distinguished by a smaller mouth and the fact that the first and second dorsal fins are connected. A tooth patch is located on the tongue and can be felt when you run the tip of your finger over it. However, a portion of Largemouth Bass also possess the tooth patch. The Alabama Bass was introduced to the state in 1974. Subsequently, angler catches of Alabama Bass over six pounds from many waters have been verified by Department biologists including the current state record that weighed 11 pounds 3 ounces, caught at New Bullards Bar Reservoir in 2015.

Smallmouth Bass, *Micropterus dolomieu*, were first introduced into California in the Napa River in 1874 from Lake Champlain, New York. Historical records indicate that anglers "fished out" the first plant and the introduction was considered unsuccessful. An introduction a few years later into Crystal Springs Reservoir, a water supply reservoir south of the city of San Francisco, was successful and provided an abundant source of smallmouth bass for additional stockings throughout the state. Most trophy-sized smallmouth bass from California have been caught in northern California waters. The current California state record Smallmouth Bass was caught from Pardee Reservoir, Amador County in 2007 and weighed 9 pounds 13 ounces.

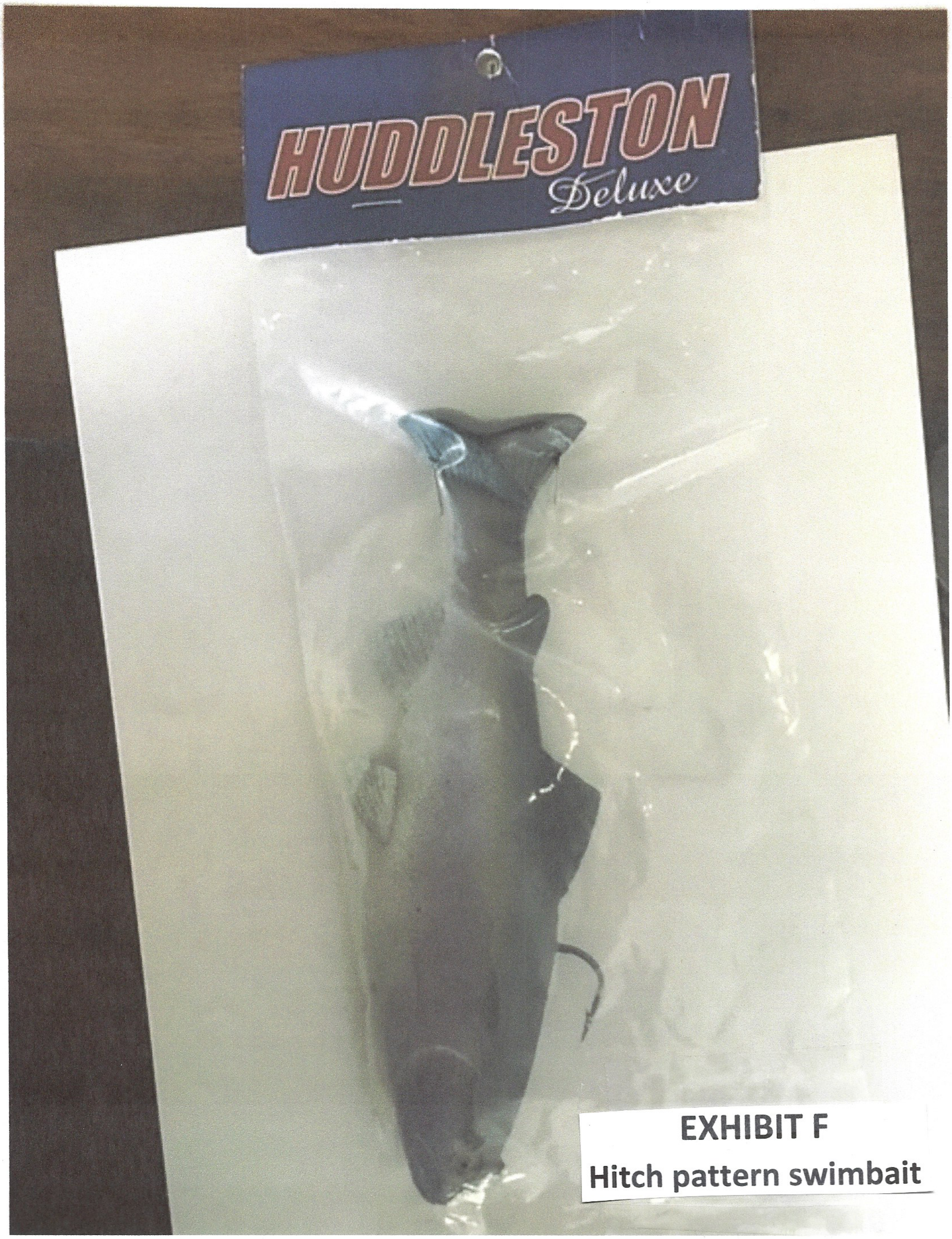


EXHIBIT F

Hitch pattern swimbait

www.huddlestondeluxe.com
P.O. Box 817
Mesquite, NV 89027
WARNING: This product contains lead, a chemical known to the state of California to cause cancer and birth defects and other reproductive harm.
Swimbaits ROCK!!!
8T12-H Hitch pattern Rof-12
patents pending
MADE IN THE U.S.A.