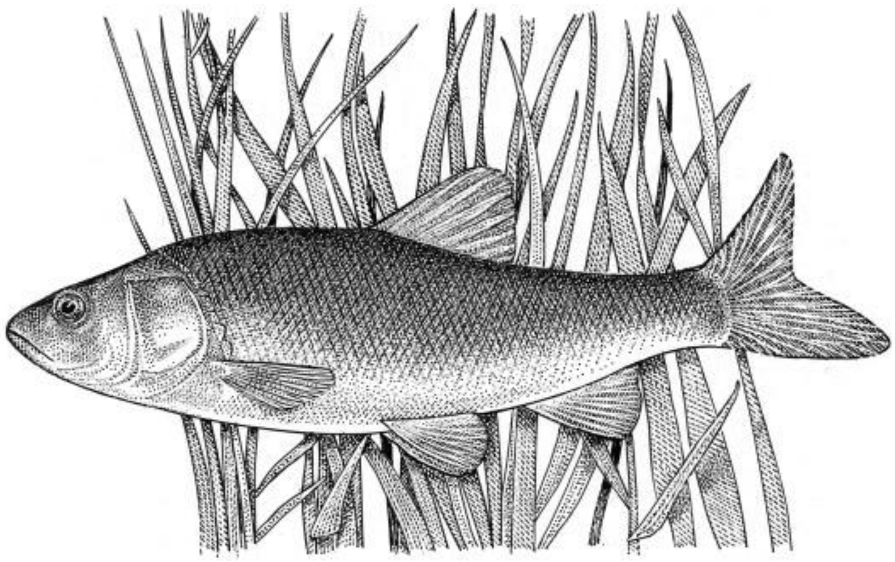
BEFORE THE SECRETARY OF INTERIOR

PETITION TO LIST THE FISH LAKE VALLEY TUI CHUB (*SIPHATELES BICOLOR SSP. 4*) AS A THREATENED OR ENDANGERED SPECIES UNDER THE ENDANGERED SPECIES ACT



Tui Chub, *Siphateles bicolor* (Avise, 2016, p. 49)

March 9, 2021
CENTER FOR BIOLOGICAL DIVERSITY

March 9, 2021

NOTICE OF PETITION

David Bernhardt, Secretary
U.S. Department of the Interior
1849 C Street NW
Washington, D.C. 20240
exsec@ios.doi.gov

Martha Williams
Principal Deputy Director
U.S. Fish and Wildlife Service
1849 C Street NW
Washington, D.C. 20240
Martha_Williams@fws.gov

Amy Lueders, Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, NM 87103-1306
RDLueders@fws.gov

Marc Jackson, Field Supervisor
U.S. Fish and Wildlife Service
Reno Fish and Wildlife Office
1340 Financial Blvd., Suite 234
Reno, Nevada 89502
marc_jackson@fws.gov

Dear Secretary Bernhardt,

Pursuant to Section 4(b) of the Endangered Species Act ("ESA"), 16 U.S.C. § 1533(b); section 553(e) of the Administrative Procedure Act (APA), 5 U.S.C. § 553(e); and 50 C.F.R. § 424.14(a), the Center for Biological Diversity, Krista Kemppinen, and Patrick Donnelly hereby petition the Secretary of the Interior, through the U.S. Fish and Wildlife Service ("FWS" or "Service"), to protect the Fish Lake Valley tui chub (*Siphateles bicolor ssp. 4)* as a threatened or endangered species.

The Fish Lake Valley tui chub is a recognized, but undescribed, subspecies of tui chub. Should the service not accept the tui chub as valid subspecies we request that it be considered as a distinct population as it is both discrete and significant.

FWS has jurisdiction over this petition. This petition sets in motion a specific process, placing definite response requirements on FWS. Specifically, the Service must issue an initial finding as to whether the petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). FWS must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." *Id.*

The Center for Biological Diversity ("Center") is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has more than 1.7 million members and online activists throughout the United States. The Center and its members are concerned with the conservation of endangered species and the effective implementation of the Endangered Species Act.

Dr. Krista Kemppinen
Staff Scientist
Center for Biological Diversity
PO Box 710
Tucson, AZ 85702
kkemppinen@biologicaldiversity.org

Patrick Donnelly
Nevada State Director
Center for Biological Diversity
2745 S. Durango Dr., B-107 Box 217
Las Vegas, NV 89048
pdonnelly@biologicaldiversity.org

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Fish Lake Valley tui chub (*Siphateles bicolor ssp. 4*) is a critically imperiled subspecies of tui chub found in Fish Lake Valley, Esmeralda County, Nevada. Its current distribution is limited to a single spring and outflow system, whereas it was previously known from several locations in the Valley. The loss of habitat within its former range is attributed to the alteration of habitats and groundwater development (Nevada Wildlife Action Plan 2012, p. 19). The last remaining population is immediately and severely threatened by over-appropriation of groundwater due to agriculture, potentially compounded by in-situ impacts from grazing and aquatic plant encroachment. The tui chub is also threatened by groundwater development from the geothermal energy sector, rapidly-developing and water-intensive lithium mining interests, and to a lesser extent, oil and gas prospecting. Other threats include invasive species, stochastic events and climate change. The Fish Lake Valley tui chub urgently needs the protections afforded by the ESA.

I. INTRODUCTION

Only five states have more endemic species than the 173 found in Nevada. However, 13 endemic species and subspecies have gone extinct. Almost 16% of Nevada's native species are in danger of extinction, many in critical danger. Fishes, amphibians and aquatic invertebrates constitute a large proportion of the imperiled taxa due to the mounting stress placed on fragile aquatic and wetland resources (Nevada Division of Natural Heritage, 2006, p. 3). Human activities such as the dewatering of streams through agricultural diversions, and the loss or reduction of spring habitats due to groundwater pumping, have led to recent contractions in the distribution and abundance of many endemic fishes in the Great Basin (Grover, 2019, p. 168).

The Fish Lake Valley tui chub is a narrowly endemic subspecies found in Fish Lake Valley, Nevada. It inhabits isolated marsh and spring outflow systems (Nevada Wildlife Action Plan 2012, p. 19). Unfortunately, this subspecies has been extirpated from all but one location within its historic range. Due to its small size, the extant population is particularly vulnerable to groundwater development and other threats such as grazing, encroachment by aquatic plants, invasive species, stochastic events and climate change. Without adequate protection, the Fish Lake Valley tui chub will join the more than dozen endemic species and subspecies that have gone extinct in Nevada.

II. NATURAL HISTORY

A. Description

Sigler and Sigler 1987 provide a description of the tui chub (*Siphateles bicolor*) (p. 166–170): the color of chubs is deep olive above, lighter on the sides, and white below. The upper parts and sides have a strong brassy reflection. Scales can vary in darkness and some are pinkish (p. 167). The color of the fins is olive and can have a strong red tint. The belly can be suffused with yellow. Others are more green than olive and a dark lateral color extending almost to the ventral surface can be seen in some. Lake dwellers have more pronounced colors. Young possess a dark stripe along the lateral line (p. 168). The tui chub's head is pointed and the mouth rather oblique. The eyes are large and the lateral line curves down slightly. The peritoneum is dusky and the intestine is approximately equal to the body length. There are 44 to 60 scales in the lateral series (Sigler and Sigler, 1987, p. 168).

The length of tui chubs is frequently between 9 and 11 inches, with individuals occasionally exceeding 16 inches (Sigler and Sigler, 1987, p. 168). However, according to California Fish Website (2020), tui chubs in large lakes commonly reach 11.8-15.7 inches SL, while chubs in ponds or springs rarely exceed 7.9 inches SL. Based on records shared by Eric Miskow, Nevada Division of Natural Heritage, in November 2020 for McNett Ranch (hereforth "NDNH McNett Ranch records") (p. 2), Fish Lake Valley tui chubs measured in 2005, and spanning several age classes, were mostly between 2.2 and 2.3 inches in size, with the largest fish measuring ca. 4.5 inches. In 2007, fish measured ranged between 0.7 and 4.6 inches.

B. Range

The tui chub (*Siphateles bicolor*) is native and widely distributed in the Lahontan Basin and Central Great Basin endorheic basins and in the Owens and Mojave rivers of California. It is highly successful over a range of different habitats and responds to these differences through changes in color, shape, size, and at times morphology. Adaptation is accomplished at the subspecies level. Nearly all isolated or partially isolated drainage systems in California, Nevada, and Oregon have at least one distinctive subspecies or form. Tui chubs should be preserved at the subspecies level as a representative of biological diversity (Sigler and Sigler, 1987, p. 167).

The Fish Lake Valley tui chub is a subspecies found in Fish Lake Valley, Esmeralda County, Nevada. The Fish Lake Valley hydrographic basin is within Esmeralda County, with portions extending into Inyo County, California (Figure 1; State Engineer, 2013, p. 3). This broad, deep alluvial Valley is 45 miles (75km) long and 1 to 5 miles (1.6-8.4 km) wide (Rafferty, 1988, p. 88).

The tui chub historically occurred at several locations in Fish Lake Valley but is now only found at a single spring system on a ranch variously referred to as McNett, Old McNett, Lower McNett, McNet or McNutt Ranch, in the northeast portion of the valley (Figure 1). It therefore has an extremely narrow distribution. As far as we understand, there are at least three small local springs tributary to another on the ranch. There is also a flowing well (Sada, 1981, p. 11; NDNH McNett Ranch records, p. 1). The spring where the last known population is found is impounded and described in DRI 2002 as being only a few feet across (Figure 2), although tui chubs have been found in the outflows.

One known former location outside of the ranch is a playa named Fish Lake, just east of Dyer, a town in the central portion of the Valley. The lake is fed by a spring, Fish Lake Spring (Figure 1). The system is now dry most of the time, however, particularly in the middle of summer during irrigation season. Bass and goldfish were introduced to the lake (pers. comm. Eric Miskow, Nevada Division of Natural Heritage, November and December 2020).

Another known former location is an impounded or formerly impounded spring source on private property, at the toe of the White Mountains on the west side of the Valley. The spring source is known as Sand Spring, between Trail Canyon and Sand Springs Canyon (pers. comm. Eric Miskow, Nevada Division of Natural Heritage, November 2020). The origin of the tui chubs is uncertain, however.

Heinrich and Sjoberg (1993, p. 11) also mention the presence of tui chubs in a pond near Lida, Nevada, that are suspected to be Fish Lake Valley tui chubs. However, as far as we are aware, their identity has not been confirmed. Regular surveys are needed to determine the tui chub's distribution (Nevada Wildlife Action Plan 2012, p. 19).

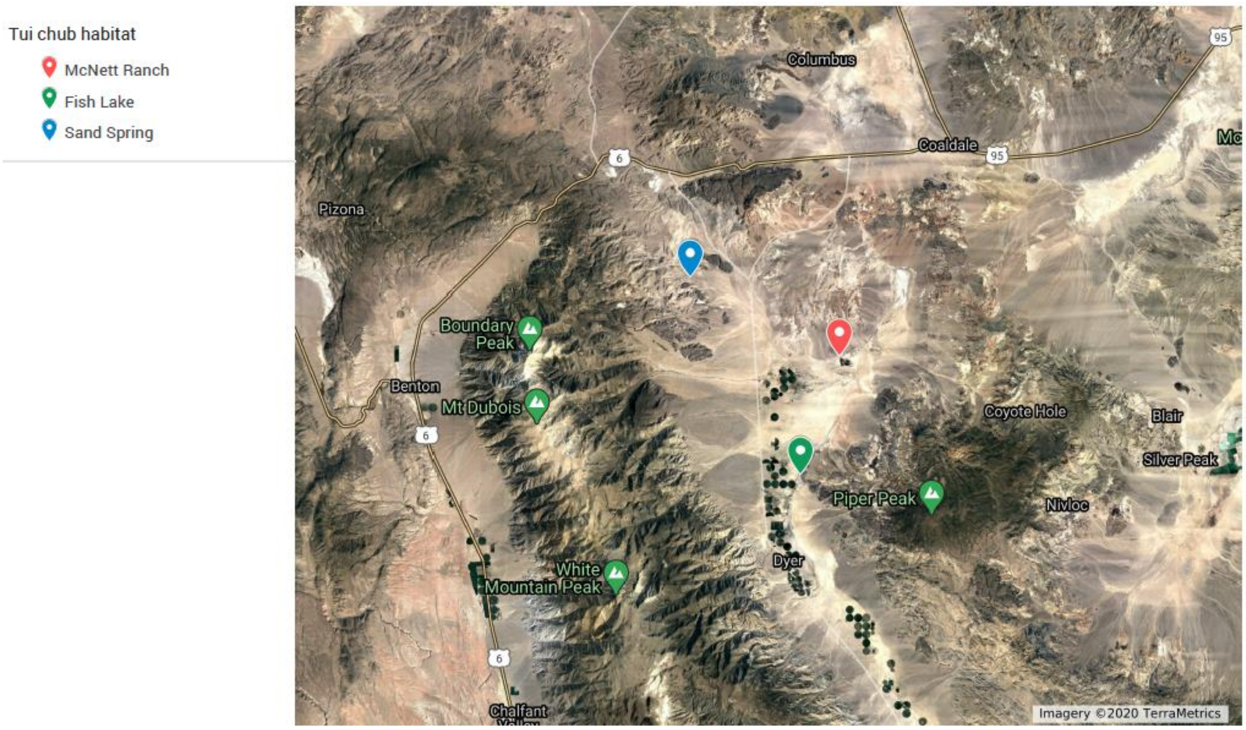


Figure 1. Location map for Fish Lake Valley and tui chub habitats.

Figure 2. McNett Ranch Spring (DRI 2002, p. 2).

C. Taxonomy

Although it has not been formally described, the Fish Lake Valley tui chub is recognized as a subspecies by the following entities and sources: Hubbs and Miller, 1948 (p. 44), Sada, 1981 (p. 11), USFWS, 1982 (p. 58455), 1985a (p. 37960), 1989 (p. 556), 1991 (p. 58815), Heinrich and Sjoberg, 1992 (p. 9), 1993 (p. 11), USFWS, 1994 (p. 58998), Sada and Vinyard, 2002 (p. 185), Nevada Division of Natural Heritage, 2006 (p. 23), Nevada Wildlife Action Plan, 2012 (p. 19), NatureServe, 2021a, Nevada Division of Natural Heritage, 2021a and Nevada Comprehensive Wildlife Conservation Strategy, date unknown (p. 201). Recent research suggests this recognition is warranted with genetic analysis distinguishing Fish Lake Valley tui chub from any other tui chub populations in the southwestern Great Basin based on F_{ST} values (Chen et al., *unpublished*, p. 2).

We caution against delays in protection driven by the lack of a full taxonomic description. The Mojave tui chub was listed as Endangered in 1970 even though it was not until 1997 that a genetics study by UC Davis confirmed it to be a distinct subspecies. It was then recommended that the chub continue to receive protection as an endangered, unique subspecies (California Department of Fish and Wildlife, 2020a). At the time of writing of the species' Recovery Plan, the Mohave tui chub had subspecific status, Gila bicolor mohavensis, but "no characters could be found to specifically separate it from all populations of G. bicolor in the Lahontan Basin" (USFWS, 1984, p. 2). Similarly, both the Hutton tui chub (*Gila bicolor* ssp.) and Foskett speckled dace (*Rhinichthys osculus* ssp.) were determined to be threatened species in 1985 despite both being undescribed subspecies (USFWS 1985b, p. 2). We believe such protection is warranted for the Fish Lake Valley tui chub.

Should the U.S. Fish and Wildlife Service (USFWS) not accept that *Siphateles bicolor ssp. 4* is a valid subspecies, the Fish Lake Valley tui chub should alternatively be listed as a Distinct Population Segment. USFWS will consider a population a DPS if it is "discrete" in "relation to the remainder of the species to which it belongs" and it is "significant" to the species to which it belongs. According to Fish and Wildlife's current policy regarding recognition of distinct vertebrate populations (Federal Register V. 61, No. 26, February 7, 1996), a species is considered discrete if it is "markedly separated from other populations" because of "physical, physiological, ecological, or behavioral factors;" or it is "delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1) (D)". The policy further clarifies that a population need not have "absolute reproductive isolation" to be recognized as discrete. A population is considered significant based on, but not limited to, the following factors: 1.) "persistence of the discrete population in an unusual or unique ecological setting;" 2.) "loss of the discrete population would result in a significant gap in range;" 3.) the population "represents the only surviving natural occurrence of an otherwise widespread population that was introduced;" or 4.) the population "differs markedly in its genetic characteristics" (Federal Register V. 61, No. 26, February 7, 1996).

1. Discreteness

The Fish Lake Valley tui chub qualifies as discrete because of geographical, ecological, and behavioral factors that separate it from other populations. All tui chubs live in water. The Fish Lake Valley tui chub is isolated from other populations of tui chub by mountain ranges and the lack of significant surface water flows between Fish Lake Valley and water bodies in adjacent valleys (see section I). Within Fish Lake Valley, the last known population is found at an isolated spring and outflow system surrounded by agricultural land.

Current evidence strongly indicates genetic isolation is occurring in the Fish Lake Valley tui chub from remaining populations of tui chub. Chen et al. (*unpublished*) (p. 2):

"Using microsatellite DNA loci, we characterized genetic variation among and within tui chub populations that occupy various basins in the southwestern Great Basin. Our results support: (1) the genetic difference of each of the previously recognized forms, i. e., Owens, toikona, Fish Lake Valley and Mohave tui chub."

The genetic isolation of the Fish Lake Valley tui chub is likely due to older climatic and tectonic effects, and more recent habitat loss due to anthropogenic processes. Beginning about 3 million years ago, increasing aridity due to the uplift of the Sierra Nevada Mountains contributed to the loss and fragmentation of aquatic ecosystems in the Great Basin. The arid conditions and isolation of aquatic ecosystems led to high rates of extinction rates among fish populations, resulting in modern fish fauna characterized by low species diversity and high endemism (Grover et al. 2019, p. 168).

In Fish Lake Valley, a Pluvial Fish Lake (Pluvial Lake Rennie) is thought to have existed until around 0.5 Ma. The lake may have overflowed northward, or it may have periodically been connected to a pluvial lake to the north in Columbus Salt Marsh (Reheis et al. 1991, p. 67). Fish could have migrated from the Lahontan Basin into Fish Lake Valley until about 2 Ma, after which the ancient lake basin was disrupted by movement along the Huntoon Valley fault system (Reheis et al. 2002, p. 102). As described in Finger and May (2015) (p. 748-750), when fish populations in different watersheds are connected, gene flow can occur, as would have been the case when the tui chub populations in the Truckee, Carson, Walker, Humboldt, Susan and Quinn rivers were connected by Lake Lahontan. When the latter receded, gene flow was restricted to inundated areas that remained connected, with subsequent flood events possibly allowing gene flow and reducing differentiation. Thus, it is likely that the Fish Lake Valley tui chub is related to Lahontan tui chub populations but also highly differentiated by now due to isolation over prehistoric and contemporary times.

Relative habitat size is another important factor in determining the extent of genetic isolation. Finger and May (2015) hypothesize that the Pyramid and Walker Lake tui chub populations incurred less genetic drift due to their large sizes (~49,000 and ~13,000 ha respectively). Less genetic drift means retention of a greater proportion of historical neutral genetic diversity, leading to greater genetic diversity and lower differentiation between Pyramid and Walker Lakes today. The Dixie Valley habitat is conversely less than 200m across and the population is highly differentiated (Id.). The small size and isolation of the Fish Lake Valley tui chub habitat means differentiation is likely to have occurred very rapidly. Significant contemporary habitat loss has occurred due to alteration of habitats and groundwater development (Nevada Wildlife Action Plan, 2012, p. 19).

The Fish Lake Valley tui chub is clearly a discrete population in relation to the remaining population of tui chubs because Fish Lake Valley is almost completely enclosed by mountain ranges, the last known population is separated from areas of potentially suitable habitat within the Valley by dry land, and the area of occupied habitat is very small. Isolation of the Fish Lake Valley tui chub is evident from genetic analyses. For these reasons, the Fish Lake Valley tui chub should be considered discrete.

2. Significance

The Fish Lake Valley tui chub meets at least three of the four factors identified by the U.S. Fish and Wildlife's policy for determining that a population is significant (Federal Register V. 61, No. 26, February 7, 1996). The Fish Lake Valley tui chub inhabits a unique ecological setting and there exist genetic differences between this and other tui chub populations. Loss of the Fish Lake Valley tui chub population may also result in a significant gap in the range of tui chubs dependent on small springs.

The tui chub (*Siphateles bicolor*) is widely distributed in the Western United States and occurs in many habitats: isolated springs, large desert lakes, sloughs, meadow streams, sluggish rivers, and backwaters of swift creeks (Sigler and Sigler, 1987, p. 167; Moyle, 2002, p. 124). The Fish Lake Valley tui chub occurs in an isolated spring outflow system and likely prefers pool habitats with low current velocities and dense aquatic vegetation (Nevada Wildlife Action Plan, 2012, p. 19). Detritus, aquatic vegetation and insects may constitute a larger proportion of the Fish Lake Valley tui chub's diet, distinct from populations that also eat fish, including small tui chubs, and/or benthic invertebrates found in lakes (Moyle, 2002, p. 125). Tui chubs are also heavily preyed upon by cutthroat trout but this predator is absent from springs and therefore the Fish Lake Valley tui chub's habitat.

Fish Lake Valley tui chub surveys further indicate that this fish is very small (see section II. A), and as far as we can tell is at the very end of the size spectrum for tui chubs. This variation is likely a response to the species' occurrence at a small spring system. The ecology of the system will also likely be unique due to the presence of other Fish Lake Valley endemics, such as the Fish Lake Valley toad (*Anaxyrus sp. 2*) and, before it went extinct in the 1990s, the Fish Lake Valley pyrg (*Pyrgulopsis ruinosa*) (Sada and Vinyard, 2002, p. 287).

Loss of this population would represent a significant loss for populations that occur in small springs, and particularly cold or relatively cold springs (see section IV. A4), given how rare these are. Due to the springs in the Great Basin being widely dispersed, the extirpation of one population would also increase the isolation of the remaining populations. Based on the distribution data shown in NatureServe Explorer (NatureServe, 2021b), the nearest tui chub population is Owens tui chub (*Siphateles bicolor snyderi*), ca. 50km away, on the other side of the White Mountains. The next closest populations occur northeast of the Fish Lake Valley population, no closer than approx. 125km (e.g. Charnock Springs tui chub, *Siphateles bicolor ssp. 10*). The loss of the Fish Lake Valley tui chub population would therefore create a gap of at least ~175km between these two geographical areas. The largest gap would however be created between the southern end of the Owens tui chub population, ca. 100 km south of the Fish Lake Valley population, and the Dixie Valley tui chub population (*Siphateles bicolor ssp. 9*) directly north of Fish Lake Valley, ca. 175 km away.

The Fish Lake Valley tui chub also has marked genetic differences from other tui chub populations in the southwestern Great Basin. Chen et al. *unpublished* (p. 8) state:

"The Fish Lake Valley was part of historical Lahontan Basin (Reheis and Sawyer 1997). Though it has long become separated from the Lahontan system, the tui chub inhabitants are thought to be a geographical population of Lahontan tui chub. In our findings, the Fish Lake Valley tui chub is genetically distinguishable from any other tui chub populations in Lahontan and southwestern Great Basin. Provided that F_{ST} values between two described subspecies, Owens (*S. b. snyderi*) and Lahontan (*s. b. obesa* and *pectinifer*) fall in the range of 0.10-0.20, the markedly higher F_{ST} values (0.19-0.42) between Fish Lake Valley and Lahontan tui chubs would justify that the tui chub population merits a subspecific status."

Combined with the likely unique habitat conditions and the small size of the Fish Lake Valley tui chub, observed genetic differences strongly suggest that this population is genetically unique.

For all of the reasons stated above, the Fish Lake Valley tui chub is discrete from and significant to the tui chub and thus qualifies as a DPS.

LIFE HISTORY

The subspecies' specific life history is unknown. Basic life history requirements are assumed to be similar to other tui chub inhabiting isolated marsh and spring outflow systems (Nevada Wildlife Action Plan 2012, p. 19). We additionally describe species-level characteristics that might be deemed relevant across the species.

D. Diet

Tui chubs are opportunistic and omnivorous (Nevada Wildlife Action Plan, 2012, p. 19). This species eats invertebrates, vascular plants, algae and occasionally fish. At less than 4 inches, there is very little consumption of plant material but at larger sizes, consumption of algae is more common. At all sizes, the heaviest predation of zooplankton occurs in winter and spring. There is some consumption of fish by large tui chubs (Sigler and Sigler, 1987, p. 168).

The Owens tui chub consumes detritus and aquatic vegetation, potentially as incidental take with insects (Nevada Wildlife Action Plan, 2012, p. 19).

E. Behavior

Little is known about the behavior of the Fish Lake Valley tui chub but, similarly to the Owens tui chub (Nevada Wildlife Action Plan 2012, p. 19), and the Hutton tui chub (USFWS, 2020), it may hide in vegetation. Some tui chubs are also schooling fish. Once hatched, Mohave tui chubs fry will school in the shallow parts of deep pools and slough-like areas, while medium-sized tui chub (1 to 3 inches) school in water one to two inches deep. Large chub tend to be solitary and found in deeper water (California Department of Fish and Wildlife, 2020a). In Pyramid Lake, tui chub form large doughnut-shaped schools near the surface over deep water in summer near midday. Some of these schools extend over more than 100 yards. Movement in shallow water schools is random or parallel to shore (Sigler and Sigler, p. 169).

F. Reproduction

Tui chubs reproduce rapidly and due to their slow growth and relatively small size are vulnerable through their life (Sigler and Sigler, 1987, p. 166-167). The fish congregates from late winter to early summer for spawning over aquatic vegetation or gravel substrate. A large number of eggs may be produced by females. Sexual maturity may be reached at 2 years and longevity can be more than 30 years in large lacustrine habitat. The age structure of this subpopulation is not known but 10+ year old adults are common in smaller environments (Nevada Wildlife Action Plan, 2012, p. 19).

G. Daily and Seasonal Activity

In addition to seasonal spawning activity, tui chubs can exhibit diurnal movements. In Pyramid Lake, tui chub migrate to the surface between 8pm and 4am to feed, following the migration pattern of zooplankton. In summer, feeding is possible at more than 200 feet deep and in dissolved oxygen concentrations of less than 2 ppm (Sigler and Sigler, 1987, p. 169).

H. Habitat requirements

The Fish Lake Valley tui chub is found throughout a spring source and outflow at McNett Ranch. Like the Owens tui chub, it likely prefers pool habitats with low current velocities and dense aquatic vegetation that provide adequate cover and habitat for insect food items (Nevada Wildlife Action Plan 2012, p. 19).

Tui chubs typically abound in alkaline waters with summer temperatures exceeding 20°C. However, they do well under a range of conditions, including the cold, clear waters of Lake Tahoe to the cool, productive waters of Pyramic Lake, Nevada which have concentrations of dissolved solids in excess of 4700 pm, and at approximately 75% sodium chloride. Mohave tui chubs, at the southern end of the species range, can survive temperatures from 2 to 36°C but prefer temperatures between 15 and 30°C. The range of alkalinities is significantly larger, with tui chubs regularly found at pH values >9 but tolerating pH levels of approximately 11. Tui chubs can also tolerate low dissolved oxygen levels. Individuals are regularly found in Pyramid Lake at oxygen levels less than 50% saturation, and can survive at less than 25%, or 4 mg/L when the water is cold (Geologica, 2003, p. 5). A trait shared by most chub species, however, is spawning temperatures between 13 and 17°C (Geologica, 2003, p. 1). Thus, it is likely that changes in water temperature at the spawning site would be detrimental to the species survival. Tolerance to a range of alkalinities also does not mean that a change in alkalinity will not negatively impact the species. Moyle et al. 1995 (p. 130) for instance noted how Pyramid and Walker Lakes were becoming increasingly alkaline due to diversions of inflowing water and could eventually become too alkaline for tui chubs. In 1992, chubs were eliminated from Goose Lake as the lake became progressively more shallow and alkaline and then dried up. Native southwestern fishes are very susceptible to habitat alteration, possibly due to their adaptation to isolated systems, and absence of a high number of competitors (Williams and Williams, 1981, p. 50).

I. Hydrogeology of Fish Lake Valley tui chub habitats

Fish Lake Valley is bordered on all sides by mountain ranges: the White Mountains to the west (peaking at 14,252 ft), Silver Peak Range to the east and south (peaking at >9000 ft), and the Volcanic Hills to the north (State Engineer, 2013, p. 3; Rafferty, 1988, p. 88). The valley fill consists of gravel, sand, silt and clay, while noncarbonate and carbonate rock form the mountain masses and also underlie the alluvium at depth (Eakin 1950, p. 17; Rush and Katzer, 1973, p. 6).

The White Mountains receive close to 10 inches of rain and snow, providing runoff to approximately 5 or 6 perennial streams used for irrigation (Rush and Katzer, 1973, p. 33; Rafferty, 1988, p. 88; State Engineer 2013, p. 3). No perennial streams reach the valley floor from the mountains on the north, east and south (Rush and Katzer, 1973, p. 16). The valley itself receives very little rain (less than 5 inches of a year). The average temperature is 48.9°F (9.4°C), with summer temperatures up to 90-100°F (32-38°C), and winter temperatures that frequently fall below 32°F (0°C) (Rafferty 1988, p. 88).

The most important stream in Fish Lake Valley is Chiatovich Creek, with an average annual streamflow of 6,700 acre-feet (Rush and Katzer, 1973, p. 1). The axial drainage in the valley tends northward to a playa where runoff collects when it occurs and then evaporates (State Engineer 2013, p. 3). The groundwater reservoir is recharged from direct downward percolation into the mountain bedrock and from deep percolation into the alluvium where precipitation has become concentrated into streams (Eakin, 1950, p. 18).

When conditions are unusually wet, some surface water may flow further than the playa and discharge through the "Gap" into Columbus Salt Marsh Valley (Rush and Katzer, 1973, p. 28). The Gap is an outlet at the north end of the Valley, roughly 1 mile in length and less than one-eighth of a mile in width on average (Eakin, 1950, p. 7). The streamflow leaving the valley is estimated to be less than 100 acre-feet per year, probably occurring infrequently over a period of years. A small amount of groundwater outflow (less than 200 acre-feet per year) is also estimated to occur through the alluvium, with a larger amount of subsurface outflow going through volcanic and carbonate rocks to Columbus Salt Marsh Valley. Outflow to Clayton Valley may additionally occur through the Silver Peak Range. Total subsurface outflow for the Valley can be assumed to amount to 3000 acre-feet per year (Rush and Katzer, 1973, p. 31).

Evapotranspiration by phreatophytes, which predominantly occur on the valley floor, is estimated to generate 24,000 acre-feet per year of outflow for native conditions (Rush and Katzer, 1973, p. 37). This includes spring discharge, with some flow going to support vegetation and the majority seeping back to the water table (Ibid. p. 33). The principal types of phreatophytes are greasewood, rabbitbrush, saltgrass, and various native meadow grasses (Ibid. p. 31). Groundwater recharge from precipitation for native conditions is about 33,000 acre-feet per year; but 30,000 acre-feet per year for both Valley inflow and outflow is realistic given uncertainties in each (Ibid., p. 37).

Per Eakin (1950), the largest spring in the Valley is Fish Lake Spring and closely related springs extending northeast for about 2 ½ miles (p. 25). Water at Fish Lake Spring is most likely transmitted through solution openings in Palezoic limestone to a point close to the land surface, from where it rises to the surface through alluvium (Ibid., p 17). The average annual discharge from this area is roughly 4000 acre-feet (Ibid., p. 25). However, as noted in section B, Fish Lake Spring and Fish Lake (a playa the Spring occasionally spills out onto) are now dry most of the time due to pumping for agriculture (pers. comm. Eric Miskow, Nevada Division of Natural Heritage, November 2020).

Discharge from the spring area at the McNett Ranch is around 700 acre-feet per year. Several springs occur south-west of this spring area but the (moderate) discharge only occurs in the spring time (Eakin 1950, p. 25). Seven hundred acre-feet per year is more than the ~215 acre-feet pumped for domestic use in the valley (State Engineer, 2013, p. 8), but two orders of magnitude less than the > 50,000 acre-feet appropriated, or >27,000 acre-feet pumped, in Fish Lake Valley for irrigation purposes (Ibid., p.1), or the groundwater pumpage that may result from the operation of a large-scale lithium or geothermal production facility (sections IV. A1, A4 and A5). Moreover, as at Fish Lake Spring, discharge is almost certainly now lower than 50+ years ago due to increasing alfalfa production in the vicinity of the ranch (section IV. A1).

In addition to the springs on McNett Ranch, there are, or have been, springs elsewhere in the Valley. Springs in the Gap are described as having a small aggregate discharge. Their outflow is likely caused by faulting and localized recharge in the vicinity of the Gap. In the northwestern part of the valley, Sand Spring (with a discharge of 10-15 gpm or <25 acre-feet per year) arises from the contact of the bedrock and alluvial deposits, and was partly developed many years ago (Eakin, 1950, p. 26). There are also a large number of smaller springs in the Palmetto and Sylvania Mountains, and about 25 gpm is exported from some small springs in Trail Canyon (Rush and Katzer, 1973, p. 33).

III. STATUS OF THE FISH LAKE VALLEY TUI CHUB

The Fish Lake Valley tui chub is ranked as critically imperiled by the State of Nevada. The subspecies historically occurred at several locations in Fish Lake Valley, but is now confined to just one spring and outflow system.

"The Fish Lake Valley tui chub is a narrowly endemic species with major threats. Significant habitat loss has already occurred in Fish Lake Valley due to alteration of habitats and groundwater development" (Nevada Wildlife Action Plan, 2012, p. 19).

Groundwater in Fish Lake Valley has primarily been developed for agriculture, and to a lesser extent other uses such as mining and domestic consumption. Fish Lake, which previously held tui chubs, now becomes desiccated during irrigation season (pers. comm. Eric Miskow, Nevada Division of Natural Heritage, November, 2020). Based on NDNH McNett Ranch records (p. 2), the tui chub was found to be extirpated from Fish Lake spring during a 1986 visit by the Nevada Department of Wildlife (NDOW). According to Heinrich and Sjoberg (1992, p. 9), a single juvenile was dip-netted from shallow areas before total drying. No chubs were found in 1993 (Heinrich and Sjoberg, 1993, p. 11). Based on records shared by Eric Miskow, Nevada Division of Natural Heritage, in November 2020, for Fish Lake ("NDNH Fish Lake records"), the lake was again dry in 1995 and no fish were observed to be present (p. 1). Exotic species were another reason behind the demise of the Fish Lake population (pers. comm. Eric Miskow, Nevada Division of Natural Heritage, December 2020).

It is not clear what caused tui chubs on the western side of the Valley to disappear. As described in section II. B, Sand Spring is one site where fish were found and the spring was and/or is impounded, possibly to store irrigation water. Impoundments alter the natural physical integrity of spring systems and are therefore harmful to many spring-dependent species (Abele 2011, p. 18). However, given the Fish Lake Valley tui chub's assumed affinity for pool habitat, the deeper low velocity water that the impoundment presumably provided may have been beneficial to the species. According to Eric Miskow, Nevada Division of Natural Heritage (pers. comm. December 2020), the impoundment on McNett Ranch indeed enhanced the tui chub population providing higher quality habitat.

From the NDNH McNett Ranch records (p. 2), it appears that in 2005, NDOW marked and released 445 fish in McNett Spring on the first day of the visit. On the second day, 224 fish were captured and 45 marked. The population was estimated to be 2210 (1652-3032, p=0.95) and included several age classes. In 2007, the fish was surveyed again, with 544 fish trapped and released into the spring pool. However, fewer fish were found in the outflows compared to previous survey efforts.

It is noted in the 2012 Nevada Wildlife Action Plan that "Although the [existing] population [on McNett Ranch] is currently relatively secure and there are no specific anthropogenic threats at this time, the habitat could be subject to loss from groundwater and geothermal development" (p. 19).

As will be shown in more detail below, there are multiple industries with impacts on the groundwater resource, including geothermal energy, that imminently threaten the Fish Lake Valley tui chub. Moreover, emergent vegetation and the presence of cattle in the vicinity of the springs should be carefully managed to avoid adverse impacts (sections IV. A2 and A3). The presence of non-native species in the chub's habitat can also lead to predation, competition and disease. Goldfish have been introduced to McNett Ranch and exotics are known to have contributed to the extirpation of the Fish Lake population (section IV. E1).

The presence of the aforementioned threats is compounded by the vulnerability of the Fish Lake Valley tui chub to extinction from stochastic (i.e., random) threats, such as demographic, genetic, and environmental stochasticity and catastrophic events due to the species' small population size (USFWS, 2009, p. 19) (section IV. E2). Due to the relative isolation and habitat requirements of the species, climate change is also a threat (section IV. E3).

IV. THREATS

A. Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Historic and continued groundwater use by multiple sectors threaten the Fish Lake Valley tui chub. Historically, agriculture has been prominent but geothermal energy development and lithium mining are now also growing rapidly in the Valley. Significant habitat loss has already occurred due to habitat alteration and groundwater development. In addition to groundwater usage, the presence of cattle near the tui chub's habitat and emergent vegetation should continue to be monitored and possibly managed. The following discussion provides additional detail on each of these threats.

1. Agriculture

While it was estimated in 1973 that much greater utilization of the water resources of Fish Lake Valley was hydrologically possible (Rush and Katzer, 1973, p. 51), the basin is now experiencing irreparable damage from water production that exceeds annual recharge (Esmeralda County 2012, p. 38). Water levels in Fish Lake Valley have declined up to 2.5 feet per year, causing more than 75 feet of cumulative drawdown (Ibid., p. 1). Historic groundwater levels are shown in Figure 3. This overdraft is causing aquifer storage to collapse, with the exact amount depending on the type of materials that comprise the local aquifers. This decrease in pore space reduces the aquifer's ability to store groundwater and cannot be reversed in the future (Ibid., p. 38).

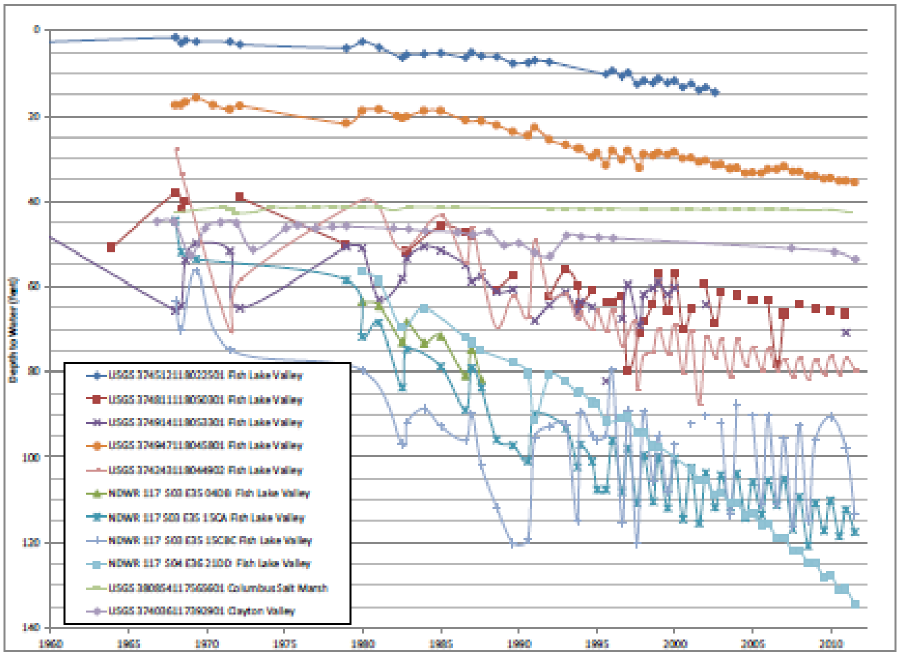


Figure 3. Selected groundwater level from 1960 to 2011 (Esmeralda County, 2012, p. 39)

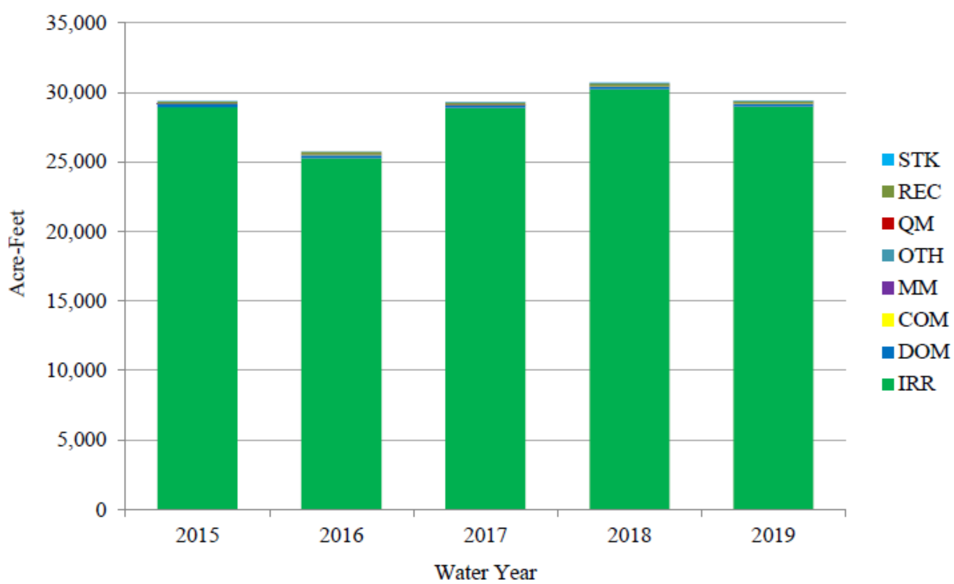


Figure 4. Fish Lake Valley historical pumpage by manner of use (State Engineer, 2019, p. 8).

Recent groundwater pumpage by manner of use, is shown in Figure 4 (State Engineer 2019, p. 8). From this figure it can be seen that the vast majority of groundwater is extracted for irrigation, and indeed Esmeralda County (2012, p. 38) notes that stabilizing the Fish Lake Valley groundwater resource will require a combination of increasing agricultural efficiency and decreasing the irrigable area within the basin. Other measures mentioned are preventing artesian flows from wells and limiting groundwater withdrawals from California.

The two main irrigation water uses are alfalfa and pasture. Fish Lake Valley "has long been a place for alfalfa farms along with cattle and horse ranches and some fruit trees" (Esmeralda County, 2011, p. 14). It is the primary area for agricultural production in Esmeralda County. In 2000-2001, 58% of the county's sales came from Alfalfa hay, while the second largest contributor was cattle and calves (40% of agricultural sales) (Suverly, 2000). Some amount of Fish Lake Valley alfalfa has historically gone to the Southern California dairy market (Orloff and Gildersleeve, 1991, p. 7). However, western hay exports have increased rapidly in recent years, with more than 17% of alfalfa production exported in 2017 (Putnam et al. 2016, p. 1; 2019). The largest exporter of US alfalfa is China, although the trade disruption that begun between the US and China in the summer of 2018 has had an impact on the hay trade (Putnam et al., 2019). Yet, improved trade relations and increased demand from other states such as Saudi Arabia and UAE (Putnam et al., 2019) could lead to the shipping of scarce water resources (embedded in water-intensive alfalfa) from Fish Lake Valley to other parts of the world.

In addition to increased groundwater withdrawal, groundwater recharge from runoff may be declining and contributing to the groundwater decline. Surface water flows are an important source of irrigation water in the agricultural areas of Fish Lake Valley, with surface water diversions for agriculture from Chiatovich, Leidy, Busher, Perry-Aiken, and McAfee Creek drainages (Esmeralda County, 2012, p. 18). The consumptive use of run-off for agriculture is estimated to be between 15 and 26% based on Eakin 1950 (p. 20), but the acreage under irrigation is certainly now higher. Figure 5 shows land under alfalfa cultivation and pasture/grass near McNett Ranch, in 2009 and 2019. Within the red boundary shown in Figure 5, we estimate that the amount of land used to grow alfalfa has increased by about 3290 acres. This increase is also evident from the figure itself. Grass/pasture has conversely decreased by ~1938 acres but practically all of the conversion was due to alfalfa cultivation. The amount of shrubland converted to grass/pasture over this time period is ~540 acres.

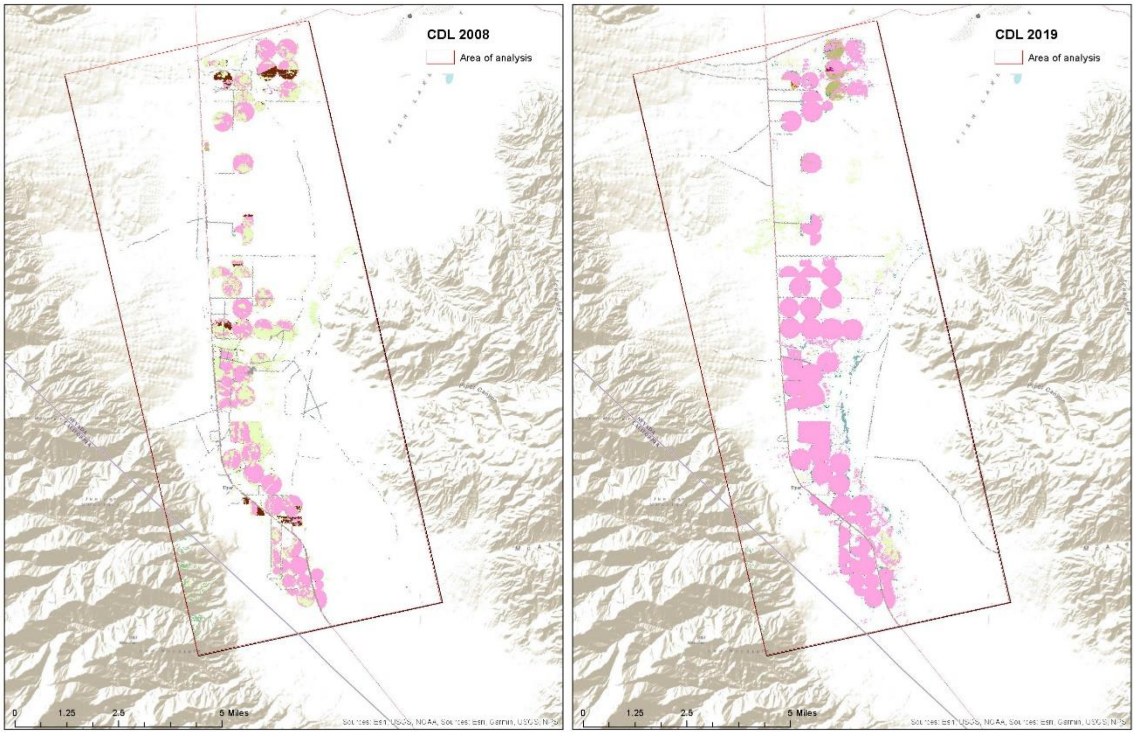


Figure 5. Agricultural land in the vicinity of McNett Ranch in (a) 2009 and (b) 2019. Alfalfa is shown in pink and grass/pasture in light green. Source: National Croplands Database, 2020.

Declining groundwater levels are a threat to the Fish Lake Valley tui chub because of their impact on spring flows and thus spring-fed habitats. The latter can disappear completely, or only intermittently hold water, as at Fish Lake, leading to the extirpation of the tui chub and other aquatic fauna.

The springs in the Valley are here inferred to predominantly be gravity springs, where: (1) water either moves from the water table aquifer through permeable materials to the land surface, or (2) issues from the intersection between the water table and the land surface (USDA, 2012, p. 5). The springs are likely also a combination of the two mechanisms, with (2) mostly involving fracture or tabular springs which form when water emerges from fractures or joints in rock, from solution channels in limestone or gypsum, or from natural tunnels in volcanic rock (Id.). In addition to gravity springs, water may flow from springs that are under "artesian pressure"- i.e. water is introduced from a higher elevation to a water bearing bed confined between relatively impervious strata (Ibid., p. 8). There are artesian wells (Esmeralda County, 2012, p. 38) in Fish Lake Valley but it is unclear how common they are relative to other types of wells.

Figure 6 conceptualizes how springs may be affected by groundwater pumping, with the potential for impact ultimately depending on the proximity of the pumping, the hydraulic characteristics of the aquifer and the magnitude and duration of pumping (Nye County, 2004, p. 23). Prior to pumping (A), the flow from recharge areas over the mountains balance the discharge areas along the valley axis or out of the basin via underflow and springs occur where the water table intercepts the land surface. With the onset and continuation of pumping (B-E), water levels are lowered around the pump, causing a hydraulic gradient that induces radial flow towards the pump. A cone of depression develops around the pump and grows until the recharge rates are in balance with the pumping rate. The drawdown may intercept water that would otherwise be discharged at springs (Ibid., p. 25).

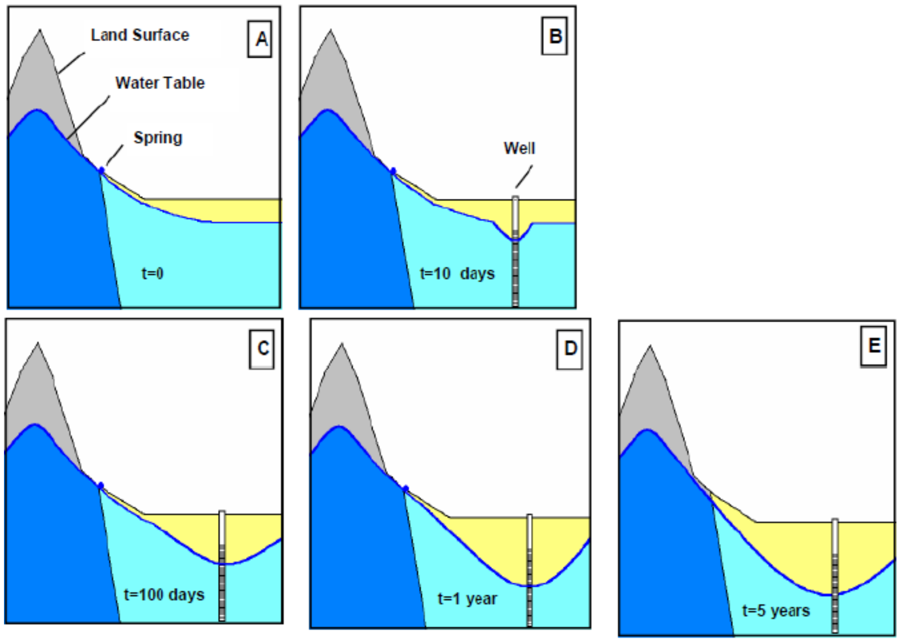


Figure 6. Potential effects of groundwater withdrawals on spring discharge rates: (A) Natural hydrologic system is in balance; (B) Water levels are lowered in the vicinity of the production wells; (C) The area of decline expands outward from the pumping well or wells; (D) Wells' area of influence approaches the edges of the valley-fill aquifer or the geologic structure controlling the spring and discharge rates may begin to decline; (E) Effects may expand beyond the valley-fill aquifer and eliminate the natural discharge of springs. Adapted from Nye County, 2004, p. 25.

The Fish Lake Valley tui chub's life cycle is entirely reliant on flows from springs. A reduction in discharge at the spring supporting the last known population would decrease the depth of the spring pool and therefore the quality and/or area of the tui chub habitat. It could also cut off the fish in the pool outflows, leading to their eventual extirpation due to the lack of a viable population size and/or the absence of suitable habitat. Reduced spring flows may furthermore change the thermal properties of the habitat as shallower water bodies gain and lose heat more quickly and groundwater is typically warmer than surface water during the winter and colder during the winter. If water temperatures in the spring-fed habitat were to change, spawning might occur earlier (or later) than expected, which could in turn result in increased mortality due to sub-optimal biotic and abiotic conditions now coinciding with the tui chub's early life stages. Moreover, although tui chubs are tolerant of a wide range of temperatures, the optimal range is 15-30°C (California Fish Website, 2020). The water quality (e.g. dissolved oxygen, salinity) in the tui chub habitat also depends on groundwater discharge.

There exist several examples of spring-dependent fish species other than the Fish Lake Valley tui chub, that have been extirpated (or been driven extinct) by groundwater pumping. Pahrump Ranch killifish (*Empetrichthys latos pahrump*) and Raycraft Ranch poolfish (*E. l. concavus*) both went extinct due to desiccation of their native springs from groundwater pumping and modification of springheads. The Pahrump poolfish (*E. latos*) was in turn extirpated from its native habitat due to desiccation of springs caused by groundwater pumping for irrigation. Now only refugium populations exist on public lands (Nevada Wildlife Action Plan, 2012, p. 42). Groundwater pumping is also a major threat to the endangered Owens tui chub. It is largely caused by agricultural irrigation and municipal demands in the Owens Basin. Most of the large Owens Valley floor springs have been eliminated by unregulated groundwater use. Without enhanced regulation, groundwater pumping could reduce or even halt water input to existing isolated springs and headwater springs of streams in the Owens Basin. This would in turn cause a further reduction or loss of the already extremely limited aquatic habitat occupied by Owens tui chub (California Department of Fish and Wildlife, 2020b, p. 12-13). Other examples of spring-dependent Nevada fish species threatened by groundwater pumping include the Clover Valley speckled dace (*Rhinichthys osculus oligoporus*) and Independence Valley speckled dace (*Rhinichthys osculus lethoporus*) (Nevada Wildlife Action Plan, 2012, pages 13 and 23).

2. Grazing

As summarised in Batchelor et al., 2015 (p. 1-2), the congregation of cattle in riparian areas is common due to ease of access to water, lush forage, and favorable terrain, and can impact ecosystems in numerous ways. Cattle grazing can alter stream cover, water depth and bank stability, and has been shown to cause declines in salmonids. It can also accelerate the erosion of stream banks, causing them to become shallower and wider and consequently have higher water temperatures. Trampled banks can furthermore lead to pollution from excrement and increased sedimentation.

Other effects that have been documented with grazing activity include decreases in the density and height of woody plants and increases in exotic species (Batchelor et al., 2005, p. 2). In Modoc county, California, livestock grazing removed most riparian vegetation from a section of Cowhead Slough, reducing cover available to the Cowhead Lake tui chub and increasing their vulnerability to predation by garter snakes and birds (Moyle et al. 1995, p. 133).

Based on a 2007 field trip report for McNett Ranch shared by Eric Miskow, Nevada Division of Natural Heritage, in December 2020 (hereforth "NDNH 2007") (pp. 1-2), however, cattle use of the pond area was moderate and was probably also keeping emergent vegetation in check and maintaining open areas along the shoreline. The effects of grazing and the effects of grazing removal therefore need to be researched (Nevada Wildlife Action Plan 2012, p. 19), and the presence of cattle carefully managed to avoid adverse impacts.

3. Encroachment of aquatic plants

Emergent vegetation was described in NDNH 2007 as being thick in places. Bulrush (*Schoenoplectus* ssp.) was present throughout the pond, with *Phragmites* ssp. observed in the center (NDNH 2007). Dense emergent vegetation can severely degrade spring habitat, and also provide cover for non-native tui chub predators such as bullfrogs (USFWS, 2009, p. 13). Active management of the tui chub habitat may be required to prevent aquatic plant encroachment, such as routine manual removal to maintain open water habitats (California Department of Fish and Wildlife, 2020b, p. 12).

4. Geothermal development

Many obvious geothermal systems in Nevada have been exploited for energy production. In addition, there has been increasing interest in the detection of geothermal systems without obvious surface features (Littlefield and Calvin, 2014, p. 1). About 60% of Nevada's geothermal generation is produced on federal land and most of the growth in recent years has been through federal leases (The Nevada Independent, 2019). A massive competitive geothermal lease sale was held by BLM on Sept. 17, 2019. Bids were made on 26% of the 142 parcels sold on 384,369.6 acres of land (BLM, 2019; Reuters, 2019).

Fish Lake Valley hosts at least 5 geothermal prospects (Figure 7). The Emigrant geothermal prospect was discovered in the 1980s as a result of a shallow mineral exploration hole uncovering high temperatures. Commercial-grade temperatures up to 162°C were recorded in 2006 when slimhole 17-31 was drilled to 2938 ft (Littlefield and Calvin, 2014, p. 3). The Fish Lake Valley geothermal prospect stretches from the southern part of the Volcanic Hills onto the valley floor (Fig. 1b). High temperatures in a deep oil exploration well led to its discovery in 1970. At least thirteen geothermal wells have since been drilled to define the resource (Id.). Four targets for ground-based exploration were identified by Littlefield and Calvin (2014, p. 9): the Emigrant Hills area, the Volcanic Hills and Silver Peak Range areas, and a target area which includes the known Fish Lake Valley geothermal prospect and a newly identified geothermal expression ~ 4 km to the northeast.

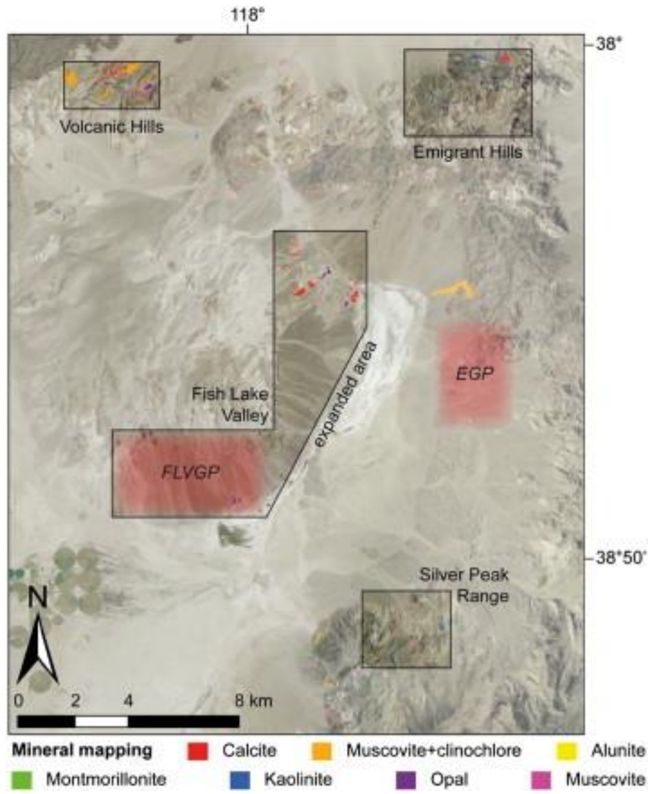


Figure 7. Mineral map over Fish Lake Valley showing the Fish Lake Valley (FLVGP) and Emigrant (EGP) geothermal prospects (red highlights) and target areas for future geothermal exploration identified by Littlefield and Calvin, 2014. Taken from Little and Calvin, 2014, p. 5.

The development of Fish Lake Valley's geothermal resources for electricity production has so far been prevented by its remote setting and the need to build costly transmission lines (Littlefield and Calvin, 2014, p. 2). However, as noted by Littlefield and Calvin (2014, p. 1), in the context of the significance of their study, the discovery of additional geothermal resources in Fish Lake Valley may incentivize the building of such transmission lines to this remote location.

In 2013, the Valley Electric Association (VEA) was reportedly seeking to "improve transmission lines from Beatty north to remote Fish Lake Valley where a number of geothermal wells have already been drilled" (Pahrump Valley Times, 2013), and in 2016 commented on the "significant potential for geothermal resource development in or near the VEA service area in the Fish Lake Valley area of Nevada" (VEA 2016, p. 4).

Figure 8 shows the active geothermal leases in Fish Lake Valley, per a recent inventory from LR2000, and as can be seen from this figure, all the leases are in the vicinity of McNett Ranch, as close as approximately 0.5 miles. At least three geothermal plants are planned or under development (Esmeralda County, 2019, p. 17).

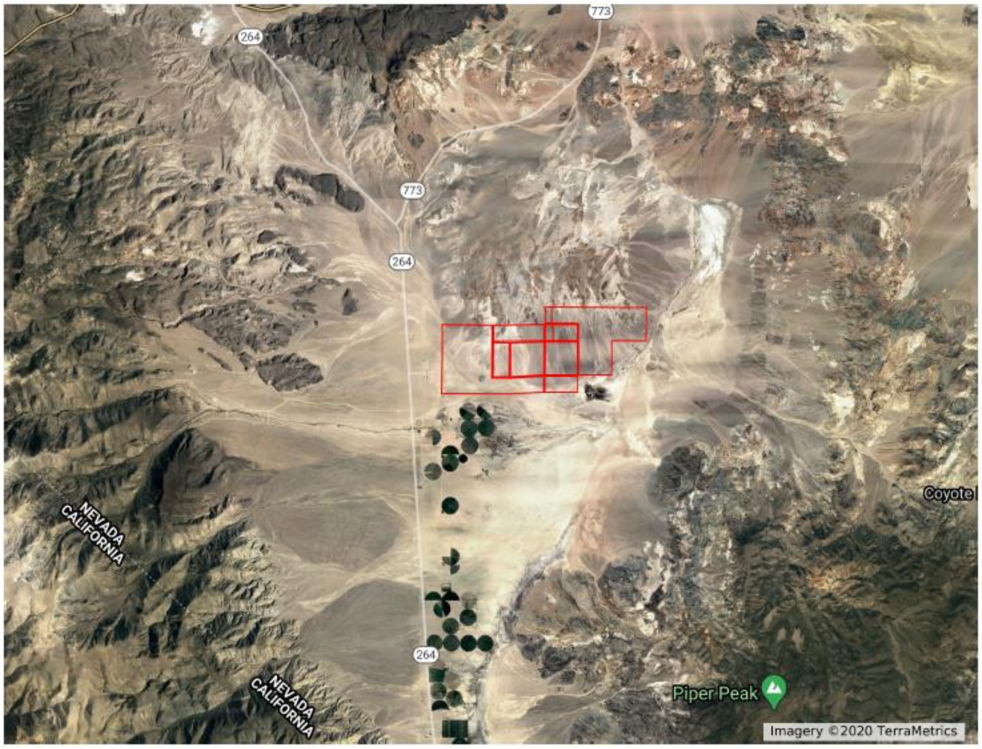


Figure 8. Active geothermal leases in Fish Lake Valley.

The main threat to the Fish Lake Valley tui chub from geothermal energy production is the impact that the latter would have on spring flows in terms of discharge and potentially water temperature and chemistry. Most modern geothermal facilities are closed-loop and dry-cooled. A close-loop geothermal facility is one which pumps groundwater from the geothermal reservoir, extracts heat from the water, and then reinjects the cooled water into the geothermal reservoir. A dry-cooled facility uses air in its cooling towers, rather than water. These two features mean that most geothermal facilities do not directly consume groundwater. Thus, they are generally exempt from needing to obtain certain water permits, for example certified water rights. However, this does not mean they do not cause impacts to surface expression of groundwater (Center Dixie Valley Toad petition, p. 12), and indeed the security of the springs on McNett Ranch ("McNutt Ranch"), and thus tui chubs at the springs, was already being questioned in the 1980s due to them being immediately adjacent to BLM parcels being leased for geothermal exploration (Sada 1981, p. 11). Plans for geothermal wells by Fish Lake Power Company in the vicinity of the ranch were also reported in Heinrich and Sjoberg (1992, p. 9) ("McNet ranch" therein) in the context of a tui chub's status assessment.

Changes in spring discharge

Pumping from the geothermal reservoir would alter the aquifer's natural pressure gradients. Water would be pulled from natural discharge zones due to depressurization at the pumping sites while high pressure would be experienced in areas near injection wells. The reinjection wells would almost certainly not replace water in the same exact locales that it was pumped from. Permeable fractures in the injection wells would not necessarily intersect the permeable features in the collection wells due to heterogeneous substrate. As a result of this, reinjected water might be lost to the circulation, particularly if reinjection reaches fractures transversal to the general fracture trend found in the fault system (Center Dixie Valley Toad petition, p. 12-13). Reinjection can also cause deformation and shattering of substrate, potentially offering new pathways for gas and water circulation and therein altering the hydrology of the adjacent surface features (Center Dixie Valley Toad petition, p. 17).

The exact nature of the effects at McNett Ranch should depend to a large degree on how closely connected the aquifer feeding the springs is to the geothermal reservoir. One indirect measure of this is the temperature of the springs. Springs can generally be divided into three categories: cold springs (springs near or below mean annual air temperature), warm or thermal springs (springs 5 to 10°C (41 to 50°F) above mean annual temperature), and hot springs (springs more than 10°C (50°F) above mean annual temperature) (Nevada Comprehensive Wildlife Conservation Strategy, date unknown, p. 201). The Fish Lake Valley tui chub is listed as a "cold springs and springsbrooks" species, whereas the Ash Meadows Amargosa pupfish and the desert dace (both spring-dependent) are for instance listed as "Thermal (warm)/Hot Springs and Springbrooks" species (Ibid., p. 202).

However, McNett Ranch is right next to geothermal fields and Eakin (1950, p. 29) reports temperatures of 77°F/25°C at the McNett flowing well, which is ca. 12°C above the average annual air temperature (Rush and Katzer, 1973, p. 39). The temperature measured at a spring on McNett Ranch was 69°F and the temperature at Fish Lake Spring, 70°F, also well above the mean annual air temperature (Eakin, 1950, p. 29). A 1993 field report shared by Eric Miskow, Nevada Division of Natural Heritage, in December 2020 ("NDNH 1993") (p. 1), further mentions the presence of a potential tui chub reintroduction site, with a temperature of 76°F, again suggesting adaptation to relatively warm spring waters.

Another indicator of geothermal input is the chemistry of the water. Eakin 1950 report that the chemical character from the McNett flowing well is indicative of water supplied, at least partially, from sources related to volcanic activity (Eakin 1950, p. 31). Water from such sources is typically characterized by relatively high chloride, fluoride and boron content compared to normal groundwater. Partial analysis of the sampled spring in turn indicates lower but still relatively high chloride content, suggesting that it may represent water similar to that of the McNett flowing well mixed in with shallow groundwater of considerably lower dissolved solids (Eakin, 1950, p. 31).

If water of geothermal origin indeed discharges at McNett Ranch, then pumping the geothermal reservoir could significantly reduce discharge at the spring site or even lead to drying of the spring system. Alternatively, even if the two systems are not directly connected, the springs at McNett Ranch could still be impacted by the reinjection of the cooled geothermal water. The latter could potentially open up new flow paths through rock fracturing, allowing the cold water aquifer feeding the spring to respond to pumping and reinjection-induced pressure changes.

A well-known Nevada example of a geothermal facility impacting adjacent geothermal features is at the Steamboat Springs hot springs and geyser complex near Reno. While the USGS found that the primary driver of the springs decline was groundwater pumping in the Truckee Meadows, it attributed declines in the water table of 1-3 feet to pumping and reinjection at the Caithness Power Incorporated geothermal energy facility nearby (Center Dixie Valley Toad petition, p. 13). Another US example is the surface thermal water features of the Long Valley caldera, near Mammoth, California. Monitoring of such features subsequent to the development of Casa Diablo, a geothermal facility, has shown "a cessation of spring flow at Colton Spring, 2 km east of Casa Diablo"; "declines in water level in Hot Bubbling Pool, 5 km east of Casa Diablo…of 1.2m" (Center Dixie Valley Toad petition, p. 14).

Changes in discharge temperature and chemistry

Reinjecting cooled waters into the hot geothermal reservoir can gradually cool off the reservoir and hence the temperature of the waters discharged at the surface. A decrease in pressure in the geothermal reservoir may also lead to inflow of cooler water from surrounding areas. Moreover, new flow paths opened up by fracturing of the rock can lead to mixing of waters with different physical and chemical properties. These changes are a potential threat its persistence of the Fish Lake Valley tui chub as this species depends on the existing properties of the spring where it occurs.

In the Long Valley Caldera of California, geothermal production has caused an overall decrease in temperature in the geothermal reservoir of 10-15°C, with localized reductions of up to 80°C, and concomitant impact on surficial expression of these waters. At the Wairakei geothermal field, the chloride content of discharge from numerous springs decreased subsequent to geothermal well development. At some springs, this decrease was at least 70% over a period of several years. Concomitantly the springs saw temperature decreases of as much as 30°C. Moreover, these changes were greatly exacerbated in springs with lower amounts of discharge (Center Dixie Valley Toad petition, p. 18).

Impossibility of effective mitigation

It was suggested in 1993 that geothermal wells planned by Fish Lake Company just north of McNet Ranch may have potential for construction of chub refugia ponds (Heinrich and Sjoberg, 1993, p. 9). The exact meaning is unclear but one possibility is that some of the geothermal water would be utilized for artificial ponds stocked with Fish Lake Valley tui chubs. While these ponds might offer a temporary sanctuary for tui chubs, they are not an adequate mitigation solution. The ponds would forever be dependent on the operation of the geothermal facilities. As soon as facilities would be decommissioned, the ponds would be abandoned and the tui chub would go extinct. Additionally, the water feeding into the ponds is unlikely to exactly match the temperature and chemistry parameters that the water discharged at the spring on McNett Ranch naturally has. Finally, it is unclear that mitigation measures would even be adhered to, should geothermal power plans go forward. A monitoring and mitigation plan was for instance developed as a part of the Jersey Valley Geothermal Project in Jersey Valley, Nevada, and yet Jersey Hot Springs, an important nearby geothermal resource still went dry (Center Dixie Valley Toad petition, p. 20).

5. Lithium development

Lithium is important for the renewable energy transition since it required for battery storage of energy. However, production systems need to maximize recycling and be sited so as to minimize impacts on species. A proliferation of lithium mining claims has been filed across the northern Mojave and southern Great Basin deserts, including in the Fish Lake Valley basin. Without legal protections for the tui chub, there is nothing stopping lithium mining companies from purchasing water rights on McNett Ranch and diverting water from the tui chub's only remaining habitat. In addition, groundwater pumping further afield could potentially still impact this species through propagation of changes in the hydraulic gradient and eventual capture of groundwaters discharging at McNett Ranch.

Lithium Brine Production

Traditional lithium production involves pumping lithium-laden brines from groundwater aquifers and evaporating the water out in pools to extract the salts therein. Lithium is then extracted from the salts and processed into lithium carbonate, which is used for batteries. The only current large-scale lithium production in the United States occurs at Silver Peak in Clayton Valley, one valley east of Fish Lake Valley. This facility, owned by Albemarle, consumes between 10,000 and 20,000 acre-feet of water annually. This is a tremendous amount of water – ranging from 3 to 7 billion gallons of water per year. This lithium production is already causing significant impacts to aquifers in Clayton Valley. "The Clayton Valley hydrographic basin is permanently losing storage because of withdrawals of groundwater." (Esmeralda County 2012, p. 46). It is likely that some of this loss in storage may be permanent: "The impact of the groundwater withdrawals for mineral concentration by evaporation will take decades for the water levels to recover and the loss of groundwater storage will never be regained" (Id.).

As of June 18, 2020, there are an estimated 9,834 active lithium placer claims in Nevada in 18 different hydrographic basins (Nevada Division of Minerals 2020). There are no fewer than fourteen lithium placer claims in the vicinity of Fish Lake Valley Hot Well, as depicted in Figure 9.

Numerous mining interests are operating and developing prospects in Fish Lake Valley. Lithium Corporation boasts on their website 6,400 acres worth of placer claims, seemingly near the Fish Lake Valley dry lake (Lithium Corporation, 2020). However, elsewhere Lithium Corporation claims to have 11,360 acres of placer claims "covering the most prospective portions of the playa." (Bloomberg, 2019). American Lithium Company has boasted it is "the dominant land holder in the Valley, with 18,552 contiguous acres under management," implying the company is unfamiliar with the exact rights conferred by a mining claim, but nonetheless indicating a substantial piece of acreage within the area of shallow groundwater at the north end of the valley which may be exposed to threats from lithium mining (American Lithium, 2018). Paired with lithium claystone lode claims (see next section), American Lithium Corp had as much as 22,332 acres of claims in northeast Fish Lake Valley as of July 2018 (Proactive Investors, 2018). In 2016, Alix Resources Corp said they acquired 12 unpatented lithium placer claims in northeast Fish Lake Valley, approximately 4 km from Rhyolite Ridge (Junior Mining network, 2016).

Development of lithium production at these placer claims constitutes a significant threat to the Fish Lake Valley tui chub.

Additionally, there are far more lithium placer claims in the adjacent valleys of Columbus Salt Marsh and Clayton Valley. As can be seen in Figure 8, there are potentially hundreds or thousands of lithium placer claims within those two valleys. This is of importance because subsurface outflow is estimated to occur from Fish Lake Valley to both Columbus Salt Marsh and Clayton Valley, with the vast majority of the ~3000 acre-feet of subsurface flow transmitted to Columbus Salt Marsh (Rush and Katzer, 1973, p. 31). Thus, if significant drawdown of aquifer levels in Columbus Salt Marsh were to occur, it could induce more interbasin flow from Fish Lake Valley, exacerbating the already alarming groundwater drawdown in that valley and further jeopardizing the springs on McNett Ranch.

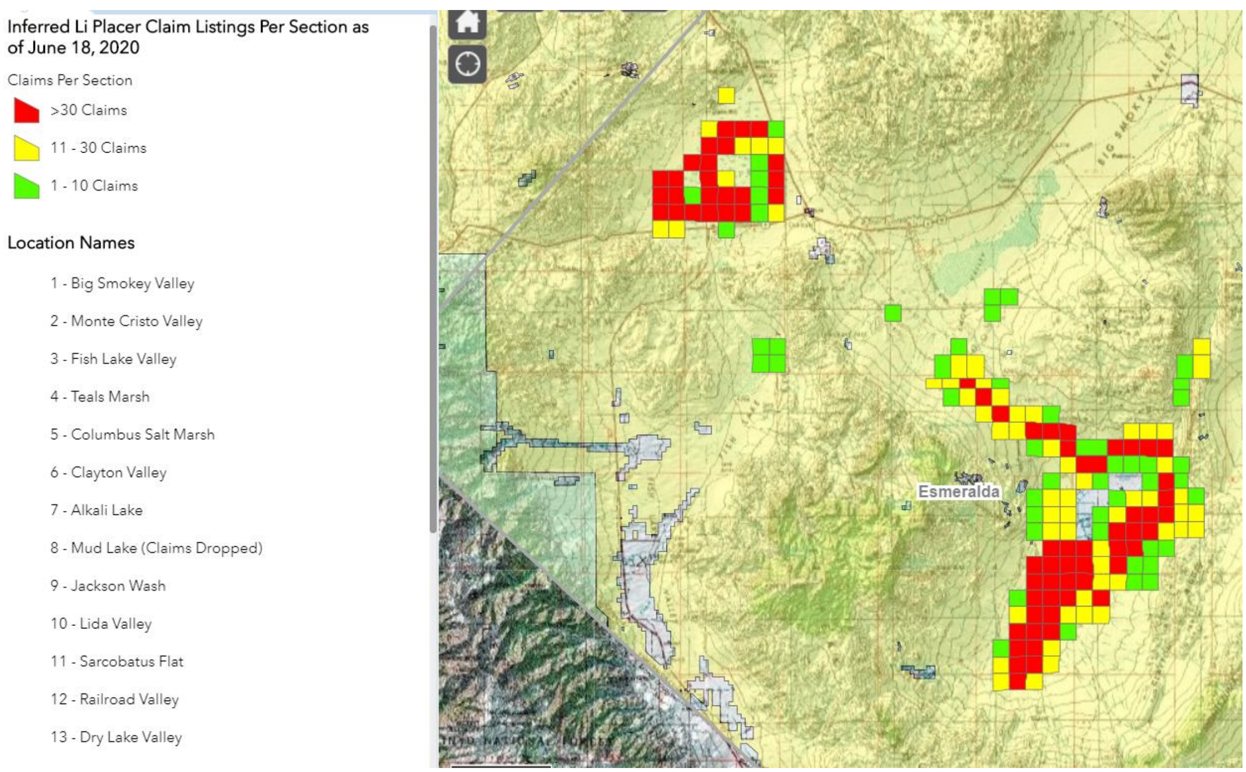


Figure 8: Lithium placer claims within Columbus Salt Marsh (north of Fish Lake Valley) and Clayton Valley (east of Fish Lake Valley). Source: Nevada Division of Minerals 2020.

Lithium Clay Mining

In addition to lithium brine production, there is an emerging market for lithium claystone mining. This involves traditional hardrock mining methods – open pit strip mining with on-site processing. This is typically targeting clays rich in lithium, boron, and other minerals. This is a novel production method, as there are no operational lithium claystone mines at scale in the world right now. Fish Lake Valley appears to be an epicenter of interest in lithium claystone mining.

The most developed lithium claystone mining project in the area is the proposed Rhyolite Ridge Mine, which is in the Silver Peak Range along an unnamed wash system which drains to Fish Lake Valley near the Hot Well. Rhyolite Ridge Mine is being developed by the Australian mining outfit Ioneer. While Rhyolite Ridge is a proposed lithium claystone mine and thus will not have the same impacts to groundwater resources that a lithium brine operation would have, Rhyolite Ridge will have impacts to groundwater resources in Fish Lake Valley and could potentially threaten the Fish Lake Valley tui chub.

First, according to the mine's plan of operations (Ioneer, 2020, p. 23), the mine will dewater its open pit at a rate of 110 gallons per minute, the equivalent of 57.8 million gallons per year or about 175 acre-feet per year. This is not a tremendous amount of water but it will incrementally decrease subsurface flow from the Silver Peak Range to the aquifers at the floor of Fish Lake Valley.

Far more concerning however is the overall water consumption of the project. Again according to the plan of operations (Ibid., p. 45), the project will consume 2,150 gallons per minute, the equivalent of 1.13 billion gallons per year or about 3,500 acre-feet per year. This is a significant amount of water. Ioneer claims they have acquired water rights to support this level of water consumption, and the plan of operations claims that all water will be sourced within the project area (Id.). This seems unlikely, as perched aquifers in volcanic formations such as the Silver Peak Range seem unlikely to occur, let alone yield 3,500 acre-feet of water per year.

American Battery Metals claims they have 1,620 acres in 81 lode mining claims in northeastern Fish Lake Valley (American Battery Metals, 2020). In 2018, American Lithium acquired 3,575 acres in 167 lode mining claims called "The Gap Lode Project," strongly implying the claims are near The Gap feature (American Lithium, 2018), where groundwater extraction could again accelerate inter-basin flow between Fish Lake Valley and Columbus Salt Marsh Valley.

6. Oil and gas

While there is not currently any oil and gas production in Fish Lake Valley, there has been in the past. On August 30, 1920, the Nevada Appeal reported, "Encountering oil from seepage at a depth of forty-five feet in the well being bored on the lower McNett Ranch, in Fish Lake valley, by the California Excelsior Oil company has been the cause of little excitement and dozens have visited for the purpose of seeing for themselves the result." (Nevada Appeal, 1920). LR2000 reveals two expired oil and gas leases NVN-026235 and NVN-038364 which had the same footprint. The latest of these leases expired in 1984. Rush and Katzer (1973, p. 10) report the drilling of an oil exploration well in the fall of 1970. Oil and gas production does not seem to be a dominant threat to the Fish Lake Valley tui chub at this time, but given geopolitical instability and uncertainty regarding future leasing of public lands for oil and gas, it is not a given that the industry won't take a closer eye at Fish Lake Valley should prices spike significantly. The concern is that groundwater would be pumped for hydraulic fracturing and that contaminants from wells would be mixed in with the groundwater being discharged at the surface.

B. Disease or predation

The tui chub has many predators, including birds and occasionally mammals (Sigler and Sigler, 1987, p. 168). Predation is also a man-made threat caused by habitat degradation (section IV. A2) and introduced species (section IV. E1).

C. Overutilization for commercial, recreational, scientific or educational purposes

Overutilization of the Fish Lake Valley tui chub for commercial, recreational, scientific or educational purposes is not known to be a factor.

D. Inadequacy of Existing Regulatory Mechanisms

There can be no question the Fish Lake Valley tui chub faces clear threats to its survival. These threats are made worse by the overall lack of protection for the tui chub's habitat.

The Fish Lake Valley tui chub is included in the Nevada Division of Natural Heritage At-Risk Plant and Animal Tracking List, which directs the data acquisition priorities of the Nevada Division of Natural Heritage and provides up-to-date information on species' status (Nevada Division of Natural Heritage, 2021b, p. 1). The Fish Lake Valley tui chub is also designated in the state of Nevada as a Sensitive Fish (NAC §503.067) and a sensitive species by the BLM (Nevada Division of Natural Heritage, 2021a). McNett Ranch is furthermore 1 of 69 Highest Priority Conservation Sites in Nevada (Nevada Division of Natural Heritage, 2006, p. 11).

At time of writing of 2012 Nevada Wildlife Action Plan, neither the species nor its habitat was protected in any way: "the single existing occupied habitat is on private land and has no specific security in place to protect the species or habitat" (Nevada Wildlife Action Plan 2012, p. 19).

It was also reported in Nevada Wildlife Action Plan (2012) that the status of the single extant population was being monitored biennially by NDOW and that the latter was developing a programmatic Candidate Conservation Agreement for the tui chub. This Agreement would support the development of conservation actions for this species where it occurs on private land. Periodic monitoring was, moreover, to occur according to the NDOW tui chub species management plan and specific conservation actions were to be developed opportunistically to restore and expand occupied and historic habitats (Nevada Wildlife Action Plan, 2012, p. 19). As far as we can tell no restoration work has yet taken place, with the tui chub last surveyed in 2007.

A Candidate Conservation Agreement would, moreover, not protect the Fish Lake Valley tui chub from effects outside of the McNett Ranch, where groundwater pumping would likely still occur and could dry up springs on the ranch. More importantly, the conservation actions would be voluntary or the result of opportunities arising and would therefore not guarantee the immediate (or long-term) protection of the tui chub.

New threats such as introduction of non-native species (see next section) may also arise over time due to the entire known population being on private land and agencies being limited in their ability to regulate and monitor such threats.

E. Other Factors

Invasive species, stochastic events and climate change are among the additional threats to the survival of the Fish Lake Valley tui chub. Each of these is discussed below.

1. Invasive species

It was noted in 1992 that "only the McNet ranch population of [Fish Lake Valley tui] chubs is healthy but goldfish have been introduced to the system" (Heinrich and Sjoberg, 1992, p. 9). Similarly, in 1993, "The McNet ranch population still remains strong although goldfish were recently introduced" (Heinrich and Sjoberg, 1993, p. 11). NDNH McNett Ranch records also reference the presence of goldfish in 1993 (p. 2): "Tui chub present, abundant, expanding into the large pond that has been created over the last couple years. Seven large goldfish were present...Only the main spring was investigated on this trip".

Multiple sources also report the presence of goldfish at Fish Lake Valley Hot Well (e.g. Travel Nevada 2020, The Ultimate Hot Springs Guide, 2020). Overflow from the concrete tub goes to adjacent natural pools surrounded by marshy vegetation (Travel Nevada, 2020). Due to the location' proximity to the ranch, hydrologic alterations, or possibly flooding (section IV. E3), could lead to mixing of surface waters.

The Fish Lake Valley tui chub was extirpated from Fish Lake in part due to the presence of exotic species. Goldfish likely competed with the tui chub for aquatic vegetation, while largemouth bass (one of the other exotic species) probably preyed on the tui chub in addition to competing for its habitat. Diseases could have also been introduced. Predation, competition, and diseases from introduced non-native fish contributed to the extirpation of the Mohave tui chub population from the Mojave river channel (Landscape Conservation Cooperative Network, 2018, p. 1). The Cabin Bar Ranch population of Owens tui chub was also extirpated in 2003 partly due to predation from introduced largemouth bass (Micropterus salmoides) and sunfish (Lepomis macrochirus) (USFWS 2009, p. 5). The High Rock Spring tui chub is presumed to have gone extinct following the "inevitable escape" of the Mozambique tilapia (Oreochromis mossambica) from a screened rearing area 100m downstream from the High Rock Spring source. The tilapia competed with and/or preyed upon the tui chubs (Moyle et al. 1995, p. 144).

2. Stochastic events

Stochasticity in the form of demographic, genetic, and environmental stochasticity, and catastrophic events, are another potential threat to the Fish Lake Valley tui chub. Demographic stochasticity is the random survival and/or reproduction variability among individuals within a population. In small populations, reduced reproduction or die-offs of a certain age-class will significantly impact the whole population. Genetic stochasticity arises from the changes in gene frequencies due to the founder effect, random fixation, or inbreeding bottlenecks (USFWS, 2009, p. 19). Founder effect is the loss of genetic variation upon establishment of a new population by a very small number of individuals. Random fixation is when some portion of loci is fixed at a selectively unfavorable allele due to insufficient selection intensity for overcoming random genetic drift. The latter occurs when only a subset of alleles in the population is transmitted to the next generation, because only a fraction of all possible zygotes become breeding adults. A bottleneck refers to an evolutionary event characterized by a significant percentage of a population being killed or prevented from breeding. In small populations, these factors may lead to less genetic diversity being retained and greater chances of deleterious recessive genes being expressed. Loss of diversity could limit the species' adaptability to environmental changes and contribute to "inbreeding depression", which is the loss of reproductive fitness and vigor. Deleterious genes could individuals' viability and reproductive success. Environmental stochasticity is the seasonal variation in birth and death rates caused by weather, disease, competition, predation, or other factors external to the population. The combination of drought or predation and a low population year could result in extinction. The environmental stochastic event can have a natural or human cause (e.g. Cabin Bar Ranch population of the Owens tui chub). Catastrophic events (e.g. severe floods or prolonged droughts) are an extreme form of environmental stochasticity (USFWS, 2009, p. 20).

3. Climate Change

The climate of Nevada is changing. Average temperatures have been increasing and 8 of the 10 warmest years since 1895 have occurred since 2000. In the near term, warming projections of 4-6°F are expected throughout the state, and reach 10-12°F in most of central and northern Nevada under a high-emissions scenario. Increasing temperatures will lead to increased water loss due to a higher evaporative demand. In the last 10 years, there has been more drought than not and the frequency and intensity of drought is suspected to increase (State of Nevada Climate Initiative, 2020). What this will likely mean for spring-fed habitat is shallower and more confined water bodies, as well as gradually warmer water temperatures.

Less precipitation is also predicted to fall as snow in Nevada and snowpacks will be more inclined to melt earlier due to the warming winters. As a result, the amount of water in April snowpacks – when snow melt usually begins to replenish streams and rivers – is projected to decrease by 30-50% by 2100 in most basins in the state (State of Nevada Climate Initiative, 2020). This will reduce the amount of surface and groundwater and shift availability to earlier in the year. Increasing air temperatures are also projected to lead to longer growing season, with plants likely demanding more water overall (State of Nevada Climate Initiative, 2020), and hence reducing the amount available to wildlife. Changes in climate can moreover increase fire risk through changes in drying and warming. Winter precipitation is projected to increase, which can lead to more vegetation and fuels growth, while increasing spring and summer evaporative demand can increase wildlife risk by faster drying of vegetation (State of Nevada Climate Initiative, 2020).

Finally, flooding may become more frequent due to more severe and more frequent storms in the future (State of Nevada Climate Initiative, 2020). The risk to McNett Ranch and northeastern portion of the Valley is unclear but past flooding events have affected the western and southern parts, presumably due to proximity to the White mountains and major surface water flows: In 1992, there was a flash flood out of Indian Creek Canyon that flooded all of the hay fields on Smith Ranch and left about 2-feet of mud and debris in the house. In 2005, Alkali Road and State Highway 264 were impassable due to flooding. In 2013, a large push of monsoon moisture lead to a prolonged period of thunderstorms across the Mojave Desert and southern Great Basin. Highway 264 was washed out at mile marker 8 due to flooding. In June 2015, an unusually late-season low pressure system combined with unusually early season deep subtropical moisture fuelled scattered thunderstorms over the Mojave Desert and southern Great Basin. Some storms produced flash flooding in Dyer, including 23 miles of road flooding. In august 2015, a flash flood event in Dyer/Fish Lake Valley closed Highway 264 for several hours, flooded agriculture fields, severely damaged surface streets and flooded one residence (Esmeralda County, 2016, p. 19-20). Negative impacts due to flooding at McNett Ranch might include altered spring pool/outflow morphology and water quality due to erosion and sedimentation, as well washing away of fish or mixing with nearby waters containing exotic species.

V. REQUEST FOR CRITICAL HABITAT DESIGNATION

The Center for Biological Diversity formally requests the Service designate critical habitat for the Fish Lake Valley tui chub concurrently with listing, as required by the ESA (16 U.S.C. 1533(a)(3A)). Critical habitat as defined by Section 3 of the ESA is: (i) the specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the provisions of section 1533 of this title, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protections; and (ii) the specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 1533 of this title, upon a determination by the Secretary that such areas are essential for the conservation of the species. 16 U.S.C. § 1532(5).

Congress recognized that the protection of habitat is essential to the recovery and/or survival of listed species, stating that “classifying a species as endangered or threatened is only the first step in ensuring its survival. Of equal or more importance is the determination of the habitat necessary for that species’ continued existence... If the protection of endangered and threatened species depends in large measure on the preservation of the species’ habitat, then the ultimate effectiveness of the Endangered Species Act will depend on the designation of critical habitat.” H. Rep. No. 94-887 at 3 (1976).

Critical habitat is an effective and important component of the ESA, without which the Fish Lake Valley tui chub's chance for survival diminishes. The Center thus requests that the Service propose critical habitat for the tui chub concurrently with its proposed listing.

Critical habitat should include all existing habitat of the Fish Lake Valley tui chub and areas with potential for recovery and determined to be important to the survival and recovery of the species. The tui chub population is restricted to one site and must be allowed to expand to other locations to prevent against stochastic events, and other threats, wiping out the entire population.

VI. CONCLUSION

The Fish Lake Valley tui chub is a narrowly endemic species that inhabits one of the most arid regions of the United States (Gordon et al., 2017, p. 123). Because of its dependence on scarce aquatic resources, the Fish Lake Valley tui chub has experienced a severe and dramatic loss of its habitat and is now critically imperiled. The only extant population is in danger of extinction due to groundwater over-appropriation from historic and prospective industries, as well as secondary threats such as grazing, aquatic plant encroachment, introduction of non-native species, stochastic events and climate change. The Fish Lake Valley tui chub therefore qualifies for protection under the Endangered Species Act.

VII. REFERENCES

1. Abele, S.L. (ed.) 2011. Nevada Springs Conservation Plan. Springs Conservation Plan Working Group. The Nature Conservancy, Reno, NV.
2. American Battery Metals, 2020. Fish Lake Valley Property. August 31, 2020.
3. American Lithium. 2018. American Lithium to expand holdings in Fish Lake Valley with acquisition of gap-lode project. Corporate News, 03/08/2018. https://www.americanlithiumcorp.com/2018/03/08/american-lithium-to-expand-holdings-in-fish-lake-valley-with-acquisition-of-gap-lode-project/ (accessed February 2021).
4. Avise, J.C. 2016. Sketches of Nature. A Geneticist's Look at the Biological World During a Golden Era of Molecular Ecology. Elsevier Inc. https://doi.org/10.1016/C2014-0-01418-9.
5. Batchelor, J.L., Ripple, W.J., Wilson, T.M. and Painter, L.E. 2015. Restoration of Riparian Areas Following the Removal of Cattle in the Northwestern Great Basin. Environmental management. DOI: https://doi.org/10.1007/s00267-014-0436-2.
6. BLM. 2019. BLM to hold geothermal lease sale September 17, 2019. Press Release, Friday August 2, 2019. Available at: https://www.blm.gov/press-release/blm-hold-geothermal-lease-sale-september-17-2019 (accessed December 2020).
7. California Department of Fish and Wildlife. 2020a. Mohave Tui Chub (*Siphateles bicolor mohavensis*). Available at: https://wildlife.ca.gov/Regions/6/Desert-Fishes/Mohave-Tui-Chub#:~:text=Mohave%20tui%20chub%20typically%20spawn,one%20to%20two%20inches%20deep (accessed December 2020).

8. California Department of Fish and Wildlife. 2020b. Five-year species review of owens tui chub (Siphateles bicolor snyderi). February 2021. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=184896&inline (accessed December 2020).
9. California Fish Website. 2020. Fish Species: High Rock Springs Tui Chub. University of California Agriculture and Natural Resources. Available at: http://calfish.ucdavis.edu/species/?uid=65&ds=698 (Accessed December 2020).
10. [Center Dixie Valley Toad petition] Center for Biological Diversity. 2017. Petition to list the Dixie Valley Toad (*Bufo (Anaxyrus) Williamsi*) as a threatened or endangered species under the Endangered Species Act. September 18, 2017.
11. Chen, Y., Parmenter, S. and May, B. Genetic relationships of tui chubs in southwestern Great Basin and management for the Mohave tui chub. *Unpublished*.
12. [DRI. 2002]. Desert Research Institute News. Summer 2002. A Snail's Tale: The amazing story of survival in North American springs and wetlands. Available at: https://www.dri.edu/wp-content/uploads/DRI-Summer-Newsletter-2002.pdf (accessed December 2020).
13. Eakin, T. E. 1950. Preliminary report on groundwater in Fish Lake Valley, Nevada and California: Nevada State Engineer's Office, Water Res Bull., no. 11, p. 7-33.
14. Esmeralda County. 2011. Master Plan Esmeralda County, Nevada. Available at: https://www.accessesmeralda.com/document_center/Es__Co___Master_Plan_adopted_Dec__7__2011.pdf (accessed December 2020).
15. Esmeralda County. 2012. Esmeralda County Water Resources Plan 2012. Available at: https://www.accessesmeralda.com/document_center/EC_Water_Resource_Plan_Dec_2012_approved_6_5_12__changes_to_be_incorporated.pdf (accessed January 2021).
16. Esmeralda County. 2016. Esmeralda County, Nevada Local Hazard Mitigation Plan. Draft. January 2016. Available at: https://www.accessesmeralda.com/January_2016_DRAFT_Esmeralda_County_LHMP.pdf (accessed January 2021).
17. Esmeralda County. 2019. Comprehensive Economic Development Strategy. Available at: https://www.accessesmeralda.com/EsmeraldaCommagenda%203-05-2019.pdf (accessed December 2020).
18. Finger, A.J. and May, B. 2015. Conservation genetics of a desert fish species: the Lahontan tui chub (*Siphateles bicolor ssp.*). Conserv Genet 16: 743-758.
19. Geologica. 2003. Evaluation of the Owens tui chub habitat. Long Valley Caldera, Mono County, California. For County of Mono Department of Economic Development and Special Projects. December 17, 2003. Available at: http://www.lewiscenter.org/documents/websites/chub%20resources/tuichubgeologica03.pdf (accessed December 2020).
20. Gordon, M.R., Simandle, E.T. and Tracy, C.R. 2017. A diamond in the rough desert shrublands of the Great Basin in the Western United States: A new cryptic toad species (Amphibia: Bufonidae: *Bufo* (*Anaxyrus*)) discovered in Northern Nevada. Zootaxa 4290 (1): 123-139.
21. Grover, M.C. 2019. Effects of groundwater fluctuations on the distribution and population structure of two cyprinid fishes in a desert spring complex. Journal of Freshwater Ecology, 34:1, 167-187, DOI: 10.1080/02705060.2019.1578699.

22. Heinrich, J.E. and Sjoberg, J.C. 1992. Status and evaluation of Nevada Fishes. In Henrickson, D.A., Pister, E.P., Findley, L.T. and Garrett, G.P. 2019. The First Fifty Years of Desert Fishes Council: Compiled Proceedings and Abstracts (1969 – 2018).
23. Heinrich, J.E. and Sjoberg, J.C. 1993. Status of Nevada Fishes. In Henrickson, D.A., Pister, E.P., Findley, L.T. and Garrett, G.P. 2019. The First Fifty Years of Desert Fishes Council: Compiled Proceedings and Abstracts (1969 – 2018).
24. Hubbs, C.L. and Miller, R.R. 1948. The Zoological Evidence: Correlation between Fish Distribution and Hydrographic History in the Desert Basins of the Western United States. In Blackwelder, E., Hubbs, C. L., Miller, R. R. and Antevs, E. (1948). The Great Basin with emphasis on glacial and postglacial times. Bulletin of the University of Utah, 38(20), 1-191. Available at: https://collections.lib.utah.edu/ark:/87278/s6w95v2t (accessed December 2020).
25. Ioneer. 2020. Plan of Operations for the Rhyolite Ridge Mine. 992 pp.
26. Junior Mining Network. 2016. Alix Acquires Fish Lake Lithium Brine Property. https://www.juniorminingnetwork.com/~jmn/junior-miner-news/press-releases/1796-tsx-venture/ili/18621-alix-acquires-fish-lake-lithium-brine-property.html (accessed February 2021).
27. Landscape Conservation Cooperative Network. 2018. Restoration: Creating Refuge for the Mohave Tui Chub at Mojave National Preserve. Updated August 2018. Available at: https://lccnetwork.org/sites/default/files/Resources/Creating%20Refuge%20for%20Mohave%20Tui%20Chub%20at%20Mojave%20National%20Preserve%20.pdf (accessed December, 2020).
28. Bloomberg. 2019. Lithium Corporation regains full control of Fish Lake Valley property. May 7, 2019. https://www.bloomberg.com/press-releases/2019-05-07/lithium-corporation-regains-full-control-of-fish-lake-valley-property (accessed February 2021).
29. Lithium Corporation. 2020. Fish Lake Valley. Available at: https://www.lithiumcorporation.com/portfolio/fish-lake-valley/ (accessed February 2021).
30. Littlefield, E.F. and Calvin, W.M. 2004. Geothermal exploration using imaging spectrometer data over Fish Lake Valley, Nevada. Remote Sensing of Environment 140: 509-518.
31. LR2000 BLM Reporting Application. Accessed November 25, 2020.
32. Miskow, E. 2020. Nevada Division of Natural Heritage. Personal Communication (November, December, 2020).
33. Moyle, P.B., Yoshiyama, R.M., Williams, J.E. and Wikramanayake, E.D. 1995. Fish Species of Special Concern in California. Second Edition. California Department of Fish and Game.
34. Moyle, P.B. 2002. Inland Fishes of California. Revised and Expanded. University of California Press.
35. National Croplands Database. 2020. Available at: https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php (Accessed November 2020).
36. NatureServe. 2021a. Fish Lake Valley Tui Chub (*Siphateles bicolor ssp. 4*). Available at: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.105276/Siphateles_bicolor_ssp_4 (Accessed March 2021).

37. NatureServe. 2021b. Tui Chub (*Siphateles bicolor*). Available at: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.101469/Siphateles_bicolor (Accessed March 2021).
38. [NDNH 1993]. Nevada Division of Natural Heritage. Fish Lake Valley Field Trip Report, July 12, 1993. Provided to the Center for Biological Diversity by Eric Miskow, December 18, 2020.
39. [NDNH 2007]. Nevada Division of Natural Heritage. Nevada Department of Wildlife native fishes and amphibians field trip report. June 4, 2007. Provided to the Center for Biological Diversity by Eric Miskow, December 18, 2020.
40. [NDNH Fish Lake records] Nevada Division of Natural Heritage. Fish Lake Valley Tui Chub monitoring records provided to the Center for Biological Diversity by Eric Miskow, November 19, 2020.
41. [NDNH McNett Ranch records] Nevada Division of Natural Heritage. Fish Lake Valley Tui Chub monitoring records provided to the Center for Biological Diversity by Eric Miskow, November 18, 2020.
42. Nevada Appeal, 2020. "Past Pages for August 29 to Sept. 1, 2020." citing article from August 29-Sept. 1, 1920.
43. Nevada Comprehensive Wildlife Conservation Strategy. Date unknown. Pp. 200-208. Available at: http://docs.springstewardship.org/PDF/200_208springs.pdf (accessed January 2021).
44. Nevada Division of Minerals 2020. Open Data Site: Lithium Exploration in Nevada. Accessed August 30, 2020.
45. Nevada Division of Natural Heritage (formerly Nevada Natural Heritage Program). 2006. Scorecard 2006: Highest Priority Conservation Sites. Carson City, Nevada.
46. Nevada Division of Natural Heritage. 2021a. Siphateles bicolor ssp. 4. Available at: http://heritage.nv.gov/taxon_detail/19870 (Accessed January 2021).
47. Nevada Division of Natural Heritage. 2021b. At-Risk Plant and Animal Tracking List January 2021. http://heritage.nv.gov/sites/default/files/library/2021-01%20Track%20List%20Jan%202021.pdf (accessed February 2021).
48. Nevada Wildlife Action Plan. 2012. Fish Lake Valley tui chub (*Gila bicolor ssp. 4*), p.19. Available at: http://www.ndow.org/uploadedfiles/ndoworg/Content/public_documents/Nevada_Wildlife/Fish.pdf (Accessed December 2020).
49. Nye County, 2004. Nye County Water Resources Plan. Department of Natural Resources and Federal Facilities. August 2004. Available at: https://www.nrc.gov/docs/ML0429/ML042950218.pdf (accessed December 2020).
50. Orloff, S.B. and Gildersleeve, R.R. 1991. Alfalfa production in the high desert. Available at: https://alfalfa.ucdavis.edu/+symposium/proceedings/1991/91-05.pdf (accessed January 2021).
51. Pahrump Valley Times. 2013. Southern Nevada eyed for geothermal potential. October 16, 2013. Available at: https://pvtimes.com/news/southern-nevada-eyed-for-geothermal-potential/ (accessed December 2020).
52. Proactive Investors. 2018. American Lithium stepping up development at Fish Lake Valley lithium project, Nevada. 16 July 2018. https://www.proactiveinvestors.com/companies/news/200875/american-lithium-stepping-

up-development-at-fish-lake-valley-lithium-project-nevada-200875.html (accessed February 2021).

53. Putnam, D., Matthews, W.A. and Sumner, D.A. 2016. Dynamic hay export growth led by China. Available at: https://aic.ucdavis.edu/publications/2016ExportSymposiumPUTNAMfinal.pdf (accessed January 2021).
54. Putnam, D.H., Matthews, W., Hanon, T. and Sumner, D. 2019. Long-term hay exports have increased dramatically, but are dampened by recent trade disputes. January 22, 2019. Available at: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=29204 (accessed January 2021).
55. Rafferty, K. 1988. Fish Lake Valley in Great Basin Prehistory. Journal of California and Great Basin Anthropology, 10(1).
56. Reheis, M.C., Slate, J.L., Sarna-Wojcicki, A.M. and Meyer, C.E. 1991. An early Pleistocene lake in Fish Lake Valley, Nevada California: Ringside resort for the eruption of the bishop tuff. Available at: https://data.nbmg.unr.edu/public/Geothermal/GreyLiterature/Reheis_FishLkVlly_PluvialLk_1991.pdf (accessed December 2020).
57. Reheis, M.C., Sarna-Wojcicki, A.M., Reynolds, R.L., Repenning, C.A. and Mifflin, M.D. 2002. Pliocene to Middle Pleistocene Lakes in the Western Great Basin: Ages and Connections. In Hershler, R., Madsen, D.B. and Curry, D.R. Great Basin Aquatic Systems History. Smithsonian contributions to the earth sciences; no. 33.
58. Reuters. 2019. Massive U.S. geothermal lease sale draws few bids. September 17, 2019. Available at: https://www.reuters.com/article/us-usa-energy-geothermal/massive-u-s-geothermal-lease-sale-draws-few-bids-idUSKBN1W22RV (Accessed December 2020).
59. Rush, E.F. and Katzer, T.L. 1973. Water resources appraisal of Fish Lake Valley, Nevada and California. Water resources – reconnaissance series report 58. State of Nevada Department of Conservation and Natural Resources, Carson City.
60. Sada, D. 1981. Area Report for the Lahontan Basin. November 19, 1981. In Henrickson, D.A., Pister, E.P., Findley, L.T. and Garrett, G.P. 2019. The First Fifty Years of Desert Fishes Council: Compiled Proceedings and Abstracts (1969 – 2018).
61. Sada, D.W. and Vinyard, G.L. 2002. Anthropogenic Changes in Biogeography of Great Basin Aquatic Biota. In Hershler, R., Madsen, D.B. and Curry, D.R. Great Basin Aquatic Systems History. Smithsonian contributions to the earth sciences; no. 33.
62. Sigler, W.F. and Sigler, J.W. 1987. *Fishes of the Great Basin*. Reno: University of Nevada Press.
63. State of Nevada Climate Initiative. 2020. Nevada's Climate Strategy. Available at: https://climateaction.nv.gov/policies/climate-nv/ (accessed January 2021).
64. State Engineer. 2013. Fish Lake Valley hydrographic basin 10-117. Groundwater pumpage inventory. Water year 2013. State of Nevada Department of Conservation and Natural Resources Division of Water Resources.
65. State Engineer. 2019. Fish Lake Valley hydrographic basin 10-117. Groundwater pumpage inventory. Water year 2019. State of Nevada Department of Conservation and Natural Resources Division of Water Resources.

66. Suverly, N. 2000. 2000-2001 Esmeralda County Agricultural Statistics, University of Nevada Cooperative Extension. Available at: https://extension.unr.edu/publication.aspx?PubID=2417 (accessed December 2020).
67. The Nevada Independent. 2019. Large-scale solar, wind and geothermal energy developers hit project headwinds on public land. April 21, 2019. Available at: https://thenevadaindependent.com/article/large-scale-solar-wind-and-geothermal-developers-hit-project-headwinds-on-public-land (accessed December 2020).
68. The Ultimate Hot Springs Guide. 2020. Fish Lake Hot Springs. Available at: http://www.ultimatehotspringsguide.com/fish-lake-hot-springs.html (accessed January 2021).
69. Travel Nevada. 2020. Fish Lake Valley Hot Springs. Available at: https://travelnevada.com/hot-springs/fish-lake-valley-hot-springs/ (accessed December 2020).
70. USDA. 2012. Part 650 Engineering Field Handbook National Engineering Handbook. Chapter 12 Springs and Wells.
71. USFWS. 1982. Endangered and Threatened Wildlife and Plants; Review of Vertebrate Wildlife for Listing as Endangered or Threatened Species. Federal Register, Vol. 47, No. 251. Thursday, December 30, 1982. Proposed Rules. Available at: https://ecos.fws.gov/docs/federal_register/fr650.pdf (Accessed December 2020).
72. USFWS. 1984. Mohave Tui Chub. *Gila Bicolor Mohavensis*. Recovery Plan. Available at: https://ecos.fws.gov/docs/recovery_plan/840912.pdf (accessed December 2020).
73. USFWS. 1985a. Endangered and Threatened Wildlife and Plants; Review of Vertebrate Wildlife. Federal Register, Vol. 50, No. 181. Wednesday, September 18, 1985. Proposed Rules. Available at: https://ecos.fws.gov/docs/federal_register/fr1022.pdf (Accessed December 2020).
74. USFWS. 1985b. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Hutton Tui Chub and Foskett Speckled Dace. Available at: https://ecos.fws.gov/docs/federal_register/fr934.pdf (accessed December 2020).
75. USFWS. 1989. Endangered and Threatened Wildlife and Plants; Animal Notice of Review. Federal Register, Vol. 54, No. 4, Friday, January 6, 1989, Proposed Rules. Available at: https://ecos.fws.gov/docs/federal_register/fr1510.pdf (Accessed December 2020).
76. USFWS. 1991. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species. Federal Register, Vol. 56, No. 225. Thursday, November 21, 1991. Proposed Rules. Available at: https://ecos.fws.gov/docs/federal_register/fr1973.pdf (Accessed December 2020).
77. USFWS. 1994. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species. Federal Register, Vol. 59, No. 219. Tuesday, November 15, 1994. Proposed Rules. Available at: https://ecos.fws.gov/docs/federal_register/fr2729.pdf (Accessed December 2020).
78. USFWS. 2009. Owens Tui Chub (*Siphateles bicolor snyderi* = *Gila bicolor snyderi*). 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service Venture Fish and Wildlife Office Ventura, California, May 19, 2009.
79. USFWS. 2020. Hutton tui chub. Oregon Fish and Wildlife Office. Available at: https://www.fws.gov/oregonfwo/articles.cfm?id=149489439 (Accessed December 2020).

80. VEA. 2016. Western Outreach - VEA Comments. Valley Electric Association, Inc. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=213617&DocumentContentId=23041 (Accessed February 2021).
81. Williams, C.D. and Williams, J.E. 1981. Distribution and status of native fishes of the Railroad Valley system, Nevada. Cal-Neva Wildlife Transactions 1981, pp. 48-51.