SPECIES STATUS ASSESSMENT FOR LONG VALLEY SPECKLED DACE
(*Rhinichthys nevadensis caldera*)

Photo Credit:USFWS

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EXECUTIVE SUMMARY

We, the U.S. Fish and Wildlife Service (Service), were petitioned to list the Long Valley speckled dace (LVSD) as either endangered or threatened with designated critical habitat in 2020 (CBD 2020), under the Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 *et seq*.). In 2021 we completed a 90-day finding where we found that the petition presented substantial scientific or commercial information indicating the petitioned action may be warranted (Service 2021). This report summarizes the results of a Species Status Assessment (SSA) that describes our current understanding of the biological status of LVSD and will inform the 12-month finding.

LVSD was historically found throughout seven historical sites, including Hot Creek and various isolated springs and ponds, within the 700,000 year-old Long Valley volcanic caldera in Mono County, CA. This subspecies was likely isolated from other speckled dace populations when Speckled Dace colonized the upper Owens Valley region from the Mono Lake Basin. During the late Pleistocene pluvial period, Mono Lake levels periodically rose high enough to spill over into the Adobe Valley, subsequently draining into the Owens River. Dace presumably were able to swim upstream into Long Valley. The formation of steep waterfalls in the Owens River Gorge separated the Owens Valley from Long Valley approximately 100,000 years ago, isolating LVSD from other speckled dace populations (Moyle et al., 2023, p. 524). The subspecies generally lives in isolated spring habitats and is genetically distinct from other members of the speckled dace complex.

The species has been extirpated from all historical collection sites except Whitmore Marsh (a 4,000–8,000 m^2 (1-2 ac) spring-fed marsh) due primarily to the effects of nonnative species, water diversion, and degraded water quality from recreational activity and cattle grazing. The remaining wild population at Whitmore Marsh has recently experienced a large decline in abundance, with a survey in 2021 and a survey in 2022 detecting only a single individual each. A refuge population containing 2,200 (1,342 – 3,431 95-percent CI) individuals is currently maintained at the White Mountain Research Center (WMRC) outside of the historical range of LVSD. This refuge population was used to translocate individuals to a second site within the historical range in 2022. LVSD has never been found at this site and it is unknown whether this second population will successfully establish.

We assessed current and future conditions qualitatively by summarizing the available demographic and habitat information for each population because of the small spatial scale, few extant sites, and localized nature of the threats. We then supplement this information with a threats analysis for the extant wild population, evaluating the risk associated with geothermal energy development, surface water diversions, habitat alteration/recreation, livestock grazing, disease and predation, inadequacy of existing regulatory mechanisms, introduced species, and climate change.

The LVSD currently exists within two populations in its historical range (one wild and one translocated), representing a loss of roughly 83–99 percent of its extent of occurrence. Such a dramatic reduction in range for a narrowly distributed species suggests that LVSD currently has little redundancy to withstand the impacts of the threats present within the Long Valley Caldera, which have led to extirpations of six historical populations. The two extant populations are roughly 14 km (8.7 mi) apart and do not share a permanent hydrologic connection, limiting opportunities for dispersal and genetic connectivity and raising concerns over the future adaptive capacity of the species.

The declines observed at Whitmore Marsh are concerning because multiple threats exist on the landscape, including a recreational swimming pool, grazing, and geothermal development, which can all be characterized as posing a risk to the current viability of the species. Multiple nonnative species and a trout hatchery exist within the historical range and have potentially contributed to the extirpation of populations at historical sites. In the Great Basin, all extinct taxon and 68% of taxa experiencing major declines were narrowly distributed, with less than 5 populations each. This information suggests that taxa with limited distribution, including LVSD, are extremely vulnerable to catastrophic events and threats within their range.

Under all plausible future scenarios, LVSD will experience reductions in its historical range. There is a high risk that both the extant historical and translocated populations within the historical range could become extirpated within the approximately 25-year timeline considered in this assessment, making the future viability of LVSD heavily dependent on reintroduction efforts from the refuge population at WMRC. Two threats can be characterized as posing a higher risk to persistence of LVSD in the future, including effects associated with climate change and expanding geothermal energy development. Several threats are expected to continue at similar rates, including grazing, disease, and introduced species. Only the risk of chlorine contamination from a recreational swimming pool at Whitmore Marsh is expected to decrease. The potential increase in some threats in the future is particularly concerning given that the continued risk of introduced species alone could be catastrophic for the remaining populations. Potential synergistic effects between the ongoing and increasing threats suggests that the viability of LVSD will decrease in the future relative to current condition.

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LIST OF ACRONYMS USED

Acronym or Abbreviation	Full Name
%	Percent
°C	Degrees Celsius
°F	Degrees Fahrenheit

3Rs	Resiliency, Redundancy, and Representation
ac	Acre(s)
BLM	Bureau of Land Management
CAS	California Academy of Science
CBD	Center for Biological Diversity
CESA	California Endangered Species Act
cfs	Cubic feet per second
CI	Confidence interval
cm	Centimeter
DPS	Distinct population segment
ESA	Endangered Species Act
FL	Fork length
ft	Foot or feet
GIS	Geographic Information Systems
HOCl	Hypochlorous acid
in	Inch(es)
IPCC	Intergovernmental Panel on Climate Change
km	Kilometer(s)
LC50	Lethal concentration 50

LVSD	Long Valley speckled dace
m	Meter(s)
mg/l	Milligrams per liter
mi	Mile(s)
mm	Millimeter(s)
mtDNA	Mitochondrial DNA
NDOW	Nevada Department of Wildlife
NDWP	Nevada Division of Water Planning
SCE	Southern California Edison
Service	U.S. Fish and Wildlife Service
SL	Standard length
sp. *or* spp.	Species or subspecies
SSA	Species Status Assessment
TL	Total length
UMMZ	University of Michigan Museum of Zoology
µg/l	Micrograms per liter
µS/cm	Micrograms per centimeter
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WAP	Wildlife Action Plan
WMRC	White Mountain Research Center
WSA	Wilderness Study Area
YOY	Young-of-year

CHAPTER 1 – INTRODUCTION

1.1 PURPOSE OF SSA

The SSA Report for Long Valley speckled dace (LVSD) is intended to provide the biological information for determining whether each species meets the definition of either a threatened or an endangered species and if so, provide the biological and ecological information to inform any critical habitat designation. A SSA Report is, in essence, a summary of the available information about a species and, simultaneously, a biological risk assessment to aid decision makers who must use the best available scientific information to make policy-guided decisions. The SSA Report provides decision makers with a scientifically rigorous characterization of the species' biological and conservation status, focusing on the likelihood of whether the species will sustain populations within its ecological settings while also explicitly acknowledging uncertainties in that characterization. The SSA process and this SSA Report do not represent a decision by the U.S. Fish and Wildlife Service (Service) on whether to list the species under the Endangered Species Act (ESA). Instead, a SSA Report provides a review of the best available scientific information for comparison to policy standards to guide decisions under the Act.

1.2 SPECIES OVERVIEW

The petitioned entity is the subspecies of speckled dace (*Rhinichthys osculus*) that occurs in the Long Valley Caldera in Southern California. A recent taxonomic revision of the speckled dace species complex recognizes the petitioned entity as the Long Valley speckled dace subspecies (*Rhinichthys nevadensis caldera*) (Moyle et al., 2023, entire). LVSD are morphologically and evolutionarily distinct (monophyletic) from other speckled dace populations throughout the overall range. The petitioned subspecies currently occurs in one spring-fed marsh and one creek. These watersheds are physically separated and not hydrologically connected with watersheds where other populations of speckled dace occur. For this report, we follow the most recent taxonomic revision that recognized LVSD as a subspecies (Moyle et al., 2023, pp. 523–524).

1.3 PREVIOUS FEDERAL ACTIONS (PETITION HISTORY FOR UNLISTED SPECIES)

On June 24, 2020, the U.S. Fish and Wildlife Service (Service) received a petition, dated June 8, 2020, from the Center for Biological Diversity (CBD) requesting that LVSD and two other speckled dace entities in the Death Valley Region be listed as a threatened or endangered species and critical habitat be designated under the Act. The petition clearly identified itself as such and included the requisite identification information for the petitioner, required at 50 CFR 424.14(c). The request for two other speckled dace entities (speckled dace populations in Amargosa Canyon and Owens Valley, California) did not qualify as petitions, and therefore are not addressed here. The request to list LVSD as an endangered, separate subspecies of speckled dace (*R. osculus*) did qualify and is addressed herein. In 2021, we completed a 90-day finding where we found that the petition presented substantial scientific or commercial information indicating the petitioned action may be warranted (Service, 2021, entire). On July 30, 2021, CBD notified us of its intent to file suit to compel us to complete a 12-month finding pursuant to 16 U.S.C. § 1533(b)(3)(B).

On November 3, 2021, CBD (Plaintiff) filed a complaint to compel us to complete the above actions by specific dates, and we subsequently reached a settlement agreement on June 1, 2022, to submit a 12-month finding for the Long Valley speckled dace to the *Federal Register* no later than July 31, 2024.

1.4 STATE LISTING STATUS

LVSD are not listed under the California Endangered Species Act (CESA).

CHAPTER 2 - METHODOLOGY AND DATA SOURCE

This document draws scientific information from resources such as peer-reviewed literature, reports submitted to the Service and other public agencies, occurrence information in Geographic Information Systems (GIS) databases, and expert experience and observations. It is preceded by, and draws upon, analyses presented in the 90-day finding (Service, 2021, entire). Finally, we coordinated with our Federal, State, Tribal, and local partners, including researchers and experts involved in field investigations. We consider the information we obtained to be the most current scientific conservation status information available for LVSD. In the future, should additional information become available, and the need arise, we will revise this document to reflect the most current scientific and conservation status information available.

2.1 SSA FRAMEWORK

The Service uses the SSA analytical framework (Figure 2-1; Service, 2016, entire) designed to assess a species' current biological condition and its projected capability of persisting into the future (Smith et al., 2018, entire). Building on the best of our current analytical processes and the latest scientific information in conservation biology, this framework integrates analyses that are common to all functions under the Act, eliminates duplicative and costly processes, and allows the Service to strategically focus on our core mission of preventing extinction and achieving recovery. The document is temporally structured, generally walking the reader through what is known from past data, how data inform current species' status, and what potential changes to this status may occur in the future. The future condition analysis includes a range of plausible conditions that the species or its habitat may face and discusses the implications for the species' viability if those conditions come to fruition. The range of plausible future scenarios include consideration of the threats most likely to impact the species in the future, at the individual, population, or range-wide scales. For this assessment, we define species viability as the ability of the species to sustain populations in the natural ecosystem over time.

Using the SSA framework (Figure 2-1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of resiliency, redundancy, and representation (also referred to as the 3Rs) (Shaffer & Stein, 2000, pp. 301–302; Wolf et al., 2015, entire). We begin the SSA with an understanding of the species' unique life history, and from that evaluate a species' resource needs or biological requirements, and the species viability using the principles of resiliency, redundancy, and representation. In general, these three concepts (or analogous ones) apply at the population and species levels and are explained that way below for simplicity and clarity as we introduce them.

1. **Resiliency** is the ability of a species to withstand stochastic events and normal year-to-year variations in both environmental conditions (i.e., temperature; rainfall; and periodic disturbances such a drought, wildfires, or floods) and demographic conditions [i.e., mortality, fecundity; (Redford et al., 2011, p. 40)]. Determined by the size and growth rate of the species population(s), resiliency can be evaluated to gauge the ability of a species to withstand the natural range of favorable and unfavorable conditions.

   In many instances, however, data are insufficient or completely lacking regarding a population's size and growth rate. In the absence of such data, it can be reasonable to examine other characteristics that may serve as surrogate indicators of general population health and subsequently, resiliency. Essentially, an assessment of the availability of a species' identified needs (e.g., suitable habitat, resources) may allow us to make assumptions about the potential resiliency of any given population. However, unless there is a documented positive correlation between species needs availability and a population's known demographic condition, the uncertainty regarding such assumptions must be made clear.

2. **Redundancy** is the ability of a species to withstand catastrophic events that would result in the loss of a substantial component of the species' total overall population. Such a loss could be of one or more populations of a species which is comprised of multiple populations or the catastrophic loss of a substantial number of individuals from a species with only a single population. However, redundancy is not simply a measure of the total number of individuals or populations of a species, but instead must also be evaluated in the context of an assessment of reasonably plausible catastrophic events. For example, a species with numerous small populations does not necessarily translate to a greater ability to withstand catastrophic events if those populations are very close together, and the only reasonably plausible potential catastrophe is one that would affect them all equally. Conversely, a species with only one population, but one which is very large and widely distributed, could have a high ability to withstand a catastrophic event that would only affect a small percentage of the total overall population. Therefore, our characterization of a species' redundancy takes into consideration both an assessment of the size and distribution of its population(s), and an evaluation of the kinds and likelihood of reasonably plausible catastrophic events to which the species could be exposed.

3. **Representation** is the ability of a species to withstand and adapt to long-term changes in environmental conditions (i.e., significant changes outside the range of normal year-to-year variations). The measure of a species' representation may be determined by the breadth of genetic diversity within and among populations, however, in the absence of information on a species' genetic diversity, we may also evaluate a species' known environmental diversity (i.e., the diversity of environmental conditions over

which it is known to occur) as an alternative measure of its ability to withstand and adapt to long-term changes.

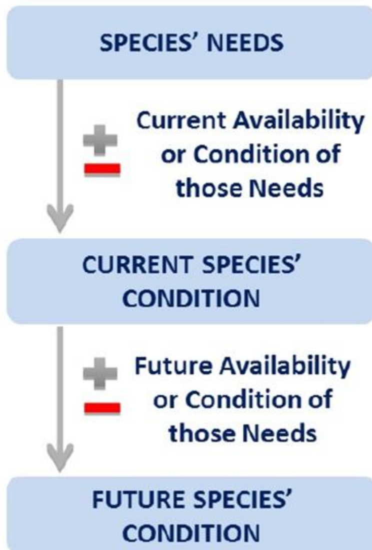

Figure 0-1. The step-wise process for assessing a species' status, as envisioned by the Services' SSA Framework (Service, 2016, p. 6).

Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of LVSD in terms of its resiliency, redundancy, and representation. The species' biology, ecology, habitat requirement, and physical and biological needs are described in Chapter 3; the current distribution and abundance are described in Chapter 4. In Chapter 4, we assess Current Conditions based on the needs outlined in Chapter 3 and discuss the factors influencing viability. Lastly, in Chapter 5 we forecast plausible future scenarios for LVSD based on the species' biology and current and future threats. Chapter 6 provides a summary of the status assessment. As a matter of practicality, the full range of potential future scenarios and the range of potential future conditions for each potential scenario are too large to analyze and describe them individually. Therefore, the chosen scenarios do not include all possible futures, but rather the upper and lower plausible limits of potential future conditions.

In summary, the SSA is a scientific review of the best information available, including scientific literature and discussions with experts, related to the biology and conservation status of LVSD.

2.2 SPECIES NEEDS

The SSA Report includes a compilation of the best available biological information on LVSD including its ecological needs based on how environmental factors are understood to act on LVSD and its habitat.

- Habitat Needs: These resource needs are those life history characteristics that influence the successful completion of each life stage.

- Demographic Needs: These components of LVSD's life history describe the resources, circumstances, and demographics that most influence **resiliency** of the populations.
- Species Needs: This is an exploration of what influences **redundancy** and **representation** for LVSD. This requires an examination of LVSD's evolutionary history and historical distribution to understand how LVSD functions across its range.

2.3 CURRENT CONDITION

The SSA Report describes the current known condition of LVSD's habitat and demographics. We considered the distribution, abundance, and factors currently influencing the viability of LVSD. We identified known historical and current distribution and examined factors that negatively and positively influence LVSD. Scale, intensity, and duration of threats were considered for their impacts on the populations and habitat across its range.

We gathered information from researchers and stakeholders to describe current conditions. Current conditions evaluated the status of LVSD from approximately 2010 through 2023 depending on the available information. Additional detail on the current condition analysis methodology is presented in Chapter 4.

2.4 FUTURE CONDITION

In the future conditions section of the SSA Report, we evaluate how the threats identified are likely to affect LVSD's needs into the future and forecast LVSD's response to a range of plausible future scenarios of environmental conditions and conservation efforts. This involves an analysis and description of a range of plausible future environmental conditions and the projected consequences on the species' ability to sustain populations in the wild over time, based on resiliency, redundancy, and representation. For this evaluation, the future extends only as far as we can reasonably project the future threats and LVSD's responses to those threats; in addition, the uncertainty increases the further into the future we look. To establish a reasonable timeframe, we consider the life-history characteristics, threat-projection timeframes, and environmental variability. Given LVSD's short generation time and the importance of the effects of climate change, we assess the potential response of LVSD under two future scenarios that illustrate a plausible range of environmental and conservation conditions by 2050.

CHAPTER 3 - SPECIES ECOLOGY AND RESOURCE NEEDS

3.1 LONG VALLEY SPECKLED DACE BIOGEOGRAPHY, BIOLOGY, AND HABITAT

3.1.1 Physical Description

The speckled dace is a small fish that typically measures less than 8 cm but can reach 11 cm standard length (SL). This species is distinguished by its small downfacing mouth, a thick caudal peduncle, small scales, and a pointed snout. The snout typically has a small barbel on each end of the maxilla and a small patch of skin connects the snout to the upper lip. Adults usually have 8 rays in their dorsal fin which originates behind the beginning of the pelvic fins, whereas the anal fin has 6-8 rays. Distinctive dark spots on the sides and upper parts of the body as well as a dark lateral band running to the snout usually occur once the fish becomes larger than 3 cm. The body is an olive to darkish yellow, with the stomach area paler in color. During the breeding season, both males and females have orange or red tipped fins, with males also exhibiting red snouts and lips. Males often develop tubercles on their head and pectoral fins (Moyle, 2002, p. 160).

LVSD are morphologically adapted to springs and exhibit fewer scales in the lateral line, fewer lateral line pores, deeper bodies, and shorter fins than fluvial speckled dace populations (Sada, 1989, pp. 3, 8). They are distinguished from a similar subspecies of speckled dace, the Amargosa speckled dace (*Rhinichthys nevadensis nevadensis*), by their higher-than-average number of pectoral and pelvic rays, increased lateral line scale count, lower lateral line pore scale count, and typically an absence of maxillary barbels and frenum. Specimens collected from Whitmore Hot Springs and Little Alkali Lake had the following mean counts (standard error): lateral line scales 61.7 (1.4); lateral line scales with pores 19.0 (5.0); dorsal-fin rays 8.0 (0.0); anal-fin rays 7.0 (0.0); pectoral-fin rays 13.0 (0.4); pelvic 7.4 (0.2) (Moyle et al., 2023, p. 523). Adult LVSD total length (TL) rarely exceeds 8 cm (Cox, 2022, p. 1).

3.1.2 Taxonomy and Genetics

The speckled dace is a fish in the family *Leuciscidae*) and genus *Rhinichthys*. Speckled dace has a wide distribution, however, as a highly variable species, there are numerous described and undescribed subspecies. The species is referred to as the speckled dace complex (SDC) which diverged from the longnose dace *R. cataractae* species complex around 6 million years ago. Jordan and Evermann (1896, pp. 305–308) described 10 species primarily basing the distinction of each on their isolation from other populations and morphological and meristic characteristics (Su et al., 2021, entire). Most of these species were later collapsed into the species *Rhinicthys osculus*.

Rhinichthys osculus exhibits extensive morphological variation which has attributed to its long and varied taxonomic history (Oakey et al., 2004, p. 208). Oakey (et al., 2004, p. 208) investigated the systematics of speckled dace through an analysis of mitochondrial DNA to construct a molecular phylogeny of the SDC. Findings presented a close match between MtDNA patterns and the isolation of three different drainage basins: Colorado River Basin and Los Angeles Basin; Great Basin (Snake River, Bonneville, Death Valley, and Lahontan); and Columbia and Klamat-Pit Rivers. In California, Moyle (2002) and Moyle (2015) recognized speckled dace as one species with seven subspecies: Lahontan speckled dace (*R. o. robustus*), Klamath speckled dace (*R. o. klamathensis)*, Sacramento speckled dace (*R. o. ssp.*), Owens speckled dace (*R. o. ssp.*), Long Valley speckled dace (*R. o. subsp.*), Amargosa speckled dace (*R. o. nevadensis*), and Santa Ana speckled dace (*R. o. ssp.*). New genome-based analysis results further corroborated the three distinct population segments described by Oakey et al. (2004) (Su et al., 2021, p. 2).

Smith (et al., 2017, entire) used mtDNA, morphology, fossils, and geologic records throughout Western North America to compare dace populations. Analysis from this study indicated that gene flow existed among populations, which prevented formation of distinct populations that could be defined as their own species because they lacked unique morphometric characterstics. Mussmann et al., (2020, entire) recognized the limitations of using mtDNA to determine evolutionary lineages and conducted a study using double-digest RAD to compare speckled dace populations throughout the Death Valley region in the Owens and Amargosa river basins. Results suggested that Death Valley has four evolutionary lineages within the subspecies *R.o. nevadensis*. Each of these lineages was treated as a Distinct Population Segment (DPS).

In 2023, Moyle et al., (2023, entire) summarized the recent genomic findings and presented a revision of taxonomy for California dace populations. The study started with the accepted designation that Speckled Dace is a single species (G. Smith et al., 2017, entire) but looked for evidence that the lineages may be distinct enough to qualify separate species and subspecies. Using the Evolutionary Species Concept, which essentially means that a species consisting of interbreeding individuals that does not breed outside of the group is independent of the similar species and maintains a distinct evolutionary identity. Smith et al., (2017, entire) assumed that isolated dace populations could interbreed at headwater connections or adjacent stream systems, however records of such interbreeding are limited. This led Moyle et al., (2023, entire) to identify cryptic species within the SDC based on taxonomy, zoogeography, geology, and genetics/genomics. The new taxonomy consists of three species: Santa Ana Speckled Dace (*R. gabrielino*); Desert Speckled Dace (*R. nevadensis*); and Western Speckled Dace (*R. klamathensis*), and six subspecies of the aforementioned three species: Amargosa speckled dace (*R. n. nevadensis*); Lahontan speckled dace (*R. n. robustus*); Long Valley speckled dace (*R. n. caldera*); Klamath speckled dace (*R. k. klamathensis*); Sacramento speckled dace (*R. k. achomawi*); and Warner Speckled dace (*R. k. goyatoka*).

Table 3.1. Hierarchy of main taxonomic ranks, scientific name, and common names of the ranks reviewed in this SSA Report.

Taxonomic Rank	Scientific Name and Author	Common Name(s)
Kingdom	Animalia	animals
Phylum	Chordata	vertebrates
Class	Actinopterygii	bony fishes
Order	Cypriniformes	ray-finned fishes
Family	Leuciscidae	minnows and carps
Genus	Rhinichthys	riffle fishes
Species	*Rhinichthys nevadensis*	desert speckled dace
Subspecies	*Rhinichthys nevadensis caldera* (Moyle et al., 2023, p. 523)	Long Valley speckled dace

LVSD are morphologically and evolutionarily distinct (monophyletic) from other speckled dace populations throughout the overall range. They are distinguished from other speckled dace by their distinct evolutionary lineage revealed by genomics and their endemism to the Long Valley region (Su et al., 2021, entire). LVSD was first recognized as a different population through isozymes and morphometrics in 1995. Sada et al. (1995, p. 353) found that the Whitmore Hot Springs and Little Alkali Lake LVSD populations were the only populations with an alternative (**D*) allele of the *PEPA** locus that segregated. Every other population examined was fixed for the same alleles at the remaining monomorphic loci. Death Valley system speckled dace within the Owens, Amargosa, and Mohave river drainages form a monophyletic clade, but mtDNA restriction site mapping and geologic evidence suggests LVSD are differentiated within this grouping because they might retain haplotypes from an earlier period (Oakey et al., 2004, pp. 211–212).

3.1.3 Age, Growth, and Population Structure

There is little information regarding the biology and life history of LVSD. Therefore, the following description is based primarily on information for general speckled dace (*Rhinichthys osculus*) and historical and current collections of LVSD. Speckled dace lifespan is coarsely correlated with maximum size, with dace under 80 mm fork length (FL) living for roughly three years. Dace grow to 20-30 mm SL by the end of their first summer, and grow each subsequent year by an average of 10-15 mm SL. Typically females grow faster than males. Under stressful environmental conditions, limited food, or high population densities, growth rates can decrease.

3.1.4 Reproduction

There is little information regarding the biology and life history of LVSD. Therefore, the following description is based primarily on information collected for other speckled dace subspecies. Dace reach sexual maturity by the end of their second summer. Females produce 190-800 eggs depending on size and location and release them underneath rocks or near gravel surfaces while males release sperm. The fertilized eggs settle into interstices and adhere to gravel, then hatch in 6 days when temperatures are 18-19 ℃ (64.4-66.2 °F). Larvae remain in the gravel for 7-8 days as they develop into fry.

3.1.5 Habitat

Speckled Dace in the Owens Basin occupy habitat ranging from cold-water streams to hot springs with water temperatures typically below 29 ℃ (84.2 °F) (Moyle et al., 2015, p. 3). Morphometric analysis of LVSD indicates that their deep-bodied form may be more adapted to springs. They occupied one large stream in the past, however, their disappearance following spring development suggested this population relied on recruitment from spring dwelling individuals (Sada, 1989, p. 13). Population collapses in formerly suitable sites that were modified and invaded by alien fish species indicates LVSD is highly susceptible to changes in their habitat. Their remaining occupied habitat includes Whitmore Marsh and translocation site O'Harrel Canyon Creek. Whitmore Marsh is a shallow (<50 cm (1.6 ft)), clear spring outflow and two open pools in a marsh. Water temperature near the spring outlet varies from 30-35 ℃

(86-95 °F) while the pools in the lower half of the marsh freeze during the winter. LVSD concentrate near the springhead in the winter. The narrow water channel flows from the spring through dense bulrush that LVSD uses for cover (Moyle et al., 2015, p. 3). O'Harrel Canyon Creek originates from the Glass Mountains, meandering through a short meadow, and terminates approximately 3 km (1.9 mi) before reaching the Owens River. The upper 0.8 km (0.5 mi) of the creek is occupied by introduced Lahontan Cutthroat Trout (*Oncorhynchus clarkii*), but they do not persist in the lower half that is suitable temperature for LVSD (Cox, 2022, p. 2).

3.1.6 Food, Water, Nutrients

Speckled dace's subterminal mouth and tooth structure make it ideal for consumption of small aquatic invertebrates (hydropsychid caddisflies, baetid mayflies, and chironomid and simuliid midges) most common in riffles. Invertebrates generally make up the bulk of their diet however they may also eat filamentous algae (Moyle et al., 2015, p. 2). Speckled dace forage opportunistically, which varies their diet of invertebrates depending on available food sources that may change during the seasons. Dace can be active both in the day and at night, with water temperatures influencing their level of activity. Dace are active year-round when stream temperatures stay above 4 °C (39.2 °F), which is typical of the waters LVSD inhabit.

3.1.7 Dispersal and Migration

The Death Valley region was a series of interconnected lakes during the pluvial periods of the Pleistocene. The lakes and rivers eventually dried up or became smaller remnants due to climate change and decreased precipitation, which isolated numerous speckled dace populations. LVSD likely originated during the late Pleistocene pluvial period when they colonized the upper Owens Valley region from Mono Lake Basin water that spilled into the Adobe Valley. The Adobe Valley drained into the Owens River and fish presumably swam upstream to Long Valley. The Owens River eventually down vaulted and formed steep waterfalls in the gorge around 100,000 years ago, ultimately isolating Long Valley from Owens Valley. LVSD currently have limited ability to disperse between populations, as many of the springs they occupied historically are not hydrologically connected or are separated by unsuitable habitat.

3.2 PHYSICAL AND BIOLOGICAL NEEDS

3.2.1 Individual-level Resource Needs

Individual needs for speckled dace revolve around having consistent clean cold water (temperatures that stay below 29 °C (84.2 °F) in the summer months) with access to aquatic invertebrates as a food source. Fertilized eggs and larvae utilize gravel substrates during development and later larvae use rocks and emergent vegetation for cover. Adults typically inhabit springs but have existed in creek systems.

3.2.2 Population-level Needs

Populations need abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction despite disturbance. For LVSD this revolves around having adequate aquifer fed spring systems or creeks that stay above 4 ℃ (39.2 °F). Having enough water in each spring or creek is important to allow dace within the population to disperse throughout the connected habitat during different seasons for reproductive purposes. Having multiple populations connected within the watershed is important to mitigate impacts from localized threats. Dace population size varies greatly based on the annual conditions of the habitat and will rebound in numbers when conditions are favorable.

3.2.2.1 Habitat Needs

Amount of Habitat

The amount of habitat is mainly driven by snowmelt from the Sierra Nevada highlands on the western edge of the caldera (U.S. Geological Survey, n.d.). The subspecies inhabits a relatively small area, making adequate amounts of suitable habitat important for the resiliency of the species.

Quality of Habitat

Quality of habitat revolves around nonnative species and water quality. Nonnative species negatively impact habitat suitability directly by changing dissolved oxygen and pH levels of the water or by increasing predation and competition levels. Having water temperatures stay below 29 ℃ (84.2 °F) as well as limiting the amount of pollution and sedimentation into the waterways which directly impacts the quality of the habitat, are also water quality priorities.

3.2.2.2 Demographic Needs

Growth of Population

Capacity for population growth, particularly from low numbers, is important for dace resiliency. LVSD currently occurs in low numbers, making it especially vulnerable to stochastic events. Having the ability to grow from small number will ensure that the species can adequately repopulate as adverse conditions within the habitat ebb and flow.

Size of Population

Having populations large enough to be self-sustaining and repopulate habitat in a highly variable and unpredictable environment is important for dace resiliency. Due to introduced species, disease, grazing, recreation, a trout hatchery, geothermal development, climate change, and small population effects in the occupied habitat, LVSD populations must be resilient enough to repopulate habitat as these adverse conditions ebb and flow.

3.2.3 Species-level Needs

For LVSD to have high viability, the subspecies needs to maintain its representation (adaptive capacity) by having multiple resilient populations (redundancy). LVSD is a narrow endemic and inherently has low redundancy, however it is still important that multiple resilient populations exist throughout its historical distribution. This allows the subspecies to still have some redundancy and representation which helps mitigate impacts from threats and stochastic events. Having multiple populations helps maintain genetic diversity and adaptive capacity, which is increasingly important due to the impacts of climate change.

3.3 SUMMARY OF SPECIES NEEDS

Level	Requirement	Life stage affected/why it is needed	Association with 3Rs
Individual	Habitat: Cold, clear water with riparian vegetation or hot-spring systems (not exceeding 29 °C (84.2 °F)) (Moyle et al., 2015, p. 3)	Juvenile and adult/survival	Resiliency
	Food: Small aquatic invertebrates or filamentous algae (Baltz et al., 1982, p. 1509; Hiss, 1984, pp. 10–11; Li, 1976, p. 118; Moyle et al., 1991, p. 269)	Larvae, juvenile and adult/survival	Resiliency
	Shelter: Rocks and emergent vegetation (Moyle et al., 2015, p. 3)	Juvenile and adult/survival	Resiliency
	Gravel substrate for eggs to adhere to and for larvae to shelter in (John, 1963, p. 289)	Eggs and larvae/survival Adult/breeding	Resiliency
	Limited sedimentation in water (Moyle et al., 2015, p. 4)	Eggs, larvae, juvenile, adult survival	Resiliency
	Adequate flows with water temperatures not greater than 29 °C (84.2 °F) (Moyle et al., 2015, p. 3)	Adult/survival	Resiliency
Population	Habitat: variable, but typically cold flowing water and hot-spring systems (not exceeding 29 °C (84.2 °F)) with gravel bottoms connected to other suitable	Maintain large, healthy, interconnected populations that can withstand and rebound from random	Resiliency and Redundancy

	patches (Moyle et al., 2015, p. 3)	environmental, genetic and demographic events.	
	High population abundance	Enables population to recover from stochastic disturbances; allows for maintenance of genetic diversity and improves efficacy of natural selection	Resiliency and Representation
Species	Habitat: variable, but typically cold flowing water with gravel bottoms or hot-spring systems (not exceeding 29 ℃ (84.2 °F)) (Moyle et al., 2015, p. 3)	Ability to sustain populations despite catastrophic events	Redundancy
	Large, multiple, resilient populations	Ability to sustain populations given natural variability, catastrophic events, and changing conditions.	Redundancy and Representation
	Wide distribution across species range	Ability to sustain populations given disturbances or catastrophes; increases exposure to different environmental regimes, increasing adaptive capacity	Redundancy and Representation
	Genetic diversity	Maintains ability to adapt to environmental changes; minimizes fitness impacts of inbreeding	Resiliency and Representation

3.4 UNCERTAINTIES

Although surveys have been completed at Whitmore Marsh as recently as 2022 and habitat has been monitored at this site over the years, there are multiple historical sites that have not been revisited and assessed for current habitat conditions. A comprehensive habitat suitability model has not been created, which would assist in finding potential reintroduction sites. An overall population estimate, and subsequent trends, are unknown for the species outside of the WMRC population. The lack of data on abundance is notable because of its link to the resiliency of this single population. O'Harrel Canyon Creek has not been surveyed since fish were translocated there, and it is currently unknown how effectively translocated LVSD can establish in a wild environment. Robust monitoring would be needed to estimate population levels as the total number of LVSD fluctuates year to year based on habitat conditions.

CHAPTER 4 – CURRENT CONDITIONS

4.1 SUMMARY OF METHODS

The LVSD is a narrow endemic subspecies known from seven historical sites within the Long Valley Caldera in Mono County, California. All but one of the seven historical sites are now thought to be extirpated (Moyle et al., 2015, p. 3). Because of the small spatial scale, few extant sites, limited survey data, and localized nature of the threats, we assessed the current conditions qualitatively by discussing range-wide factors affecting viability (e.g., the extent of occurrence and number of extant populations) and by summarizing the available demographic and habitat information for each population. The available data are interpreted within the context of the 3Rs throughout. We then supplement the limited demographic and habitat quality data with a threats analysis for the extant wild population. We provide qualitative descriptions of the factors influencing viability and summarize these influences using a risk matrix approach to highlight major threats and their expected impacts.

4.2 DISTRIBUTION AND RANGE CONTRACTION

The spatial structure of LVSD populations is related to the species' resiliency, redundancy, and representation. Extent of occurrence is a common metric used to assess spatial structure and measures the degree of risk-spreading across a species' range (Gaston & Fuller, 2009, pp. 4–6). We evaluated the change in extent of occurrence based on the minimum convex hull polygon around known historical localities and the two currently extant localities. Values were estimated based on locality data referenced to the Albers Equal Area North American Datum 1983 Coordinate Reference System (ESRI: 102003).

The LVSD is a narrow endemic subspecies known from seven historical sites within the Long Valley Caldera in Mono County, California (Figure 4-1), encompassing a historical extent of occurrence of 18.5 km^2 (4,571 ac). Whitmore Marsh is the sole remaining historical population and covers roughly 4,000–8,000 m^2 (1–2 ac) based on accounts by (Moyle et al., 2015, p. 3) and GIS calculations using satellite imagery of wetland vegetation over multiple years. LVSD was translocated to O'Harrel Canyon Creek from the refuge population at WMRC in 2022 (Cox, 2022, p. 2). This suggests a reduction in extent of occurrence of roughly 83–99 percent depending on the success of the translocated population. This range is based on the upper estimate for the area of Whitmore Marsh and a minimum convex hull of 3.1 km^2 (766 ac) around Whitmore Marsh and the translocation sites in O'Harrel Canyon Creek.

Such dramatic reductions in extent of occurrence for a narrowly distributed species suggests that LVSD currently has little redundancy to withstand the impact of the threats present within the Long Valley Caldera, which have led to extirpations of six historical populations in habitats similar to the extant areas. Whitmore Marsh and O'Harrel Canyon creek are roughly 14 km (8.7 mi) apart, do not share permanent hydrologic connections (Cox, 2022, p. 2), and are separated by areas containing non-native species, limiting opportunities for dispersal in the face of stochastic events or changes in habitat quality. The isolated nature of the two remaining populations also limits genetic connectivity, which combined with the expected low population size of Whitmore Marsh (see section 4.3.7 below) leads to concerns over the future evolutionary potential of the remaining populations.

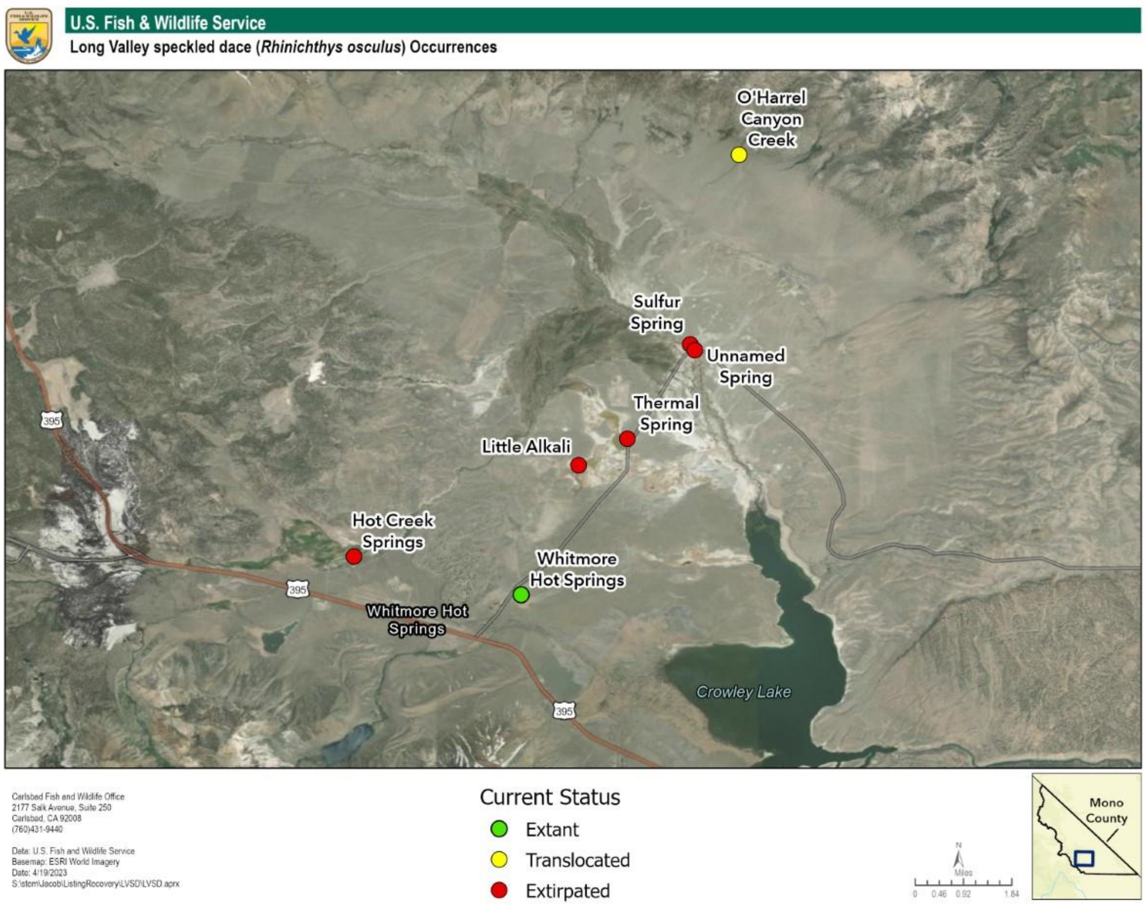

Figure 4-1. Current distribution of Long Valley speckled dace.

4.3 POPULATION STATUS

The LVSD is known from a total of eight sites in the wild (Table 1): seven historical sites within the Long Valley Caldera in Mono County, California and one translocated site established in 2022 (Cox, 2022, p. 2). Only one historical population (Whitmore Marsh) and one translocated population with an unknown chance of success (O'Harrel Canyon Creek) are extant, with six other populations considered extirpated (Table 1). A refuge population was established in 2017 at WMRC outside of the historical range, following concerns that the last remaining wild population at Whitmore Marsh was declining (Cox, 2022, p. 2). This refuge population currently contains 2,200 individuals (1,342 – 3,431 95-percent CI). An additional refuge population established in a private pond in 2006 and supplemented with individuals in 2011 has since been extirpated (Cox, 2022, p. 2).

The available survey effort varies for each site but suggests large declines in population size across the range. Given the small number of sites, we summarize the available survey data for each locality below and discuss any known habitat characteristics. We also identify any threats that may have contributed to extirpations or may be operating on extant populations. A more detailed discussion of the mechanisms of each threat can be found in Section 4.5.

Table 1: LVSD occurrence information. Data from reports cited in text. Hypothesized occupancy status is based on the most recently available information.

Site Name	Current Status	Last year observed	Last year surveyed	Ownership
Hot Creek Springs	Extirpated	1934	1988	LADWP
Sulfur Spring	Extirpated	1937	1988	LADWP
Thermal Spring	Extirpated	1938	1988	BLM
Unnamed Spring	Extirpated	1939	1988	LADWP
Hot Creek	Extirpated	1932	1988	BLM, LADWP
Little Alkali	Extirpated	1988	2006	LADWP
Whitmore Marsh	Extant	2023	2023	LADWP
O’Harrel Canyon Creek	Extant	2023	2022	USFS

4.3.1 Hot Creek Springs

Hot Creek Springs was a feeder of Hot Creek in the Owens River drainage. A specimen was collected in 1934 for the University of Michigan Museum of Zoology (UMMZ). Sada (1989, p. 11) was unable to locate a population of dace while surveying this location in 1988 and hypothesized that habitat alteration and introduction of nonnative species during the Hot Creek Springs Hatchery development may have contributed to its extirpation.

4.3.2 Sulfur Spring

Sulphur Spring was a seepage tributary to Owens River near Benton's Crossing on the eastern side of Long Valley. A specimen was collected in 1937 for the UMMZ. Sada (1989, p. 11) was unable to locate this site while surveying Long Valley for dace in 1988 and speculated it either dried up or was inundated by the Owens River.

4.3.3 Thermal Spring

Thermal Spring is a hot spring within the Owens River drainage situated at 2,088-2,103 m (6,850-6,900 ft) of elevation. A specimen was collected in 1938 for the UMMZ. Sada (1989, p. 11) was unable to locate the dace while surveying Long Valley in 1988.

4.3.4 Unnamed Spring

Unnamed spring flows into the Owens River near Benton Crossing. Eleven specimens were collected in 1939 for the California Academy of Science (CAS). Sada (1989, p. 11) was unable to locate the dace while surveying Long Valley in 1988.

4.3.5 Hot Creek

Hot Creek is the only stream where LVSD were historically found. Sixty-nine specimens were collected in January of 1932 and one additional specimen was collected in March for the CAS. Sada (1989, p. 11) was unable to locate the dace while surveying Long Valley in 1988.

4.3.6 Little Alkali

Little Alkali is a thermal spring tributary to Little Alkali Lake. Sada (1989, p. 12) discovered this population September 30, 1988 and revisited the site December 12, 1988. The site was heavily impacted by cattle grazing during each visit. The tributary is supported by spring flow discharge of approximately 0.75 cfs. LVSD were observed in approximately 548 m (1,800 ft) of stream averaging 0.6 m (2 ft) wide and 7.6 cm (3 in) deep. Dace were not found near the spring source where temperatures were greater than 28.9 °C (84 °F) or downstream from Little Alkali Lake. The population was small, healthy, and did not exhibit any signs of parasitism. No other fish species were present.

Little Alkali was surveyed again June 19, 1996. Four adults, one juvenile, and one young-of-year (YOY) were observed. Lahontan Creek tui chub (*Siphateles bicolor obesus*) and western mosquitofish (*Gambusia affinis*) were both abundant at the site. The following year, zero dace were observed during visual and dip net surveys at "bathtub spring". Lahontan Creek tui chub and western mosquitofish were still abundant. No dace were observed on July 17, 1998, during a dip net and an unbaited minnow trap survey. On August 28, 1998, 2 dace measuring 30-60 mm were observed during an electrofishing survey. This site was surveyed visually and via trapping June 15, 1999, February 28, 2002, and June 10, August 10-11, and December 7-8, 2006, but LVSD were not found.

4.3.7 Whitmore Marsh

The Whitmore Marsh LVSD population was discovered in 1988 (Sada, 1989, p. 10). Sada (1989, p. 11) visited this site four times between July 31 and December 12, 1988, to collect population size and habitat quality data. The habitat was supported by spring discharge that flowed through a chlorinated swimming pool owned and maintained by Town of Mammoth Lakes on LADWP property. The spring discharge was approximately 2 cfs and flowed into the marsh about 137 m (450 ft) downstream from the pool. Visual estimates were not made during the first site visit in July due to dense coverage of cattails (*Typha sp.)* in the water but were made during subsequent visits after cattle grazing reduced cattails to water level. On September 30, 1988, 17 minnow traps were set and 117 dace were captured over the course of 123 trap-hours. These results in combination with the visual estimates indicated the subspecies was common at this site and that they occupied approximately 45.7 m (750 ft) of stream and two 4,000 m^2 (1 ac) ponds in the marsh. The majority of fish caught were in poor condition due to heavy parasite infestation (Sada, 1989, pp. 10–12).

California Department of Fish and Wildlife (CDFW) surveyed Whitmore Marsh again in 2002 and 2009 and characterized the population as relatively stable, although CDFW did not define the term "relatively stable" and no abundance data or estimates were generated in those surveys. In 2011, LVSD were translocated from this site to a private pond ("Becky's Pond), which was originally founded in 2006. No population estimates were recorded for this event. Individuals from Becky's Pond were later moved to a refuge population established at the WMRC. The Becky's Pond population was subsequently confirmed to be extirpated.

In 2017 and 2019, CDFW conducted extensive surveys and attempted to capture LVSD at Whitmore Marsh. The surveys yielded very few individuals, indicating that Whitmore has had a low abundance since 2017 (Cox, 2023, p. 1).

CDFW and the Service conducted two surveys in June 2021. Twenty-nine minnow traps (1/8" mesh Gee traps) were set in the evening during the first survey on June 4, 2021, between 1630 and 1730 and retrieved on June 5, 2021 between 0930 and 1130. One LVSD measuring 68mm TL was captured from the westernmost pond (37.6282276°, -118.8104297°). Thirty traps were set on the evening of June 21, 2022 at 1930 then retrieved and reset in place between 1000 and 1200 on the mornings of June 22, 2022 and June 23, 2022. One LVSD measuring 70mm was caught in the west pond on June 22, 2022, then marked and recaptured two more times over the course of the survey.

Recent low numbers have been attributed to a die-off that likely occurred in spring of 2017. While the cause of the population crash is unknown, it is hypothesized that an unusually heavy snowpack during the previous winter may have prevented the majority of LVSD from dispersing lower in the marsh and away from the spring source due to colder temperatures from meltwater. LVSD concentrating near the warm pool outlet stream could have been exposed to chorine from the public swimming pool upstream that has historically discharged lightly chlorinated water into the marsh during the summer operating season. Other possible explanations for the population die-off include parasites, grazing impacts, or unprecedented winter kill (Cox, 2023, pp. 1–2).

Although we do not have direct population estimates, such decreases in catch-per-unit-effort, which is the number of fish caught in numbers with one standard unit of fishing effort, suggest that the population has experienced dramatic declines that may limit its ability to persist and raise concern for the genetic health of the population.

4.3.8 O'Harrel Canyon Creek

O'Harrel Canyon Creek is a spring-fed creek situated at 2,083 m (6,834 ft) of elevation in Mono County, CA near Benton Crossing. This creek originates in the Glass Mountains and terminates before reaching the Owens River. Introduced Lahontan Cutthroat Trout occupy the upper 0.8 km (0.5 mi) of the creek but are not found in the lower reaches that provide suitable habitat and water temperature for LVSD. CDFW monitored the habitat in 2015-2016 and determined that drought did not have an effect on the creek despite its size and watershed. These factors influenced CDFW to create a plan to translocate LVSD and create another wild population to supplement the Whitmore Marsh population.

CDFW collected 413 dace from the WMRC Northeast pond refugium population on June 30, 2022, using 10 traps set at 0820 and pulled at 0915. Fish were collected from 4 of the 10 traps to ensure only 20 percent of the source population was used for translocation. Collected LVSD were transported and released at three locations within O'Harrel Canyon Creek. Four hundred seven fish survived the translocation and the six mortalities were preserved for genetic/morphometric analysis (Cox, 2022, pp. 2–3).

Monitoring efforts will be used to determine success of population establishment at O'Harrel Canyon Creek, however heavy snowpack prevented staff members from accessing the site during the first winter in 2022/2023. The likelihood that this population will successfully establish is therefore currently unknown.

4.4 ADAPTIVE CAPACITY

The speckled dace (or speckled dace complex) is one of the most widely distributed species of freshwater fish in Western North America, occurring in a variety of habitats including streams, rivers, springs, and lakes (Moyle et al., 2023, p. 501). In addition, the species' morphology varies across these different habitats (Moyle et al., 2023, p. 502), suggesting some inherent adaptive capacity. The LVSD subspecies appears to be genetically distinct (Moyle et al., 2023, p. 524) and specifically adapted for isolated springs and smaller streams (Sada, 1989, p. 3).

Although the speckled dace complex appears to have inherent adaptive capacity, LVSD's limited historical range, lack of dispersal opportunities, and presumed small population size likely limit this capacity for the subspecies. The wild and translocated populations of LVSD are not connected hydrologically, limiting any potential for dispersal in response to localized threats, as well as any ability for recolonization following catastrophic events. In addition, the lack of genetic exchange is concerning given the population decline at Whitmore Marsh that occurred in 2017. Managing genetic diversity both within the historical population and the refuge population will be critical to conservation efforts for LVSD and maintenance of the subspecies' adaptive capacity.

4.5 FACTORS INFLUENCING VIABILITY

In this section, we further describe the current conditions by providing a summary of potential factors influencing the species. We consider the potential contributions of these threats and how these threats are negatively impacting the species' habitat and demography. We evaluate these threats in the context of (1) any existing regulatory mechanisms that may reduce impacts to the species or its habitat, and (2) other existing efforts to protect or conserve the species. In this section, we identify current threats affecting LVSD. We use the term threat to refer to actions or conditions that may be or are reasonably likely to negatively affect individuals of the species directly or impact aspects of their ecology. Threats include actions or conditions that have a direct impact on individuals, as well as, those affecting individuals through alteration of their habitat or required resources. Threats may encompass the source of the action or condition or the action or condition itself. Threats may be reduced through existing conservation mechanisms or management activities and those mitigating measures are described below where appropriate.

A threat's significance depends upon a population-level assessment of the scope, level of impact on LVSD, and the likelihood of the threat occurring. After discussing each threat individually, we summarize our assessment using a risk matrix approach to help visualize the relative importance of each threat to the viability of LVSD. Category definitions used to construct the risk matrix are provided in Table 2. Scope refers to the spatial extent of a threat within the context of the species' range and is defined here as either localized to specific populations or range-wide. Level of impact indicates the magnitude of the impact on LVSD populations (low, medium, high, extreme). Likelihood describes the probability that the threat will occur over the next 10 years (remote, unlikely, likely to occur, known or very likely to occur). The likelihood of occurrence and level of impact were then combined into an overall risk level based on the relationships outlined in Table 3. Our certainty in the risk levels was classified on a scale of 1 (very low) to 5 (very high) based on the strength of evidence and understanding of the mechanism for each threat (Table 2).

Table 2. Categories used in the threat assessment. Likelihood of occurrence refers to the probability of a specific threat occurring for a given area over 10 years. Level of impact refers to the magnitude of the impact

caused by a given threat and the level to which it affects the viability of the population(s). The impact is a result of both the scope and severity of a given threat. Causal certainty reflects the strength of evidence linking the threat to the survival and recovery of the population. Numeric ranges represent the authors' judgments and are provided only to reduce linguistic uncertainty in categorical labels, following best practices for communicating risk.

Likelihood of Occurrence	**Definition**
Known or very likely to occur	This threat has been previously recorded or there is a 91-100% chance this threat is or will be occurring
Likely to occur	There is a 51-90% chance that this threat is or will be occurring.
Unlikely	There is a 11-50% chance that this threat is or will be occurring
Remote	There is a 1-10% or less chance that this threat is or will be occurring.
Unknown	There are no data or prior knowledge of this threat occurring now or in the future.
Level of Impact	**Definition**
Extreme	Severe population decline (e.g., 71-100%) with the potential for extirpation.
High	Substantial loss of population (e.g., 31-70%) or threat would greatly reduce resiliency
Medium	Moderate loss of population (e.g., 11-30%) or threat is likely to reduce resiliency
Low	Little change in population (e.g., 1-10%) or threat is unlikely to reduce resiliency
Unknown	No prior knowledge, literature or data to guide the assessment of threat severity on population.
Causal Certainty	**Definition**
5 - Very high	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified
4 - High	Substantial evidence of a causal link between threat and population decline or decreased resiliency

3 - Medium	There is some evidence linking the threat to population decline or decreased resiliency
2 - Low	There is a theoretical link with limited evidence that threat is leading to a population decline or decreased resiliency
1 - Very low	There is a plausible link with no evidence that the threat is leading to a population decline or decreased resiliency

Table 3. Risk categories defined by level of impact and likelihood of occurrence of each threat.

		Level of Impact				
		Low	*Medium*	*High*	*Extreme*	*Unknown*
Likelihood of Occurrence	*Known or very likely to occur*	Low	Medium	High	High	Unknown
	Likely to occur	Low	Medium	High	High	Unknown
	Unlikely	Low	Medium	Medium	Medium	Unknown
	Remote	Low	Low	Low	Low	Unknown
	Unknown	Unknown	Unknown	Unknow	Unknown	Unknown

Below we outline the main threats currently affecting LVSD as informed by the recent past. We evaluated impacts from the following primary threats on LVSD: (1) disease; (2) introduced species (increased competition and predation); (3) grazing; (4) recreation; (5) trout hatcheries; (6) geothermal development; (7) changing climate trends (e.g., increased temperatures and longer, more frequent drought periods); and (8) small population effects (Figure 6-1).These influences may impact individual, population, and species needs, and ultimately the viability of LVSD. The relationships between threats, sources, species' ecology and demographic parameters are illustrated in the effects pathway (Figure 4-2).

Figure 4-2 is a conceptual model showing the relationships of the identified threats impacting the species' habitat and life history needs directly or indirectly at the population level. While we generally discuss these threats individually, threats can also occur simultaneously with synergistic effects on the resiliency of LVSD. Where different individual threats occur at the same time and place, we will describe how they may interact with one another below as well as in the future. Threats may be reduced through the implementation of existing regulatory mechanisms or other conservation efforts that benefit LVSD and its habitat.

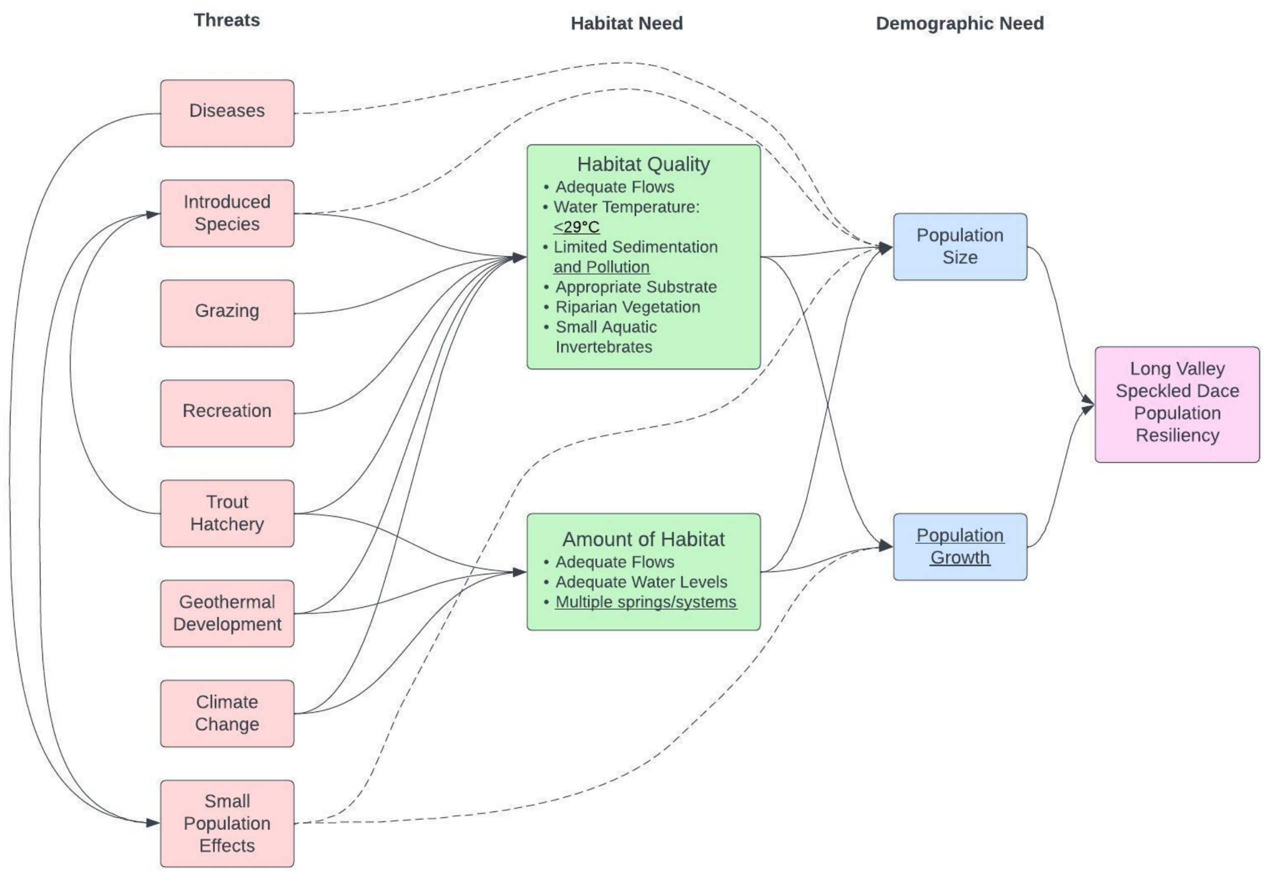

Figure 4-2. LVSD Effects Pathway. Threats are highlighted in red, habitat needs in green, demographic needs are in blue which all contribute to LVSD resiliency. Dashed lines indicate threats that impact demographic needs directly.

4.5.1 Disease

Growth and health status of fish may be negatively affected by parasites (Raissy & Ansari, 2012, p. 74). Parasites may cause stress, reduced growth, increased risk of infection or secondary disease, and possibly death of individual fish (Hejna et al., 2023, entire). In 1988, LVSD found in Whitmore Marsh were in poor condition due to a heavy parasite infestation (Table 4).Bogan et al. (2002, p. 4) observed cysts most likely resulting from a trematode infection caused by yellow grub (*Clinostrum marginatum).*

Table 4: Occurrence and Threats, Table. Long Valley speckled dace threats information. Hypothesized occupancy status is based on the most recently available information.

Site Name	Current Status	Last Year Observed	Current/Past Threats	Citation

Hot Creek Springs	Extirpated	1934	Alteration to system, including Hot Creek Hatchery and introduction of non-native trout	(Sada, 1989, p. 11), UMMZ
Sulfur Spring	Extirpated	1937	Alteration to system, cattle grazing	(Sada, 1989, p. 11), UMMZ
Thermal Spring	Extirpated	1938	Alteration to system	(Sada, 1989, p. 11), UMMZ
Unnamed Spring	Extirpated	1939	Alteration to system	(Sada, 1989, p. 11), SU
Hot Creek	Extirpated	1932	Alteration to system, including Hot Creek Hatchery and introduction of non-native trout to stream, not ideal habitat for spring adapted fish	(Sada, 1989, p. 11), CAS
Little Alkali	Extirpated	1988	Western mosquitofish, cattle grazing, and recreation	(Sada, 1989, p. 11), CAS
Whitmore Marsh	Extant	2022	Parasites, cattle grazing, downstream of a recreational swimming pool, alien tiger salamanders	(Cox, 2023, p. 2)
O'Harrel Canyon Creek	Extant	2022	Lahontan cutthroat trout predation	(Cox, 2022, p. 3)

4.5.2 Introduced Species

4.5.2.1 Predation and Competition from nonnative species

The introduction of nonnative species may stress indigenous fish populations via increased predation, competitive interactions, transmission of pathogens, or hybridization (Cucherousset & Olden, 2011, pp. 216–221; Mills et al., 2004, pp. 719–720). Invasive species compete with or prey upon speckled dace and may introduce parasites and disease into freshwater ecosystems (Stone et al., 2007, p. 131). LVSD have rarely been found in springs where other fish species are present, suggesting their ability to compete with or avoid predation from nonnatives is limited (Sada, 1989, p. 10). There has only been one account of LVSD occurring with western

mosquitofish (*Gambusia affinis*) and Lahontan tui chub (*Gila bicolor*) in Little Alkali, however this population collapsed before the next survey occurred the following year (L. Greene, Memorandum to File, 2006, p. 4). Therefore, nonnative species may pose a significant threat to the survival of LVSD populations.
Out of all invasive fish species found in the area, the western mosquitofish poses the largest and most direct threat to the continued existence of LVSD. Western mosquitofish have high reproduction rates and are adapted to expand rapidly into unoccupied habitat. They display active exploratory and aggressive behaviors that allow them to find new habitats and are very tolerant of poor habitat and water quality allowing them to disperse through potential barriers such as water less than 2.5 cm (1 in) deep. Females can store sperm from multiple mates over multiple seasons so that a single fish can populate an area with limited genetic impacts (Rehage & Sih, 2004, entire). These adaptations allow mosquitofish numbers to increase rapidly once they have invaded a new area, greatly increasing competition with native fishes. Adult mosquitofish prey on terrestrial and aquatic arthropods as well as larval fishes (Etnier & Starnes, 1993, p. 372). The competition for resources and predation of larval dace and eggs by the mosquitofish could have led to the extirpation of dace from the Little Alkali Lake spring system (Table 4). Mosquitofish are also a host for larval and adult parasites, including helminth species, such as trematodes, cestodes, and nematodes, which have been found to parasitize speckled dace in the Grand Canyon (Carpenter & Herrmann, 2020, p. 268).

Introduced tiger salamanders exist within three miles of Whitmore Marsh and have been collected from four localities in the Long Valley Caldera region (Johnson et al., 2011, p. 358) , including near Hot Creek Springs which was historically occupied by LVSD (Figure 4-3). Although the precise rate of spread is unknown, it is plausible that the tiger salamanders could reach Whitmore Marsh based on the distances between the known occurrences. These salamanders prey on native fish species in the area and pose a direct threat to the continued persistence of the last historical LVSD population (Table 4).

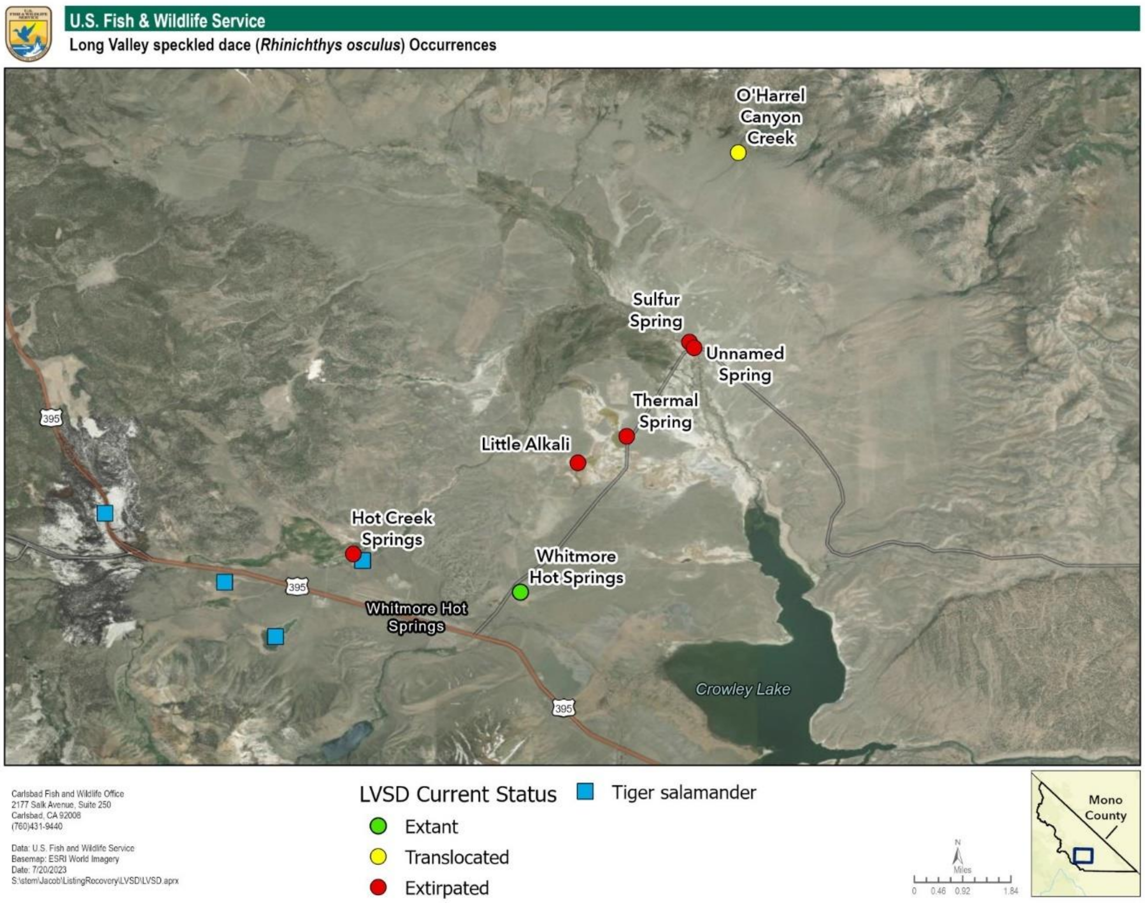

Figure 4-3. Occurrences of nonnative tiger salamanders in relation to LVSD occurrences.

4.5.2.2 Invasive Aquatic Vegetation

Aquatic habitat may be modified by the presence of invasive vegetation in a variety of ways. Cattails produce an abundance of wind dispersed seeds, allowing it to aggressively expand and create dense stands. These stands have potential to impact plant and animal life, biogeochemical cycling, and hydrology (U.S. Geological Survey (USGS), 2020, entire). Dense stands of Cattails (*Typha* sp.) currently exist at Whitmore Marsh and it is unclear whether their existence has impacted the LVSD population at this site.

4.5.3 Grazing

Cattle access is known to increase bank erosion, increasing turbidity and sedimentation in the springs. Speckled dace require clear water for their spawning and clean vegetation for egg laying. Sedimentation from cattle also has the potential to fill in spring pools and runs, reducing habitat area (AFS, n.d., entire). The increased turbidity and reduced riparian vegetation lead to increased water temperatures which reduce dissolved oxygen levels and can stress dace and increase the competitive advantage for mosquitofish. Influxes of large amounts of cattle waste increases the amount of nutrients in the water and further reduces visibility which can impact the spawning of LVSD. Higher levels of nutrients result in higher biological oxygen demand and reduce the dissolved oxygen levels in the water. Increased bacterial levels may also reduce egg viability and increase the risk of infection (Pat Rakes, pers. comm.).

The Bureau of Land Management (BLM) manages the following 5 grazing allotments within the Long Valley Caldera: Hot Creek CA06018, Wilfred Creek CA06022, Tobacco Flat CA06045, Long Valley CA06044, and Casa Diablo CA06081(Bureau of Land Management, 2023).

Hot Creek allotment is approximately 25.1 km^2 (6,203 ac) of public land available for grazing (Bureau of Land Management, 2023). The majority of the allotment is National Forest System land and most of the remaining acreage belongs to LADWP. Little Alkali site is located within this allotment (Table 4).

Long Valley allotment is approximately 1.2 km^2 (303 ac) available for grazing (Bureau of Land Management, 2023). From 1860 to 1956, this allotment included Bald Mountain, Chidago, Casa Diablo, Ford, Symons, and Round Mountain rangelands and was grazed by all classes of livestock. In 1956, the allotment was designated for cattle and horses, and the private lands were fenced separate making the boundary what it is currently (U.S. Forest Service, 2009, p. 5). Whitmore Marsh is located within this allotment (Table 4).

Tobacco Flat is approximately 6.5 km^2 (1,603 ac) of National Forest System lands with about 4.9 km^2 (1,200 ac) suitable for livestock grazing. The allotment was designated for cattle and horses until 1979 when a portion of the allotment was overlapped by the McGee Creek Sheep and Goat Allotment (U.S. Forest Service, 2009, p. 6).

Casa Diablo is a sheep and goat allotment established in 1923. It is comprised of approximately 200.8 km^2 (49,613 ac) with the majority of acreage being suitable grazing habitat (U.S. Forest Service, 2009, p. 4).

Wilfred Creek allotment is comprised of 21.2 km^2 (5,229 ac) and is currently grazed by cattle. Thermal Spring, Unnamed Spring, and Sulfur Spring are located within this allotment.

Grazing has been occurring in Long Valley since before the discovery of LVSD and historical grazing has altered stream habitat and riparian areas. In 1989, Sada, (1989, p. 10) documented that the habitat at Whitmore Marsh and Little Alkali was heavily impacted by cattle grazing, however both populations appeared to be stable at the time (Sada, 1989, p. 12). While this suggests that grazing appears to impact habitat, it may have less immediate impact to individuals and the local population, relative to other threats that have caused extirpations, there is no additional information available to quantify the specific effects on LVSD populations.

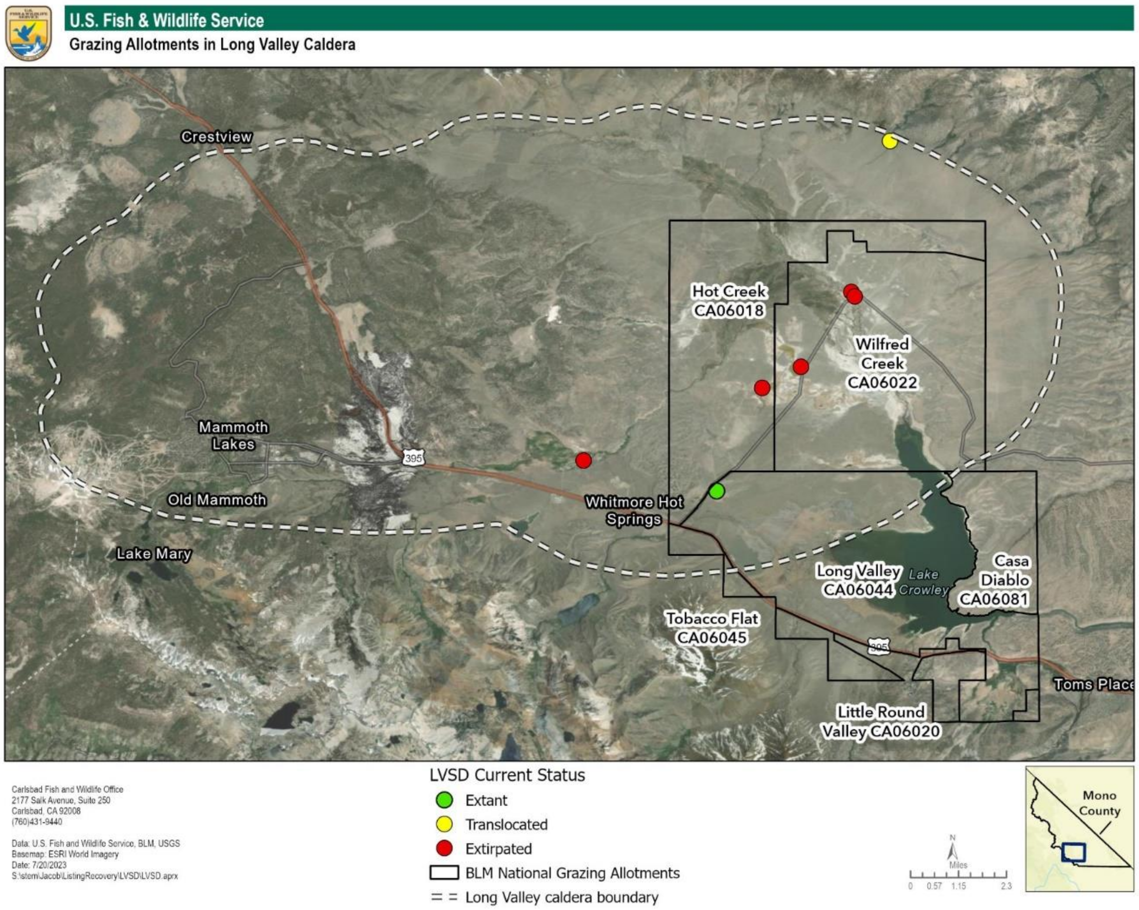

Figure 4-4. Grazing allotments in Long Valley Caldera.

4.5.4 Recreation

Recreation activities may impact water quality, substrate and vegetation, and free-flowing water. The spring source that supplies Whitmore Hot Spring marsh also feeds a public swimming pool (Figure 4-5). Historically, the pool has discharged lightly chlorinated water into the marsh from May to September (Cox, 2023, p. 1). The effluent from the spring is undiminished by pool operations and maintained sufficient flows to support this dace population, however a spill of over-chlorinated water could extirpate the population (Moyle et al. 2015, p. 4). Chlorine is toxic to aquatic life and acute toxicity of chlorine affects species differently among individuals of different sizes and life history stages. Continuous exposure of residual chlorine compounds may affect development, reproduction, and growth of fish, even in low concentrations. Limited data suggests that concentrations greater than 0.008 mg HOC1/l could be harmful or lethal to fish within four days (European Inland Fisheries Advisory Commission, 1973, p. VI). Blackside dace (*Phoxinus cumberlandensis*) with a mean weight of 0.02 gram had a lethal concentration 50 (LC50), known as the amount of substance needed to kill 50 percent of test animals during an observational period, of approximately 400 µg/l at 19.6 °C (67.3 °F). Larger dace with a mean weight of 0.33 gram had an LC50 of about 700 µg/l at 19.6 °C (67.3 °F) (Larson et al., 1978, p. 41). For comparison, the Centers for Disease Control and Prevention generally recommend a free chlorine concentration of at least 1,000 µg/l in swimming pools, depending on temperature and pH levels (CDC, 2022, entire). When exposed to nonlethal concentrations of chlorine, blackside dace swimming activity continuously declined and resting occurred well before “turnover,” or death (Larson et al., 1978, p. 64).

Figure 4-5. Aerial imagery of Whitmore Marsh, showing proximity to the public swimming pool.

4.5.5 Water Diversion

Individuals from Hot Creek disappeared shortly following the development of the CDFW owned facility, Hot Creek Trout Hatchery, and associated water diversions, in the 1960s. Surface water diversions have the potential to affect fish survival directly or indirectly. Water diversions reduce the amount of water available to stream resources and return the remaining water distant from the intake. Flow alterations directly impact fish by blocking migration routes, trapping fish in dewatered sections, and by disrupting breeding habits. Diversions indirectly affect fish by removing stream habitat, degrading water quality parameters, and introducing competing non-native species (American Fisheries Society, n.d., p. 2). The disappearance of LVSD shortly following the development of the hatchery indicates that the diversions may have had an impact on LVSD habitat in Hot Creek and adjacent springs (Sada, 1989, p. 3)

4.5.6 Geothermal Development

Prior to geothermal development of a particular area, the flow path of water underneath the land surface is usually not known with sufficient detail to understand and prevent surface impacts that may be caused by such development (Sorey, 2000, p. 705). Changes associated with surface expression of thermal waters from geothermal production are common and are expected. Typical changes seen in geothermal fields across the globe include, but are not limited to, changes in water temperature, flow, and quality(Bonte et al., 2011, pp. 4–8; Chen et al., 2020, pp. 2–6; Kaya et al., 2011, pp. 55–64; Sorey, 2000, entire), which are all needs of LVSD.

In an effort to minimize changes in water temperature, quantity and quality, and to maintain pressure of the geothermal reservoir, geothermal fluids may be reinjected into the ground, as part of a “binary cycle” production process. Binary cycle power plants use the heat from geothermal fluids pumped above ground from the geothermal reservoir, which heats a secondary fluid (e.g., butane) that generally has a much lower boiling point than water. This process is accomplished through a heat exchanger, and the secondary fluid is flashed into vapor by the heat from the geothermal fluid; the vapor drives the turbines to generate electricity. The geothermal fluid is then reinjected back into the ground in a process that is expected to reheat the used fluids and maintain local geothermal reservoir pressure (*Electricity Generation*, n.d., entire). This practice entails much trial and error in an attempt to equilibrate subsurface reservoir pressure and it can take several years to understand how a new geothermal field will react to production and reinjection wells (Kaya et al., 2011, pp. 55–64).

Changes in surface-expressed water temperature and flow from geothermal production areas have been documented within the Long Valley Caldera at historical localities of LVSD and near the remaining historical population (Sorey, 2000, entire). Geothermal pumping between 1985–1998 at Casa Diablo Geothermal Plant, part of Ormat Technologies, Inc., Mammoth Geothermal Complex, resulted in flow ceasing at Colton Spring and declines in water level at Hot Bubbling Pool (Sorey, 2000, p. 706), which are located roughly 6.4 km (4 mi) and 4.8 km (3 mi) from Whitmore Marsh, respectively. Based on historical operations of the Casa Diablo geothermal site and surface water monitoring at Whitmore Marsh, this remaining historical population of LVSD is outside of the range where detectable changes in surface features have occurred. However, the Casa Diablo-IV power plant put into service in 2022 will nearly double the capacity of the geothermal facility, and future impacts may extend further into LVSD’s historical range.

On February 17, 2010, ORNI 50 LLC, a wholly owned subsidiary of Ormat Nevada Inc. submitted an application to the BLM to construct, operate, and following the expected 30-year useful life, decommission the Casa Diablo-IV Project in Mono County, California. Since 2010, the Casa Diablo-IV Project constructed a new 30-Megawatt binary power plant, developed an expanded geothermal well field of up to 16 geothermal resource wells, constructed pipelines to bring the geothermal brine to the power plant and pipelines to take the cooled brine to injection wells, and installed an electric transmission line to interconnect to the Southern California Edison (SCE) Substation at Substation Road. This geothermal plant began production in 2022.

4.5.7 Climate Change

Changes in climate have already been observed in California where LVSD occur and are expected to continue. Current climate change forecasts for terrestrial areas in the Northern Hemisphere predict warmer air temperatures, more intense precipitation events (both drought and flooding), and increased summer continental drying by the year 2100 (IPCC, 2014, entire). Little is known about how and when spring flows may be affected by changes in climate. Direct hydrological connections have not been established in most cases, and for many areas, these connections remain difficult to make.

Increased variations in temperature and precipitation in the range of LVSD may result in effects on the life history of the species, especially considering reproductive behavior of speckled dace in the Chiricahua Mountains, Arizona, appears to be strongly influenced by flood events and prolonged periods of drought (Mueller, 1984, p. 355). Thermal springs that comprise a major part of Long Valley are fed by aquifers dependent on snowmelt for recharge. LVSD are currently found in a hot spring-fed marsh and a creek, with temperatures that stay below 29 ℃ (84.2 °F). They are capable of withstanding elevated water temperatures (Moyle et al., 2015, p. 11), but the lethal upper temperature limit is unknown. Fish are generally more stressed at the upper extremes of their temperature range and though they may be able to survive, elevated temperature is an example of a stressor that may affect them through reduced disease resistance (Moyle 2015, p.11). Average annual temperatures have increased almost 1.1 ℃ (1.9 °F) over the last century (Garfin et al., 2014, p. 464), and an additional increase of 1.9 to 5.3 ℃ (3.5 to 9.5 °F) is predicted to occur by the year 2100 (Walsh et al., 2014, p. 23). In recent decades, reductions in precipitation and winter snowpack have been observed, and this pattern is expected to continue (Garfin et al., 2014, . 465; Figure 4.8). The frequency and intensity of these reductions have increased on a global scale (IPCC, 2014, p. 77), and climate change is projected to reduce surface and groundwater resources in most subtropical deserts (IPCC, 2014, p. 14).

Climate change is also predicted to increase fire frequency and severity. Whitmore Marsh, O’Harrel Canyon Creek, and historical sites Little Alkali and Hot Creek Springs are located within a moderate fire hazard severity zone. Historical sites Unnamed Spring and Sulfur Spring are located within a high fire hazard severity zone. In southern California mountains, debris flows can occur in both burned and unburned terrain. Wildfires greatly increase the likelihood of debris flows within the burned area by removing vegetation and temporarily elevating soil hydrophobicity (Staley et al., 2017, entire). Excess overland flow from intense precipitation events caused by climate change may exacerbate the effects of debris flows in areas affected by wildfire. When debris flows occur, they can cause significant erosion to hillslopes and channels, resulting in large amounts of sediment being carried downstream. This excessive sediment can have profound negative impacts on local wildlife, including fish such as LVSD. Wildfire also eliminates vegetation that shades the water and moderates water temperature and may further impact water transport, sediment transport, water quality, and flow regime. Burned uplands in the watersheds may affect LVSD habitat by producing silt-and-ash-laden runoff that can fill in pools and significantly increase turbidity of rivers. Large wildfires have caused local extirpations in isolated dace occurrences (Expert Working Group, 2023, p. 23). Wildfire may impact LVSD throughout its remaining range, although the location, frequency, and size of these events cannot be precisely predicted

Increased frequency of snow drought induced by climate change may also affect the flow rates and temperatures of hydrologic features inhabited by LVSD (Hatchett & McEvoy, 2018, pp. 11–12). Monitoring of the springs at Hot Creek Fish Hatchery showed temperature declines of approximately 2.2 °C (4 °F) in 1995 related to high winter precipitation and greater snow melt resulting in colder groundwater flowing into the springs in the summer.

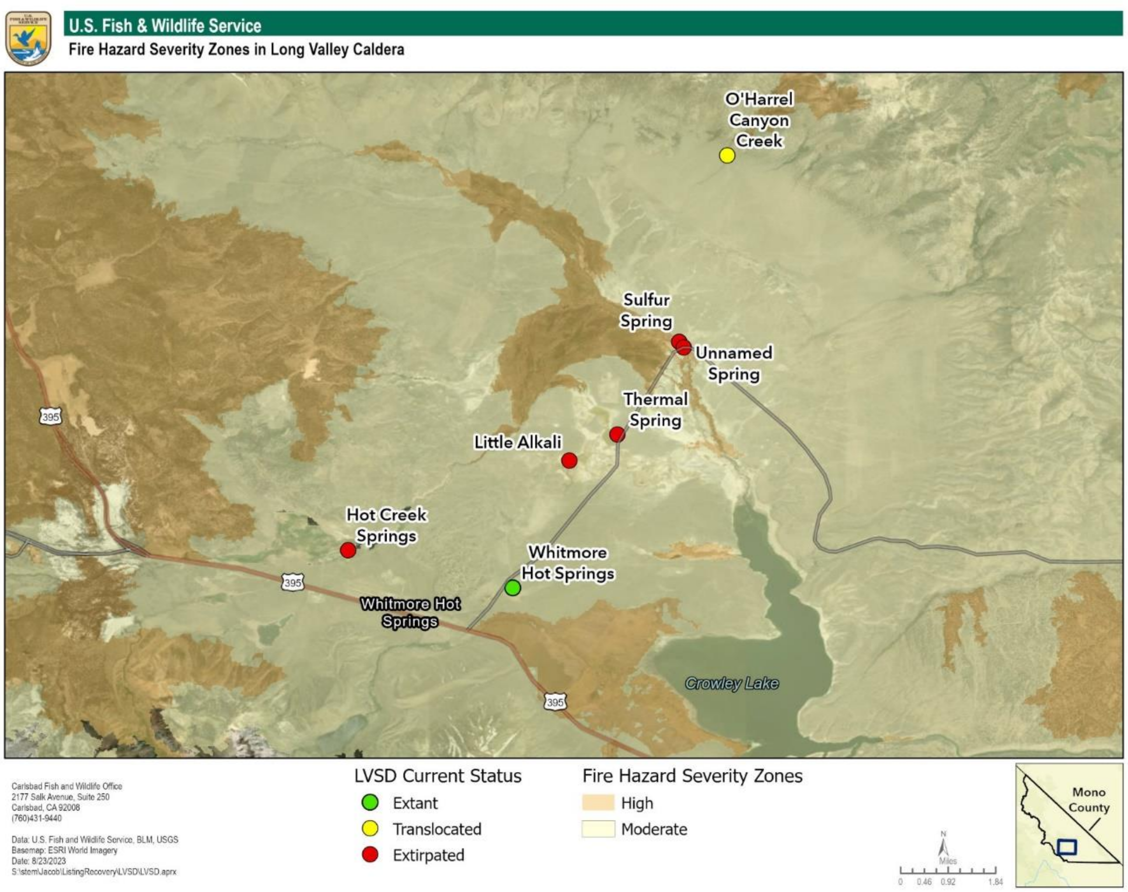

Figure 4-6. Map depicting CAL Fire's Fire Hazard Severity Zones in Long Valley Caldera with known LVSD occurrences.

4.5.9 Small Population Effects

LVSD mostly occur in small, isolated populations throughout their range. These small, isolated populations are vulnerable to a number of deleterious effects including: "(1) demographic fluctuation due to random variation in birth and death rates and sex ratio, (2) environmental fluctuation in resource or habitat availability, predation, competitive interactions and catastrophes, (3) reduction in co-operative interactions and subsequent decline in fertility and survival (i.e., Allee effects), (4) inbreeding depression reducing reproductive fitness, and (5) loss of genetic diversity reducing the ability to evolve and cope with environmental change" (Traill et al., 2010, p. 29).

For example, small populations of LVSD are more vulnerable to extirpation during environmental fluctuation, such as flooding (that can physically wash dace away), fire (and its subsequent impacts on LVSD habitat and water quality), or sustained drought (that can result in the loss or reduction of surface flows and concomitant increases in water temperature). Habitat fragmentation has subjected the small populations to genetic isolation, reduced space for rearing and reproduction, reduced adaptive capabilities, and increased the likelihood of extinction. Isolation means that any remnant populations following these events are unlikely to benefit from demographic or genetic rescue, further elevating risks of inbreeding depression, loss of genetic diversity, and reductions in evolutionary potential that can contribute to population extirpation. These small population effects interact with other factors to pose a moderate threat across LVSD's current range. Thus, because LVSD currently occur in small, isolated populations, the magnitude of the threat posed by environmental stochasticity and inbreeding depression is elevated.

4.6 CONSERVATION MEASURES

Due to concerns over the future viability of the last remaining historical population of LVSD, CDFW staff deemed it necessary to establish a refuge population in a 12.2 x 12.2 m (40 x 40 ft) artificial pond at the WMRC outside of the native range (Cox, 2021, p. 1). This population was sourced from individuals at Whitmore Marsh and a previous refuge population known as Becky's Pond, also sourced from Whitmore Marsh, which has since been extirpated. The current estimated size of the WMRC refuge population is 2,161 (1,342–3,431) individuals and collected individuals ranged in size from 31-80 mm (Cox, 2021, pp. 2–3). Although the refuge population appears stable, CDFW recommends continued monitoring for disease that may have been present in source individuals from Whitmore Marsh and management of water quality and water levels to maintain this population. Monitoring the genetic health of the refuge population will also be important for understanding and managing its long-term viability.

The refuge population at WMRC represents a critical component of LVSD conservation and has already been used in translocation efforts. The population occurs within the northeast pond that possesses physical and hydrological attributes capable of supporting LVSD. The pond is fed by well water and is approximately 40 feet by 40 feet with a max depth of four feet. A spray nozzle maintains a continuous flow within the pond, which is drained via a standpipe in the center. The standpipe is backflushed yearly to prevent clogging. The pool is lined with hypalon™ to prevent cattail encroachment and used tires for fish cover and artificial spawning substrates were placed around the pond. The electrical conductivity is ~470 μS/cm which is sufficient to minimize osmoregulatory stress in Cyprinids. In 2022, CDFW staff introduced 407 individuals from WMRC into O'Harrel Canyon Creek (Cox, 2022, pp. 2–3). We are not aware of follow up monitoring and the chances of this population successfully establishing are unknown. Translocation efforts in many parts of LVSD's historical range will first require elimination of the threats that led to extirpation. For example, BLM and CDFW are cooperating to restore the unnamed spring tributary to Little Alkali Lake to expand the range of LVSD. Three fish barriers have been constructed and staff are attempting to eradicate mosquitofish through mechanical removal and spring diversion under freezing temperatures (S. Parmenter, CDFW, pers. comm. 2014 in Moyle 2015).

Similar efforts to mitigate threats have also been initiated for the last remaining historical population. A public swimming pool operated by Mammoth Lakes historically discharged chlorinated water into Whitmore Marsh, possibly contributing to the population decline occurring around 2017 (Cox, 2023, p. 1). The town has since agreed to a management plan to limit the risk of introducing chlorinated water into the marsh in the future. A storage tank was constructed in 2022 to store discharged pool water until it can be transported off site to a sewage treatment plant (Cox, 2023, p. 2). Because this strategy was implemented so recently, we are unable to speak to its effectiveness or quantify its effect on the species, although it will likely reduce the risk of future catastrophic events if the population is able to rebound from the previous decline.

Table 55: Summary of current threats to LVSD and its habitat. Scope (localized/range-wide) is in reference to the historical range.

Threat	Need Affected	Scope	Likelihood	Level of Impact	Causal Certainty (1-5)	Risk Level
Introduced Species	Food resources, Direct Mortality	Range-wide	Known or very likely to occur	Extreme	5	High (5)
Disease	Direct Mortality	Localized (Whitmore)	Known or very likely to occur	Medium	2	Medium (2)
Grazing	Substrate, Vegetation Cover, Water Quality	Range-wide	Known or very likely to occur	Medium	3	Medium (3)
Water Diversion	Food Resources, Water Availability, Water Quality, Direct Mortality	Localized (Hot Creek)	Known or very likely to occur	High	5	High (5)
Recreation	Substrate/Vegetation Cover, Water Availability, Water Quality	Localized (Whitmore)	Known or very likely to occur	High	4	High (4)
Geothermal Development	Water Availability, Water Quality	Range-wide	Remote	High	4	Low (4)

Threat	Need Affected	Scope	Likelihood	Level of Impact	Causal Certainty (1-5)	Risk Level
Climate Change	Water Availability, Water Quality	Range-wide	Known or very likely to occur	Medium	2	Medium (2)
Small Population Effects	Direct Mortality	Localized (Whitmore)	Known or very likely to occur	Extreme	4	High (4)

4.7 SUMMARY OF CURRENT CONDITIONS

The LVSD is a narrow endemic subspecies known from seven historical sites within the Long Valley Caldera in Mono County, California. Six out of the seven populations have been extirpated due primarily to the effects of nonnative species, water diversion, and degraded water quality from recreational activity and cattle grazing. Only one historical population remains in a roughly 4,000–8,000 m^2 (1-2 ac) spring-fed marsh and the subspecies has lost roughly 83–99 percent of its historical extent of occurrence. Such a dramatic reduction in range for a narrowly distributed species suggests that the LVSD currently has little redundancy to withstand the impact of the threats present within the Long Valley Caldera, which have led to extirpations of six historical populations. A recently translocated population is roughly 14 km (8.7 mi) away and does not share a permanent hydrologic connection (Cox, 2022, p. 2), limiting opportunities for dispersal in the face of stochastic events or changes in habitat quality. The isolated nature of the two remaining populations also limits genetic connectivity and raises concerns over the future adaptive capacity of the subspecies.

The available data suggest that the remaining historical population has recently experienced a decline and may be persisting at extremely low densities relative to previous surveys. Although speckled dace populations can naturally experience large fluctuations in response to environmental variation, the declines observed at Whitmore Marsh are concerning because multiple threats exist on the landscape that are not part of the historical environmental variation experienced by this population. At least three threats can be characterized as currently posing a high risk to persistence, including impacts associated with introduction of nonnative species, a recreational swimming pool, and low population numbers (Table 5). Several threats with less severe impacts are also present, including grazing and disease. Reduced abundance at this site may limit the ability of the population to withstand the synergistic effects of multiple threats and is a concern for the viability of the population and the subspecies.

Any decrease in the resiliency of the Whitmore Marsh population places a large burden on the refuge population at WMRC for maintaining the viability of the species. Although the captive population appears to be currently stable, other populations in private/artificial ponds have failed (Cox, 2022, p. 2) and maintaining the refuge population in more than one pond would decrease the chances of a catastrophic event. The recently translocated population at O'Harrel Canyon Creek currently has an unknown chance of successfully establishing. While translocation will likely be a key conservation action for this species, evidence of successful reproduction would be required to meaningfully increase resiliency or redundancy across the range.

CHAPTER 5 - FUTURE CONDITIONS

Scenario planning is a comprehensive exercise that involves the development of scenarios that capture a range of plausible future conditions, which is then followed by an assessment of the potential effects of those scenarios on a given species. Scenarios are not projections or forecasts of what will happen in the future for a species but are projections or explorations into the range of conditions that may exist based on current information (Figure 5-1). The scenarios are intended to provide the "upper" and "lower" bounds of plausible conditions (Figure 5-2), outline uncertainties, and provide decision makers with a means for managing risk in current and future decisions.

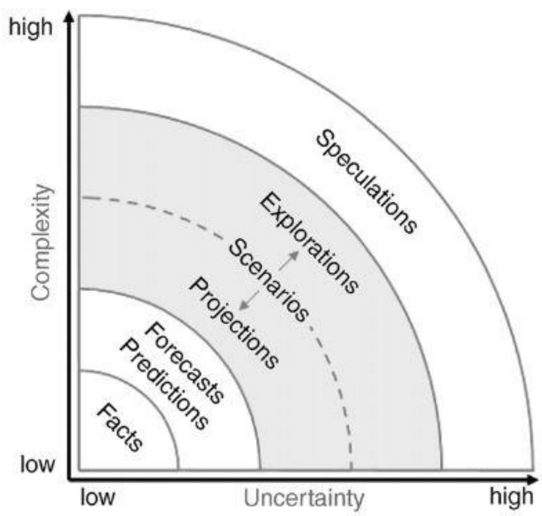

Figure 5-1. The levels of uncertainty and complexity in situations for which scenarios can be useful in considering future possibilities (adapted from Roland et al. 2014).

Exploring a range of plausible future scenarios allows us to create a risk profile for LVSD and its viability into the future. While we do not expect every condition for each scenario to be fully realized, we are using these scenarios as examples for the range of possibilities to aid decision making. Because of the small spatial scale, few extant sites, and localized nature of the threats, we developed qualitative future scenarios. We first describe how the threats may change in the future, then summarize these changes in terms of the likelihood and level of impact using the same methods described in section 4.5. Finally, we evaluate how these changes may impact each population and the viability of LVSD. Our future projections consider changes over the next 25 years approximately. This timeframe was selected because it covers multiple generations of LVSD and because several threats currently pose a high risk to the species, such that longer-term projections may not provide further insight into the decision. We used the best available science to project trends in future threats facing LVSD. Data availability varies across the threats. Where data on future threats or trends are not available, we look to past threats and their trends. We evaluate if it is reasonable to assume these trends will continue into future and to what degree.

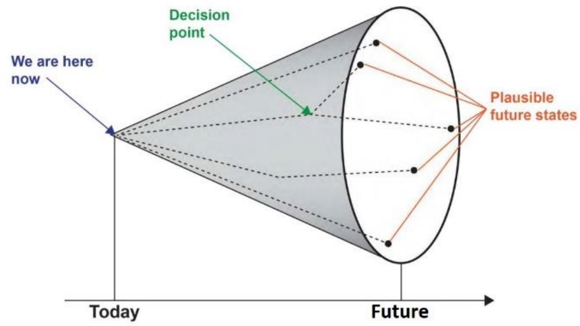

Figure 5-2. Conceptual diagram of the broadening range of plausible alternative futures as one moves farther away from the present and different events and decision points shift trajectories. (Roland et al. 2012, adapted from Reclamation 2012).

5.1 FUTURE SCENARIO CONSIDERATIONS

Several threats are expected to continue at levels similar to their current condition (Table 6), with the risk to LVSD viability accumulating over time without additional conservation efforts. For example, the rate of spread of nonnative species within Long Valley will likely remain similar over the near term; however, the chances that individuals arrive at Whitmore Marsh increases the farther out you consider. Exclusion barriers and removal may reduce the likelihood of nonnative colonization in some locations, but these conservation actions have not occurred at Whitmore Marsh or O'Harrel Canyon Creek. Disease, grazing, and small population size have already been documented in Whitmore Marsh and their effects on LVSD are expected to continue, although the exact magnitude of these effects on the population are unknown (Table 6). The direct effects of trout hatcheries have occurred mostly in populations that are currently extirpated and their influence on the future viability of LVSD is expected to be largely related to the risk of introduced species at other sites.

Table 6. Plausible changes in each threat within the next approximately 25 years. Upper and lower plausible limits are defined relative to the effects on the species, with the upper limit being threat levels most favorable to species viability.

Threat	Expected Change	Lower Plausible Limit	Upper Plausible Limit
Introduced Species	Continue	Current rate of nonnative spread continues	Conservation actions reduce the likelihood of nonnative colonization in some locations
Disease	Continue	Effects of disease remain similar	Effects of disease remain similar
Grazing	Continue	Effects of grazing remain similar	Effects of grazing remain similar

Threat	Expected Change	Lower Plausible Limit	Upper Plausible Limit
Water Diversion	Continue	Current trout hatchery remains	Current trout hatchery remains
Recreation	Decrease	Risk of chlorine contamination from public pool remains at current levels	Recently implemented mitigation measures reduce the risk of chlorine spills
Geothermal Development	Increase	Increased production causes impact zone to expand	Current impact zone does not expand
Climate Change	Increase	SSP5-8.5 or RCP 8.5	SSP2-4.5 or RCP 4.5
Small Population Effects	Continue	Population continues to decline until extirpated	Population rebounds to carrying capacity of the habitat

The effects of recreation on the Whitmore Marsh population are expected to decrease in the future (Table 6). The public swimming pool operated by the Town of Mammoth Lakes has initiated a management plan to limit the risk of introducing chlorinated water into the marsh in the future. A storage tank was constructed in 2022 to store discharged pool water until it can be transported off site to a sewage treatment plant (Cox, 2023, p. 2). Because this strategy was implemented so recently, we are unable to quantify its effect on the species, although it will likely reduce the risk of future catastrophic events if the population is able to rebound (Table 7). We therefore change the likelihood from known-to-occur to unlikely-to-occur in the future, reducing the overall risk level from high to medium (Table 7). It is unknown whether these changes in water management at the pool will impact water availability in the marsh.

The effects of geothermal development on surface waters have not appeared to be a major influence on LVSD historically, however, the Casa Diablo-IV power plant brought online in 2022 introduces a new 30-Megawatt binary power plant with an expanded geothermal well field of up to 16 geothermal resource wells. With the increase in production, it is plausible that future impacts may extend further into LVSD's range than they have historically, and the likelihood of impact is expected to increase. Past effects from Casa Diablo resulted in flow ceasing at Colton Spring and declines in water level at Hot Bubbling Pool (Sorey, 2000, p. 706), which are located roughly 4 and 3 miles from Whitmore Marsh, respectively. Because there may be some capacity to detect changes at these localities before the impacts reach Whitmore Marsh, we increased the likelihood of occurring from remote to unlikely (Table 7). This results in the overall risk level from geothermal increasing from low to medium (Table 7).

Changes in climate have already been observed in this region and are expected to increase in the future. The hydrological cycle is expected to intensify with climate change, leading to an increase in intensity of extreme precipitation events and extreme drought conditions. Increasing air temperatures and decreasing precipitation levels in the summer, predicted to occur as a result of climate change, are likely to impact the availability of suitable cooler-water habitat during the summer and fall months, when dace are already most vulnerable to low flows and high water temperatures. The combination of elevated water temperatures and higher chances of drought throughout the remaining range of LVSD makes climate change a significant threat that is modeled to increase into the future. Due to the projected increase in the level of impact, the overall risk level from climate change is expected to increase from medium to high (Table 7).

Additionally, years of extreme precipitation and high snowpack may prevent LVSD from dispersing to cooler waters in the summer and restrict them to warmer waters near springheads. A die-off of LVSD at Whitmore Marsh in the spring of 2017 occurred after an unusually large winter snowpack. LVSD most likely avoided dispersing into lower colder reaches of the marsh, creating more restricted habitat and causing the population to become more susceptible to stochastic events.

Table 7. Summary of future threats to LVSD and its habitat in the next approximately 25 years. Scope (localized/range-wide) is in reference to the historical range.

Threat	Need Affected	Scope	Likelihood	Level of Impact	Causal Certainty (1-5)	Risk Level
Introduced Species	Food resources, Direct Mortality	Range-wide	Known or very likely to occur	Extreme	5	High (5)
Disease	Direct Mortality	Localized (Whitmore)	Known or very likely to occur	Medium	2	Medium (2)
Grazing	Substrate, Vegetation Cover, Water Quality	Range-wide	Known or very likely to occur	Medium	3	Medium (3)
Trout Hatcheries	Food Resources, Water Availability, Water Quality, Direct Mortality	Localized (Hot Creek)	Known or very likely to occur	Extreme	5	High (5)
Recreation	Substrate/Vegetation Cover, Water	Localized (Whitmore)	Unlikely	High	4	Medium (4)

Threat	Need Affected	Scope	Likelihood	Level of Impact	Causal Certainty (1-5)	Risk Level
	Availability, Water Quality					
Geothermal Development	Water Availability, Water Quality	Range-wide	Unlikely	High	4	Medium (4)
Climate Change	Water Availability, Water Quality	Range-wide	Known or very likely to occur	High	2	High (2)
Small Population Effects	Direct Mortality	Localized (Whitmore)	Known or very likely to occur	Extreme	4	High (4)

5.2 LOWER PLAUSIBLE LIMIT SCENARIO

To develop future scenarios, we considered the plausible range of values for each threat (Table 6), as well as the outcome of the translocation at O'Harrel Canyon Creek (i.e., successful or unsuccessful). Given the independent nature of the threats, it seems unlikely that the lower limit of all threats would happen simultaneously. However, the addition of even one high impact threat, such as nonnative species, on top of the ongoing effects of disease, grazing, and recreation would likely lead to extirpation of the Whitmore Marsh population. We therefore define the lower plausible limit scenario to be if any of the extreme or high impact threats occurred at Whitmore Marsh in addition to the translocated population at O'Harrel Canyon Creek failing to establish.

Under this scenario, both remaining populations within the historical range would become extirpated. The only extant population would remain in an artificial pond at the WMRC outside of the historical range of the species. The future viability of LVSD would be entirely dependent on maintaining this refuge population and on reintroduction efforts.

5.3 UPPER PLAUSIBLE LIMIT SCENARIO

The upper plausible limit scenario is largely similar to the current condition of the species, with the exception of reduced risk from chlorine contamination, a rebound of the abundance at Whitmore Marsh, and increased risk of effects from climate change and geothermal development. In addition, this scenario assumes that the translocation at O'Harrel Canyon Creek is successful over the short term.

This scenario results in two extant populations within the historical range of LVSD. Although there would be two populations with higher abundance compared to current condition, they remain hydrologically disconnected and many of the same threats would still be present on the landscape. For example, each population would be at high risk from introduced species, in addition to several other ongoing threats presenting a medium risk (Table 7). Given the increased effects of climate change in the future, there is also an increased risk of synergistic effects between climate-driven habitat availability (i.e., summer droughts or high winter snowpack) and other influences such as recreation, grazing, or geothermal development. These conditions could plausibly lead to future events similar to the conditions that caused the recent decline in the Whitmore Marsh population.

5.4 SUMMARY OF FUTURE CONDITIONS

Under all plausible future scenarios, LVSD will be extirpated in at least six of seven historical populations. Under the lower plausible scenario, both remaining populations within the historical range would become extirpated. The only extant population would remain in an artificial pond at the WMRC outside of the historical range of the species. The future viability of LVSD would be entirely dependent on maintaining this refuge population and on reintroduction efforts. Under the upper plausible scenario, the two current populations within the historical range of LVSD remain extant. Although these populations may have higher abundance compared to current condition under this scenario, they remain hydrologically disconnected and many of the same threats would still be present on the landscape.

Two threats can be characterized as posing a higher risk to persistence of LVSD in the future, including effects associated with climate change and geothermal energy development. Several threats are expected to continue at similar rates, including grazing, disease, and introduced species. Only the risk of chlorine contamination from a recreational swimming pool is expected to decrease. The increase in some threats is particularly concerning given that the continued risk of introduced species alone could be catastrophic for the remaining populations. Potential synergistic effects between the ongoing and increasing threats suggests that the viability of LVSD is expected to decrease in the future relative to current condition. These results suggest that the future viability of LVSD will depend heavily on human intervention through maintenance of a refuge population, reintroductions, translocations to new sites within the historical range, and conservation efforts to reduce the risk of multiple threats present on the landscape. There is a high risk that both populations within the historical range of LVSD could become extirpated within the next 25 years, making the future viability of LVSD entirely dependent on reintroduction efforts from the refuge population at WMRC. Such a dramatic reduction in range for a narrowly distributed species suggests that LVSD would have little redundancy to withstand the impact of the threats present within the Long Valley Caldera, which have led to extirpations in all other populations of the subspecies. The disconnected nature of the remaining populations limits opportunities for dispersal in the face of stochastic events or changes in habitat quality and raises concerns over the future adaptive capacity of the subspecies due to limited genetic connectivity.

CHAPTER 6 – STATUS ASSESSMENT SUMMARY

We used the best available scientific and commercial information to evaluate the status of the LVSD. Our results described the range of plausible conditions that LVSD may experience in the next 25 years. Despite the qualitative nature of the available data, the small occupied area, isolated single natural population, and available surveys all suggest that LVSD have experienced large declines in resiliency, redundancy, and representation. The best available information suggests that the threats discussed in this SSA Report are already occurring and may occur with similar or increased intensity in the future. Despite limited species-specific information on how habitat changes influence the species, several threats have led to extirpations of historical LVSD populations and reductions in the abundance of the current extant population. Concern over these threats led CDFW staff to establish a refuge population in an artificial pond as a source for reintroduction efforts. Because most of these threats have not been removed from the landscape, we have high confidence that they continue to represent a high risk to the viability of LVSD.

REFERENCES CITED

American Fisheries Society. (n.d.). *AFS Policy Statement #9* (p. 5). American Fisheries Society.

American Fisheries Society (AFS). (2015). *AFS Policy Statement #23 The Effects of Livestock Grazing on Riparian and Stream Ecosystems*.

Baltz, D. M., Moyle, P. B., & Knight, N. J. (1982). Competitive Interactions Between Benthic Stream Fishes, Riffle Sculpin, Cottus gulosus, and Speckled Dace, Rhinichthys osculus. *Canadian Journal of Fisheries and Aquatic Sciences*, *39*(11), 1502–1511. https://doi.org/10.1139/f82-202

Bogan, M., Zugmeyer, C., & Parmenter, S. (2002). *2002 Monitoring of Sensitive Aquatic Animals in the Owens Basin, Inyo and Mono Counties, California* (p. 97). California Department of Fish and Game.

Bonte, M., Stuyfzand, P. J., Hulsmann, A., & Van Beelen, P. (2011). Underground Thermal Energy Storage: Environmental Risks and Policy Developments in the Netherlands and European Union. *Ecology and Society*, *16*(1). https://www.jstor.org/stable/26268838

Bureau of Land Management. (2023). *BLM Reporting Application*. https://reports.blm.gov/report/RAS/33/Allotment-Information

Bureau of Land Management (BLM), United States Forest Service (USFS), & Great Basin Unified Air Pollution Control District. (2013). *Casa Diablo IV Geothermal Development Project Final Joint Environmental Impact Statement and Environmental Impact Report* (1).

Carpenter, N., & Herrmann, K. K. (2020). Parasitism in Gambusia affinis: Fitness Effects in an Incipient Matrotroph. *Journal of Parasitology*, *106*(2), 268–275. https://doi.org/10.1645/20-7

Center for Disease Control and Prevention (CDC). (2022). *Water Treatment and Testing*. https://www.cdc.gov/healthywater/swimming/residential/disinfection-testing.html

Chen, S., Zhang, Q., Andrews-Speed, P., & Mclellan, B. (2020). Quantitative assessment of the environmental risks of geothermal energy: A review. *Journal of Environmental Management*, *276*, 111287. https://doi.org/10.1016/j.jenvman.2020.111287

Cox, R. (2021). *Mark-Recapture of Long Valley Speckled Dace at White Mountain Research Station*. California Department of Fish and Wildlife.

Cox, R. (2022). *2022 Long Valley Speckled Dace (Rhinicthys osculus ssp.) Translocation to O'Harrel Canyon Creek* (p. 7). California Department of Fish and Wildlife.

Cox, R. (2023). *Long Valley Speckled Dace surveys at Whitmore Marsh 2021, 2022*. California Department of Fish and Wildlife.

Cucherousset, J., & Olden, J. D. (2011). Ecological Impacts of Nonnative Freshwater Fishes. *Fisheries*, *36*(5), 215–230. https://doi.org/10.1080/03632415.2011.574578

Etnier, D. A., & Starnes, W. C. (1993). *The Fishes of Tennessee*. University of Tennesee Press. https://fwslibrary.on.worldcat.org/search/detail/23144624?queryString=au%3A%28etnier%20and%20starnes%29&expandSearch=true&translateSearch=false&databaseList=638&clusterResults=true&groupVariantRecords=false

European Inland Fisheries Advisory Commission. (1973). *Water quality criteria for European freshwater fish: Report on chlorine and freshwater fish* (p. 23). Food and Agriculture Organization of the United Nations.

Expert Working Group. (2023). *Notes from Expert Input Workshop for Santa Ana Speckled Dace* (p. 35) [Meeting Notes]. U.S. Fish and Wildlife Service, Carlsbad Field Office.

Garfin, G., Franco, G., Blanco, H., Comrie, A., Gonzalez, P., Piechota, T., Smyth, R., Waskom, R., Melillo, J. M., Richmond, T. (T. C.), & Yohe, G. W. (2014). *Ch. 20: Southwest. Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program. https://doi.org/10.7930/J08G8HMN

Gaston, K. J., & Fuller, R. A. (2009). The sizes of species' geographic ranges. *Journal of Applied Ecology*, *46*(1), 1–9. https://doi.org/10.1111/j.1365-2664.2008.01596.x

Greene, L. (2006). *Long Valley Speckled Dace Update: Little Alkali Lake and Becky's Pond* [Personal communication].

Hatchett, B. J., & McEvoy, D. J. (2018). Exploring the Origins of Snow Drought in the Northern Sierra Nevada, California. *Earth Interactions*, *22*(2), 1–13. https://doi.org/10.1175/EI-D-17-0027.1

Hejna, M., Bogdanoff, A. K., Fusaro, A., Iott, S., & Sturtevant, R. (2023). *Asian tapeworm (Schyzocotyle acheilognathi)—Species Profile*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=2798

Hiss, J. M. (1984). *Diet of Age-0 Steelheaed Trout 1984*. Humboldt State University.

IPCC. (2014). *Climate change 2014: Impacts, adaptation, and vulnerability: Working Group II contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change* (C. B. Field, V. R. Barros, & Intergovernmental Panel on Climate Change, Eds.). Cambridge University Press.

John, K. R. (1963). The Effect of Torrential Rains on the Reproductive Cycle of Rhinichthys osculus in the Chiricahua Mountains, Arizona. *Copeia*, *1963*(2), 286–291. https://doi.org/10.2307/1441345

Johnson, J. R., Thomson, R. C., Micheletti, S. J., & Shaffer, H. B. (2011). The origin of tiger salamander (Ambystoma tigrinum) populations in California, Oregon, and Nevada: Introductions or relicts? *Conservation Genetics*, *12*(2), 355–370. https://doi.org/10.1007/s10592-010-0144-2

Jordan, D. S., & Evermann, B. W. (1896). *The Fishes North and Middle America: A Descriptive Catalogue of the Species of Fish-like Vertebrates Found in the Waters of North America, North of the Isthmus of Panama: Vol. v.1* (pp. 1–1310). Smithsonian Institution, United States National Museum. https://doi.org/10.5962/bhl.title.46755

Kaya, E., Zarrouk, S. J., & O'Sullivan, M. J. (2011). Reinjection in geothermal fields: A review of worldwide experience. *Renewable and Sustainable Energy Reviews*, *15*(1), 47–68. https://doi.org/10.1016/j.rser.2010.07.032

Larson, G., Warren, C., Hutchins, F., Lamperti, L., Schlesinger, D., & Seim, W. (1978). *Toxicity of Residual Chlorine Compounds to Aquatic Organisms* (Ecological Research Series, p. 105). Environmental Research Labratory Office of Research and Development.

Li, H. W. (1976). Feeding Ecology of the Pit Sculpin. *BULLETIN SOUTHERN CALIFORNIA ACADEMY OF SCIENCES*, *75*, 111–118.

Mills, M. D., Rader, R. B., & Belk, M. C. (2004). Complex interactions between native and invasive fish: The simultaneous effects of multiple negative interactions. *Oecologia*, *141*(4), 713–721. https://doi.org/10.1007/s00442-004-1695-z

Moyle, P. B. (2002). *Inland Fishes of California. Revised and Expanded Edition*. University of California Press.

Moyle, P. B., Buckmaster, N., & Su, Y. (2023). Taxonomy of the Speckled Dace Species Complex (Cypriniformes: Leuciscidae, Rhinichthys) in California, USA. *Zootaxa*, *5249*(5), 501–539. https://doi.org/10.11646/zootaxa.5249.5.1

Moyle, P. B., Kennedy, T., Kuda, D., & Martin, L. (1991). Fishes of Bly Tunnel, Lassen County, California. *GREAT BASIN NATURALIST*, *51*(No. 3).

Moyle, P. B., Quiñones, R. M., Katz, J. V., & Weaver, J. (2015). *FISH SPECIES OF SPECIAL CONCERN IN CALIFORNIA* (p. 25). Sacramento: California Department of Fish and Wildlife. www.wildlife.ca.gov

Mueller, G. A. (1984). Spawning by Rhinichthys osculus (Cyprinidae), in the San Francisco River, New Mexico. *The Southwestern Naturalist*, *29*(3), 354–356. https://doi.org/10.2307/3671369

Mussmann, S. M., Douglas, M. R., Oakey, D. D., & Douglas, M. E. (2020). Defining relictual biodiversity: Conservation units in speckled dace (Leuciscidae: *Rhinichthys osculus*) of the

Greater Death Valley ecosystem. *Ecology and Evolution*, *10*(19), 10798–10817. https://doi.org/10.1002/ece3.6736

Oakey, D. D., Douglas, M. E., & Douglas, M. R. (2004). Small Fish in a Large Landscape: Diversification of Rhinichthys osculus (Cyprinidae) in Western North America. *Copeia*, *2004*(2), 207–221. https://doi.org/10.1643/CG-02-264R1

Raissy, M., & Ansari, M. (2012). Parasites of Some Freshwater Fish from Armand River, Chaharmahal va Bakhtyari Province, Iran. *Iranian Journal of Parasitology*, *7*(1), 73–79.

Redford, K. H., Amato, G., Baillie, J., Beldomenico, P., Bennett, E. L., Clum, N., Cook, R., Fonseca, G., Hedges, S., Launay, F., Lieberman, S., Mace, G. M., Murayama, A., Putnam, A., Robinson, J. G., Rosenbaum, H., Sanderson, E. W., Stuart, S. N., Thomas, P., & Thorbjarnarson, J. (2011). What Does It Mean to Successfully Conserve a (Vertebrate) Species? *BioScience*, *61*(1), 39–48. https://doi.org/10.1525/bio.2011.61.1.9

Rehage, J. S., & Sih, A. (2004). Dispersal Behavior, Boldness, and the Link to Invasiveness: A Comparison of Four Gambusia Species. *Biological Invasions*, *6*(3), 379–391. https://doi.org/10.1023/B:BINV.0000034618.93140.a5

Sada, D. W. (1989). *STATUS AND DISTRIBUTION OF SPECKLED DACE (RHINICHTHYS OSCULUS) IN THE OWENS RIVER SYSTEM INYO AND MONO COUNTIES, CALIFORNIA* (Contract Report FG7343). California Department of Fish and Game.

Sada, D. W., Britten, H. B., & Brussard, P. F. (1995). Desert Aquatic Ecosystems and the Genetic and Morphological Diversity of Death Valley System Speckled Dace. *American Fisheries Society Symposium*, *17*, 350–359.

Shaffer, M. L., & Stein, B. A. (2000). Safeguarding our precious heritage. *In Precious Heritage. Oxford University Press.*

Smith, D. R., Allan, N. L., McGowan, C. P., Syzmanski, J. A., Oetker, S. R., & Bell, H. M. (2018). Development of a Species Status Assessment Process for Decisions under the U.S. Endangered Species Act. *Journal of Fish and Wildlife Management*, *9*(1), 302–320.

Smith, G., Chow, J., Unmack, P., Markle, D., & Dowling, T. (2017). Evolution of the Rhinichthys osculus complex (Telostei: Cyprinidae) in Western North America. *Miscellaneous Publications Museum of Zoology, University of Michigan*, *204*, 45.

Sorey, M. L. (2000). *Geothermal development and changes in surficial features: Examples from the western United States*. 705–711.

Staley, D. M., Negri, J. A., Kean, J. W., Laber, J. L., Tillery, A. C., & Youberg, A. M. (2017). Prediction of spatially explicit rainfall intensity–duration thresholds for post-fire debris-flow generation in the western United States. *Geomorphology*, *278*, 149–162. https://doi.org/10.1016/j.geomorph.2016.10.019

Stone, D. M., Van Haverbeke, D. R., Ward, D. L., & Hunt, T. A. (2007). DISPERSAL OF NONNATIVE FISHES AND PARASITES IN THE INTERMITTENT LITTLE COLORADO RIVER, ARIZONA. *The Southwestern Naturalist*, *52*(1), 130–137. https://doi.org/10.1894/0038-4909(2007)52[130:DONFAP]2.0.CO;2

Su, Y., Moyle, P. B., Campbell, M. A., Finger, A. J., O'Rourke, S. M., Baumsteiger, J., & Miller, M. R. (2021). *Population genomic analysis of the speckled dace species complex (* Rhinichthys osculus *) identifies three species-level lineages in California* [Preprint]. Genomics. https://doi.org/10.1101/2021.12.14.472667

Traill, L. W., Brook, B. W., Frankham, R. R., & Bradshaw, C. J. A. (2010). Pragmatic population viability targets in a rapidly changing world. *Biological Conservation*, *143*(1), 28–34. https://doi.org/10.1016/j.biocon.2009.09.001

U. S. Department of Energy (DOE). (n.d.). *Electricity Generation*. Energy.Gov. Retrieved July 26, 2023, from https://www.energy.gov/eere/geothermal/electricity-generation

U.S. Fish and Wildlife Service (Service). (2016). *USFWS Species Status Assessment Framework*. *Version 3.4 dated August 2016*, 21.

U.S. Fish and Wildlife Service (Service). (2021). *Endangered and Threatened Wildlife and Plants; 90 Day Findings for Five Species* (Federal Register, Vol. 86, No. 186; pp. 53937–53941). https://www.govinfo.gov/content/pkg/FR-2021-09-29/pdf/2021-20963.pdf

U.S. Forest Service. (2009). *Environmental Assessment for Crowley Lake Watershed Grazing Allotment Analysis*. United States Department of Agriculture Forest Service. http://inyo-monowater.org/wp-content/uploads/2011/09/Crowley_Lake_Watershed_GAA_EA_2009.pdf

U.S. Geological Survey. (n.d.). *Hydrothermal Monitoring at Long Valley Caldera | U.S. Geological Survey*. Retrieved July 7, 2023, from https://www.usgs.gov/volcanoes/long-valley-caldera/hydrothermal-monitoring-long-valley-caldera

U.S. Geological Survey (USGS). (2020). *A Review of Cattail (Typha) Invasion in North American Wetlands* (Fact Sheet).

Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., & Somerville, R. (2014). *Ch. 2: Our Changing Climate. Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program. https://doi.org/10.7930/J0KW5CXT

Wolf, S., Hartl, B., Carroll, C., Neel, M. C., & Greenwald, D. N. (2015). Beyond PVA: Why Recovery under the Endangered Species Act Is More than Population Viability. *BioScience, 65*(2), 200–207. https://doi.org/10.1093/biosci/biu218