U.S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT
AND LISTING PRIORITY ASSIGNMENT FORM
March 14, 2023

SCIENTIFIC NAME: *Lirceolus smithii*

COMMON NAME: Texas Troglobitic Water Slater

LEAD REGION: Region 2

LEAD REGION CONTACT: Southwest Regional Office, Ecological Services, Susan Oetker, susan_oetker@fws.gov

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DATE INFORMATION CURRENT AS OF: September 2023

STATUS/ACTION

___Species petitioned for listing which we have determined is not a listable entity

_X_ Species petitioned for listing which we have determined does not warrant listing (does not meet the definition of a threatened or endangered species)

___Non-listed species for which we have not received a petition but for which we have undertaken a species status assessment on our own initiative and which we have determined does not warrant listing (does not meet the definition of a threatened or endangered species)

Petition Information:
___ Non-petitioned
_X_ Petitioned; Date petition received: 6/25/2007
90-day “substantial” finding FR publication date; citation: 12/16/2009, 74 FR 66866

PREVIOUS FEDERAL ACTIONS:

On June 25, 2007, the U.S. Fish and Wildlife Service (Service) received a petition dated June 18, 2007, from Forest Guardians (i.e., WildEarth Guardians) requesting that the Service list 475 species, including the Texas troglobitic water slater (Forest Guardians 2007, p. 19), as threatened or endangered species and designate critical habitat under the Endangered Species Act (Act). All 475 species occur within the Southwest Region and were ranked as G1 or G1G2 species by NatureServe at the time. In a July 11, 2007, letter to the petitioner, the Service acknowledged receipt of the petition and stated that the petition was under review by staff in the Southwest Regional Office. On December 16, 2009, the Service published a partial 90-day finding on the Texas troglobitic water slater and 191 other species, stating that the petition presented substantial scientific information indicating that listing may be warranted for 67 of the 192 species (74 FR 66866). This document constitutes our 12-month finding on the June 25, 2007, petition to list Texas troglobitic water slater under the Act.

ANIMAL GROUP AND FAMILY: Crustraceans, Asellidae

ANALYTICAL FRAMEWORK

To assess the viability of the Texas troglobitic water slater, we conducted a species status assessment (SSA) using the three conservation biology principles of resiliency, redundancy, and representation (the “3 Rs”; Shaffer and Stein 2000, pp. 306–311). Briefly, resiliency supports the ability of the species to withstand environmental and demographic stochasticity (for example, wet or dry, warm or cold years, variation in demographic rates), redundancy supports the ability of the species to withstand catastrophic events (for example, droughts, large pollution events), and representation supports the ability of the species to adapt to both near-term and long-term changes in its physical and biological environment (for example, climate change, disease). A species with a high degree of resiliency, representation, and redundancy is better able to adapt to novel changes and to tolerate environmental stochasticity and catastrophes. In general, species viability will increase with increases in resiliency, redundancy, and representation (Smith et al. 2018, p. 306). Using these principles, we identified the species’ ecological requirements for survival and reproduction at the individual, population, and species levels, and described the beneficial and risk factors influencing the species’ viability.

We use the SSA framework to assemble the best scientific and commercial data available for this species. The SSA framework consists of three sequential stages. During the first stage, we evaluate the species’ needs. The next stage involves an assessment of the historical and current condition of the species’ demographics and habitat characteristics, including an explanation of how the species arrived at its current condition (i.e., how threats and conservation actions have influenced the species). The final stage of the SSA framework involves assessing the species’ plausible range of future responses to positive and negative environmental and anthropogenic influences. The SSA framework uses the best available information to characterize viability as the ability of a species to sustain populations in the wild over time and is used to inform our regulatory decision.

The SSA report does not represent a decision by the Service on whether the Texas troglobitic water slater should be listed as an endangered or threatened species under the Act. However, it does provide the scientific basis that informs our regulatory decisions, which involve the further application of standards within the Act and its implementing regulations and policies. The Species Status Assessment Report for the Texas Troglobitic Water Slater (*Lirceolus smithii*) – January 2023, Version 1.1 (SSA Report) is a summary of the information we have assembled and reviewed and incorporates the best scientific and commercial data available for this species. Excerpts of the SSA Report are provided in the sections below. For more detailed information, please refer to the SSA Report (Service 2023 entire).

BIOLOGICAL INFORMATION

The Texas troglobitic water slater is a minute, aquatic subterranean crustacean located in the artesian zone of the southern segment (also referred to as the San Antonio segment) of the Edwards (Balcones Fault Zone) Aquifer (herein referred to as the "Edwards Aquifer") in Hays County, Texas. Texas troglobitic water slaters are expelled from the artesian zone of the Edwards Aquifer through artesian wells and springs, with the species likely occupying depths somewhere between 60 meters (m) (197 feet (ft)) to 152 m (498 ft) below the surface as indicated by their primarily non-photosynthetic diet and high well mortality relative to other collected subterranean taxa (potentially indicating a longer distance traveled to the surface) (Bowman and Longley 1976 pp. 489–490; Lewis and Bowman 1996 p. 483; Hutchins et al. 2016 p. 1536; Schwartz et al. 2018 pp. 6, 17; Texas Water Development Board 2021 unpaginated; Service 2023 p. 44). This species of water slater has been collected from three discharge sites: the San Marcos artesian well, Diversion Spring, and the training area well (sometimes referred to as Spring Lake outflow well) (all collectively located within the San Marcos Springs) (Service 2023 p. 18; Figure 1). These sites are all within 600 m (2,000 ft) of each other and in close proximity (less than approximately 100 m [330 ft]) to the freshwater/saline-water zone of the Edwards Aquifer (Hutchins et al. 2021 p. 2).

Aquifer habitats are characterized by the absence of light, relatively stable physiochemical properties, and can be buffered against abrupt changes, depending on their distance from surface and terrestrial inputs (Hutchins et al. 2016 pp. 1532–1533). Pore spaces serve as microhabitats for subterranean invertebrates, and thus the sizes of the pore space select for smaller and more elongated invertebrates with certain physiological characteristics (Danielopol et al. 1994 pp. 218–221; Howarth and Moldovan 2018 pp. 56, 58). The Texas troglobitic water slater lives in these water-filled voids within the aquifer, although the species has never been directly observed in its natural subterranean habitat and thus its specific habitat preferences are not known. Since the water slater is the smallest known member of the genus and has a slender body, sheltering in pore spaces may also be an adaptation to avoid larger taxa (i.e., niche-partitioning) by hiding in pores that accommodate their smaller size as seen in other subterranean environments of the world (Leys et al. 2003 pp. 2819, 2830; Fišer et al. 2019 pp. 1213, 1220–1221; Dumnicka et al. 2020 pp. 4–5; Borko et al. 2021 pp. 2–3). Observations of congeneric species indicates the capacity for high rates of reproduction and benthic (crawling) movement of the species (Service 2023 pp. 35–36). Stable isotope data suggests the Texas troglobitic water slater is relatively low on the food web, serving as a benthic forager and/or scraper (Hutchins et al. 2016 pp. 1536–1537, 1539). The primary type of food consumed by the Texas troglobitic water slater is produced at the freshwater/saline-water interface, which likely necessitates that the species live within close proximity to this interface (Service 2023 p. 37; Figure 1). The microbial communities in the deeper portions of the Edwards Aquifer are supported by chemolithoautotrophic organic matter (i.e., energy derived from organisms like sulfur-reducing bacteria that derive energy from inorganic compounds) and surface-derived photosynthetic organic matter (i.e., energy derived from light energy and other organic compounds by plants, algae, and bacteria) (Sarbu et al. 1996 entire; Birdwell and Engel 2009 p. 154; Gray and Engel 2013 pp. 329–331, 333; Hutchins et al. 2013 pp. 255–256). Microbial reduction of sulfate to organic molecules can form the basis of diverse deep surface food webs, including karst systems (Engel 2007 pp. 188–190, 194; Brad et al. 2021 pp. 1–4).

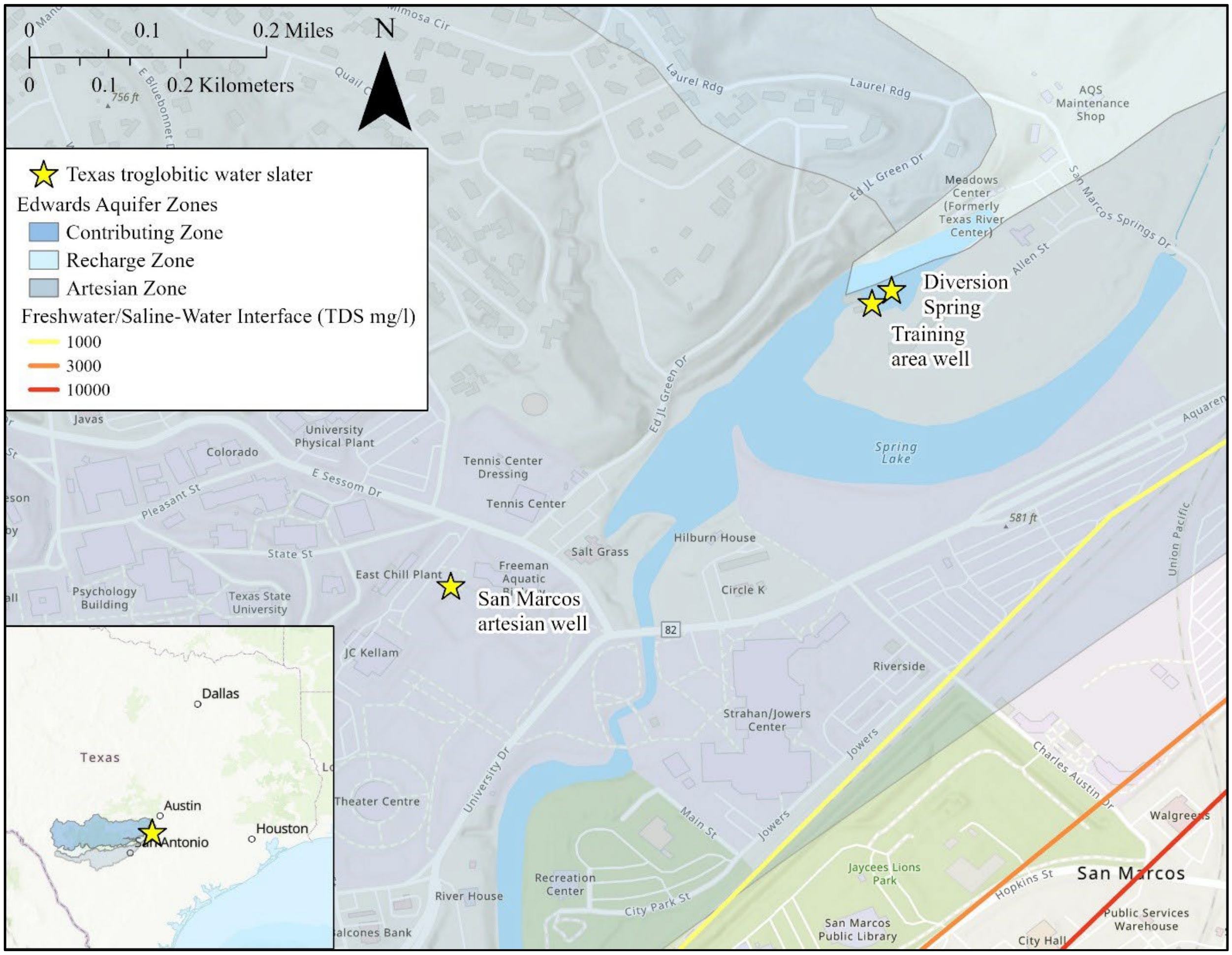

Figure 1. Texas troglobitic water slater collection sites (star symbols) in the City of San Marcos, Hays County, Texas.

For additional information on the species description, taxonomy, habitat/life history, historical and current range/distribution please refer to pp. [16–38 of the SSA report. For additional information on population and species needs, please refer to pp. [39–40] of the SSA report.

FACTORS INFLUENCING THE STATUS

The Act directs us to determine whether any species is an endangered species or a threatened species because of any factors (or threats) affecting its continued existence (i.e., whether it meets the definition of a threatened species or an endangered species). We use the term “threat” to refer in general to actions or conditions that are known to or are reasonably likely to negatively affect individuals of a species. The term “threat” includes actions or conditions that have a direct impact on individuals, as well as those that affect individuals through alteration of their habitat or required resources. The term “threat” may encompass—either together or separately—the source of the action or condition, or the action or condition itself.

However, the mere identification of any threat(s) does not necessarily mean that the species meets the statutory definition of an “endangered species” or a “threatened species.” In determining whether a species meets either definition, we must evaluate all identified threats by considering the expected response by the species, and the effects of the threats—in light of those actions and conditions that will ameliorate the threats—on an individual, population, and species level. We evaluate each threat and its expected effects on the species, then analyze the cumulative effect of all of the threats on the species as a whole. We also consider the cumulative effect of the threats in light of those actions and conditions that will have positive effects on the species—such as any existing regulatory mechanisms or conservation efforts. The Secretary determines whether the species meets the definition of an “endangered species” or a “threatened species” only after conducting this cumulative analysis and describing the expected effect on the species now and (if evaluating whether a species is a threatened species) in the foreseeable future.

Threats, Conservation Measures, and Existing Regulatory Mechanisms

Reductions in Groundwater Quantity

Groundwater quantity may be reduced by several sources, including pumping and development. These are discussed below.

Groundwater Pumping

Springflows at San Marcos Springs are tied inseparably to water usage from the Edwards Aquifer (LBG-Guyton Associates et al. 2004 p. B-42). Water levels of the Edwards Aquifer are dynamic and fluctuate with recharge (i.e., distribution, amount, and intensity of rainfall) and discharge (i.e., wells or springs) (Buszka 1987 pp. 24–27; Maclay 1995 pp. 48, 52; Worthington 2003 p. 4; Lindgren et al. 2004 pp. 40–41, 45). Removal of groundwater to meet municipal, industrial, and agricultural irrigation uses from an aquifer leads to water level decline, especially if discharge of groundwater significantly exceeds recharge (Guyton & Associates 1979 pp. 11, 79; Alley et al. 2002 p. 1986; Lindgren et al. 2004 p. 41; de Graaf et al. 2019 pp. 92–93)

Artesian well infrastructure use in the Edwards Aquifer has existed since the 1880s but was not utilized heavily until the 1950s (Votteler 1999 p. 5). Groundwater that historically discharged at spring opening was later diverted to artificial wells after development, decreasing discharge to streams and springs after 1970. The highest water use was in 1989 (Kuniansky and Holligan 1994 p. 32; Mace 2019 p. 210).

Prolonged dry periods result in aquifer water level declines, but aquifer water levels rebound rapidly with return of precipitation (Petitt, Jr. and George 1956 p. 49). Groundwater discharge exceeded recharge during several droughts since 1970 (Maclay 1995 p. 40; Mace 2019 pp. 208, 210). However, historical analyses of the southern segment of the Edwards Aquifer indicates that despite intensive pumping and drought, the region did not experience substantial declines in water levels and no net loss in aquifer storage (Maclay 1995 pp. 48, 52; Lindgren et al. 2004 pp. 40–41, 45).

San Marcos Springs is the second largest spring system in Texas and historically exhibited the most consistent flow and environmental stability of any spring system in the southwestern United States. Fluctuations in spring discharge occur often, but springflow has never ceased in recorded history, even during multiple droughts, including the drought of record (Nace and Pluhowski 1965 pp. 81–87; Ogden et al. 1986 pp. 117–118; LBG-Guyton Associates et al. 2004 p. B45; Johnson and Schindel 2008 p. 18). The regional downgradient flowpath to San Marcos Springs ensured the continuation of springflow during the drought of record at this location. Because of both current groundwater regulations and this downward slope towards San Marcos Springs, it is likely that it will continue to have springflow even with extreme future droughts (LBG-Guyton Associates et al. 2004 p. B-42; Ding and McCarl 2019 pp. 10–11).

Groundwater pumping that exceeds recharge rates within the Texas troglobitic water slater range could cause a reduction in groundwater flow. This reduced flow could lead to lower water levels in the aquifer and reduce oxygenated freshwater and accessible wetted pore spaces, potentially impacting the Texas troglobitic water slater by reducing available habitat (Konikow and Kendy 2005 p. 317). Our analysis showed 93 active wells within the localized area of influence and at depths where the species occurs (Service 2023 pp. 44–45). This localized area of influence encompasses the area around the species' capture sites with direct flowpath connections, and therefore would be the area that likely contributes to immediate groundwater contamination and groundwater reduction through well extraction (Service 2023 pp. 71–72). Municipal, industrial, and agricultural irrigation uses in this area of influence are not substantial groundwater extractors compared to large municipal and agricultural irrigation wells within the City of San Antonio, Texas and further west.

Current regulations that limit the use of groundwater also benefit the Texas troglobitic water slater. If current regulations remain in place, the use of groundwater is not expected to negatively influence the Texas troglobitic water slater (Lang 1954 p. 47; Ding and McCarl 2019 pp. 10–11; Mace 2021 pp. 32–34). Between 1997 to 2014, regulations preserved 3.2 million megaliters (2.6 million acre-feet) for springflows, securing groundwater quantity conditions for the Texas troglobitic water slater and its deeper habitat (Hamilton and Winterle 2017 entire). Species that rely on springs at the surface are at higher risk of losing habitat than species that live at deeper depths in the aquifer, such as the Texas troglobitic water slater (LBG-Guyton Associates et al. 2004 p. C–6). We do not have evidence that springflow rates are currently inadequate or unsuitable for Texas troglobitic water slater viability and habitat connectivity underground.

Development

Urban sprawl that accompanies rapidly growing metropolitan populations can lead to substantial loss of natural habitat and species abundance for subterranean endemics, including the Texas troglobitic water slater (Culver and Pipan 2009 pp. 185–186, 200–207; Krejca and Reddell 2019 pp. 165–167). Conversion of natural habitat to urban, suburban, and exurban development is likely to accompany this population growth. These land-use changes have the potential to alter recharge rates (whether increased or decreased) and sources of recharge to the landscape and aquifer (Fahlquist and Ardis 2004 p. 16; Sharp 2010 pp. 3–4; Passarello et al. 2012 p. 34; Guerra and Debbage 2021 pp. 2–3). In scenarios where droughts were projected to increase in occurrence and duration, economic losses from irrigated lands would shift competing water rights interests to municipal and industrial uses which creates the need to incorporate adaptive strategies to limit pumping and thus implications to potential ecological changes and stress to subterranean habitat condition (Ding and McCarl 2019 pp. 10–11).

Several counties that lie within the recharge and contributing zones that feed San Marcos Springs (Kendall, Travis, Hays, and Comal) were ranked among the fastest growing in the United States from April 2010 to July 2019 (U.S. Census Bureau 2020 unpaginated). Projections indicate that the human populations of several counties feeding the San Marcos Springs (Bexar, Comal, Hays, and Kendall) will continue to increase substantially over the next three decades (Texas Demographic Center 2021 unpaginated). Since 2000, Hays County has doubled in population and has seen substantial urban development within city limits. The draft preferred scenario map prepared by the City of San Marcos expects more development (estimated 42,000 to 64,000 new homes for the entire city) and roads in the recharge zone northwest of the city, which could negatively influence the quality and quantity of groundwater near Texas troglobitic water slater sites (City of San Marcos 2023a unpaginated, 2023b p. 144).

The dominant land cover in the Upper San Marcos River Watershed is forest (Nowlin and Schwartz 2012 p. 39). Clusters of Ashe juniper (*Juniperus ashei*) and live oaks (*Quercus virginiana*) increase soil infiltrability (via root action bypassing the soil and enlarging the joints directly into the limestone), can enhance groundwater recharge, add gains in streamflow, and reduce runoff (Wilcox et al. 2008 p. 4; Sassen et al. 2009 pp. 435–437; Leite et al. 2020 entire). Subterranean recharge is strongly related to the amount of vegetated land surface because loss of vegetated cover reduces infiltration and evapotranspiration (Barnes et al. 2018 pp. 5206, 5209; Burri et al. 2019 p. 140). The replacement of native plants with impervious cover, lawns, and gardens that require more water ultimately alters groundwater dynamics (Sharp 2010 p. 4; Burri et al. 2019 p. 140). Therefore, development that replaces forested land may affect aquifer water recharge and alter Texas troglobitic water slater habitat.

Groundwater Contamination

The Edwards Aquifer is vulnerable to contamination (Mahler and Musgrove 2019 p. 240; EAHCP 2020 pp. 4151). Groundwater flowpaths transport water containing minerals, food resources (e.g., organic matter), and anthropogenic contaminants (e.g., pesticides, personal care products) throughout the artesian zone of the Edwards Aquifer (Gibert et al. 1994 p. 446; Mahler and Musgrove 2019,entire). Because of the complexity of the flowpaths, once a source of pollution enters groundwater, it can be difficult if not impossible to track, intercept, and remediate (Humphreys 2011 p. 297; Becher et al. 2022 p. 2).

The artesian zone in the southern segment of the Edwards Aquifer is covered by low permeability rocks that afford some protection from direct entry of surface contaminants (Clark 2000 p. 6; Humphreys 2011 pp. 285–289; Musgrove et al. 2019 p. 14). However, faults within these strata can contribute unfiltered contaminants to the underlying aquifer, thus contributing to the possibility of contamination in close proximity to Texas troglobitic water slater habitat (Livingston et al. 1936 p. 70; Ford and Williams 2007 pp. 31–35, 104, 112–114; Stafford and Arens 2014 p. 13). The recharge zone is most likely to introduce contaminants because it is exposed at the surface of the aquifer and is composed of highly porous and permeable rock layers (Clark 2000 pp. 1–2, 8–9; Opsahl et al. 2018 p. 58; Mahler and Musgrove 2019 pp. 245–246).

With adequate springflows or recharge events (e.g., storms) these contaminants can be diluted over distance and time and “flushed” through discharge points, such as springs or wells (Gibert et al. 1994 p. 446; Marmonier et al. 2013 pp. 128–129). Groundwater flowpaths traveling north are diluted with local recharge as they reach San Marcos Springs (Johnson and Schindel 2008 pp. 45–47).

There are currently no instances where degraded water quality has been documented at the Texas troglobitic water slater sites, and the most recent water quality report states that San Marcos Springs’ water is of high quality with a limited number of detectable compounds (SWCA 2021 p. 74). Preliminary studies in the San Antonio, Texas area suggested that groundwater contaminants are most prevalent at relatively shallow aquifer depths in the southern segment of the Edwards Aquifer. Greater amounts of contaminants occurred in shallow areas of the recharge zone, particularly in areas with urban land uses, and the number and concentration of contaminants present in groundwater wells decreased with depth (Musgrove et al. 2014 pp. 69–70; Opsahl et al. 2018 p. 58), and contaminants have not been detected at the depths where the Texas troglobitic water slater occurs.

The presence of agriculture, residential and commercial developments, industrial facilities, military installations, and transportation infrastructure correlates with increased presence of pollutants (Fahlquist and Ardis 2004 p. 7; Johnson et al. 2009 p. 46; Musgrove et al. 2014 pp. 67–71; Opsahl et al. 2018 pp. 17–30). Semi-volatile organic compounds have been detected in low levels at San Marcos Springs, which are less mobile than volatile organic compounds and are associated with site-specific incidents from fuels, or sealants for asphalt parking lots (Johnson and Schindel 2014 pp. 23, 27). Oil and gas transmission pipelines are another potential source of hazardous material spills on the contributing and recharge zones of the aquifer. Between 1987 to 2021, there were 35 petroleum storage tank leaks in the Edwards Aquifer recharge zone (Texas Commission on Environmental Quality 2022a unpaginated; U.S. Environmental Protection Agency 2022 unpaginated). However, many of the current sources of contamination (e.g., septic and sewer lines, nonpoint source runoff, and/or ill-maintained water wells) detected in groundwater and spring water samples for the Edwards Aquifer do not exceed protective concentration levels established by the Texas Commission on Environmental Quality (TCEQ) (Johnson and Schindel 2014 pp. 59, 63). During the 1990s, the Edwards Aquifer Authority tested for industrial pollution. Finding that the aquifer maintained high water quality standards, the Edwards Aquifer Authority later discontinued this testing program. (Edwards Aquifer Authority 2021a entire; Edwards Aquifer Authority 2021b unpaginated).

Within the local area of influence for the Texas troglobitic water slater, there are 12 wells with available water quality data which have been sampled sporadically over the last 20 years. The most common variables assessed were chloride, nitrate, and total dissolved solids. The average values for these three variables were below the Environmental Protection Agency's drinking water quality standards (U.S. Environmental Protection Agency 2009 entire). One well (State Well Number 5857802) had two nitrate samples (i.e., 12 mg/l; 20 mg/l) that exceeded the drinking water quality standard of 10 mg/l. This well is the furthest and slowest dye trace tied to a Texas troglobitic water slater site (Diversion Spring). Contaminants would likely dilute with recharge across this distance leading to minimal impact on Texas troglobitic water slater habitat upon arrival at Diversion Spring.

While contamination events have impacted fauna in relatively shallow subterranean systems, it is unknown if these impacts would similarly impact species further separated from surface pollution (Dickson et al. 1979 p. 11; Simon and Buikema 1997 pp. 392–399; Elliott 2000 pp. 675–681; Graening et al. 2013 pp. 1503–1506). Due to the lack of studies and barriers to researching these subterranean species, at this time there is no consensus if subterranean species are more or less tolerant to contamination than surface species (Castaño-Sánchez et al. 2020 p. 10; Manenti et al. 2021 p. 8). Isopods are generally tolerant to pollutants (e.g., subterranean *Caecidotea recurvata* and riverine *Asellus aquaticus*), but the current best available information does not indicate if this applies to the subterranean population of the Texas troglobitic water slater (Aston and Milner 1980 pp. 1, 12–13; Simon and Buikema 1997 pp. 398–399). Regardless, there is limited evidence for persistent and elevated levels of contamination at a local scale around Texas troglobitic water slater sites.

Climate Change

Anthropogenic climate change has the potential to impact groundwater quantity in the southern segment of the Edwards Aquifer (Green et al. 2011 pp. 538–546; Kløve et al. 2014 pp. 252–253, 258; U.S. Global Climate Change Research Program 2017 p. 14; Wineland et al. 2022 pp. 8–10). The Edwards Aquifer relies on rainfall for recharge through highly permeable rock and is vulnerable to short-term climate change effects such as changes in precipitation, temperature, and drought occurrences (Mace and Wade 2008 p. 659; Taylor et al. 2013 p. 312; Ding and McCarl 2019 p. 11; Nielsen-Gammon et al. 2020 p. 9). While average rainfall is not projected to change significantly in central Texas, the distribution of precipitation is anticipated to change with more extreme droughts and extreme rain events by 2100, ultimately altering surface run-off and aquifer recharge (Chen et al. 2001 p. 398; Geos Institute 2015 pp. 14–15; Chakraborty et al. 2021 p. 2). Additionally, regional population growth and development could exacerbate the effects of decreased water supply during droughts (U.S. Global Change Research Program 2018 p. 1002–1003).

Extreme droughts in Texas are more likely than they were 40 to 50 years ago (Rupp et al. 2012 p. 1054; Nielsen-Gammon et al. 2020 entire). This is exacerbated by increasing temperatures, which creates drier conditions due to increased evapotranspiration (Benz et al. 2016 entire; Loáiciga and Schofield 2019 p. 224). It is not possible to ensure there will be sufficient groundwater levels and adequate flow to these springs without planning for more extreme droughts than the drought of record (Loáiciga and Schofield 2019 p. 236; Mace 2019 p. 212). The sustainable water yield for the Edwards Aquifer will decrease in a dry climate while human demand for groundwater will increase, making it more challenging to balance groundwater use for human needs and ecosystem function (EARIP HCP 2012 pp. 3-10–3-11, 3-12, 3-31, 3-43; Loáiciga and Schofield 2019 pp. 223, 235–236).

Average annual air temperature in Texas has risen 1°C (2°F) since the early 1900s (Geos Institute 2015 p. 4). Future air temperature changes will depend on the amount of future greenhouse gas emissions (U.S. Global Change Research Program 2018 p. 995). Based on current projections of greenhouse gas emissions, air temperature is projected to increase 2.0 to 2.8 °C (3.6 to 5.1 °F) by 2050, and 2.4 to 4.7 °C (4.4 to 8.4 °F) by 2100 for the southern Great Plains (U.S. Global Change Research Program 2018 p. 995). Climate projections for this region predict a greater rise in air temperature by 2100, 2.7 to 5.6 °C (5 to 10 °F) (Sharif 2018 p. 4). Studies have not explicitly addressed groundwater temperature increases for the Edwards Aquifer. Based on other aquifer research, it is reasonable to expect that groundwater temperature will increase as air temperature increases, with a possible lag in groundwater temperature increase (Mahler and Bourgeais 2013 p. 295). Groundwater temperature also increases with urbanization and vegetation removal (Sharp 2010 p. 2; Benz et al. 2017 entire; Böttcher and Zosseder 2022 pp. 8, 10–11).

For ectothermic animals like the Texas troglobitic water slater, overall vulnerability to climate change will depend on thermal sensitivity and how quickly their buffered environment changes (Pallarés et al. 2021 p. 487; Delić et al. 2022 p. 2). Increased temperatures can alter mobilization of contaminants (i.e., change in recharge rates), stimulate metabolic processes, and disrupt biogeochemical processes (e.g., carbon or nitrogen cycle) (Kløve et al. 2014 p. 263; Castaño-Sánchez et al. 2020 p. 7; Simčič and Sket 2021 entire; Becher et al. 2022 pp. 4–5). Some subterranean species would likely be incapable of adapting to modified temperatures in the medium to long-term and unable to flee rising temperatures (Culver and Pipan 2009 pp. 207–208; Mermillod-Blondin et al. 2013 pp. 1691–1692; Taylor et al. 2013 pp. 324–325; Mammola et al. 2019 p. 646).

The best available information does not indicate whether increased temperatures will affect different life stages or reproduction of the Texas troglobitic water slater, or how quickly groundwater temperature will change in the Edwards Aquifer in response to climate change at the surface.

Mortality from Groundwater Wells

Texas troglobitic water slaters collected from the San Marcos artesian well may originate either from flowpaths directly under the well or infrequently from further away in the aquifer (Hutchins et al. 2021 p. 12). A species' biology (e.g., swimming ability) or a storm event can predispose individuals to discharge more frequently through wells, but this is not the case for Texas troglobitic water slaters from the San Marcos artesian well (Hutchins et al. 2021 pp. 12–14). The benthic nature of the species may make it less susceptible to well capture and their likely high reproductive rates mean the species is less sensitive to population-level impacts from well mortality.

When the Texas troglobitic water slater is expelled from the San Marcos artesian well, it travels long distances to the surface, and individuals often suffer physical damage and potential mortality due to rapid changes in water temperature or depressurization at the surface (Schwartz et al. 2018 pp. 2, 17; Coleman 2020 pers. comm., Hutchins 2021 pers. comm.). The individuals that survive expulsion do not live more than a month in captivity (Schwartz et al. 2018 p. 17; Service 2019 pp. 39–40).

There are 85 active wells within the localized area of influence and at depths where the species occurs (Service 2023, pp. 44–45). On average, three wells were drilled per year from 2000 to 2020, with no new wells drilled in the area since July 2020 (Texas Water Development Board 2021 unpaginated). We assume new aquifer disturbances have been minimized in comparison to historical aquifer over-utilization because of the modern improvements in pumping technologies, plugging of abandoned or derelict wells, and the implementation of permits and pumping restrictions regulated by groundwater conservation districts (Guyton and Associates 1979, pp. 11, 15; Hamilton and Winterle 2017 entire; Mace 2019 pp. 208–210).

We do not know to what magnitude wells negatively impact the Texas troglobitic water slater population or if these events are stochastic. While we are aware of some impacts at an individual level, the best available information does not allow us to determine how many of these wells intersect habitats where the Texas troglobitic water slater occurs because the majority of these sites have not been surveyed for the species. Based on the continued collection of the Texas troglobitic water slater and relatively low pumping rate at the San Marcos artesian well, as well as the species' benthic nature and high reproductive rate, we assume that groundwater pumping through wells has not greatly reduced the Texas troglobitic water slater population.

Conservation Measures and Existing Regulatory Mechanisms

Edwards Aquifer Authority

In the early 1990s, federal litigation (i.e., Sierra Club vs. Secretary of the Interior [No. MO-91-CA-069] United States District Court for the Western District of Texas) led to the creation of the Edwards Aquifer Authority (historically referred to the as Edwards Underground Water District) in 1993 by the State of Texas to manage groundwater withdrawals (i.e., by nonexempt wells) from the southern segment of the Edwards Aquifer (National Research Council 2015 pp. 24–26; Hardberger 2019 pp. 193–194; Payne et al. 2019 p. 199). The regulatory area of the Edwards Aquifer Authority includes all or a portion of Bexar, Comal, Hays (where the Texas troglobitic water slater occurs), Uvalde, and Medina Counties. The Edwards Aquifer Authority is charged with protecting terrestrial and aquatic life, domestic and municipal water supplies, the operation of existing industries, and the economic development of the entire Edwards Aquifer (Chapter 626, Laws of the 73rd Texas Legislature, 1993). Aquifer management since these rules were implemented have been successful at reducing groundwater withdrawals, thereby minimizing declines in groundwater quantity.

Edwards Aquifer Habitat Conservation Plan

The Edwards Aquifer Authority developed the Edwards Aquifer Habitat Conservation Plan (EAHCP). The EAHCP was finalized in 2013 and authorizes the incidental take of eleven covered species, including the Texas troglobitic water slater. Participants in the EAHCP include the Edwards Aquifer Authority, City of San Antonio acting through the San Antonio Water System, City of New Braunfels, City of San Marcos, and Texas State University (National Research Council 2015 pp. 25–26). The EAHCP authorizes activities through 2028 that minimize and mitigate impacts and contribute to the recovery of the 11 covered species. The EAHCP addresses a variety of aquifer management issues, including ensuring springflow during a drought of record, when aquifer recharge would be at its lowest recorded level (Payne et al. 2019 p. 200; EAHCP 2020 pp. 4-57–4-59, 4-62–4-66). Long-term commitments to protect listed species in the Edwards Aquifer beyond the EAHCP are not in place; a new EAHCP is expected in 2028.

There are four primary spring protection measures in the EAHCP (National Research Council 2015, pp. 32–36; National Academies of Science, Engineering, and Medicine 2018, pp. 19–20; EAHCP 2020 pp. 5-1–5-10, 5-38–5-41):

- Critical Period Management Stage V: Tiered reductions in groundwater withdrawals when Comal and San Marcos Springs flow or water levels at reference wells (i.e., J-17 and J-27) fall below certain volumes;
- Regional Water Conservation Program: Municipal conservation programs to reduce usage of groundwater;
- Voluntary Irrigation Suspension Program: Suspends use of Edwards Aquifer for irrigation during drought periods when reference wells reach specific water levels;
- Aquifer Storage and Recovery: Storage of excess permitted Edwards Aquifer in the Carrizo Aquifer.

While there are no explicit biological goals or objectives for the Texas troglobitic water slater in the EAHCP, the species is protected by the springflow management efforts in the EAHCP (National Research Council 2015 pp. 96–97). Due to the subterranean nature of the Texas troglobitic water slater, if springflows that continually cover the spring are protected from dewatering, then subterranean habitats will also be protected. Thus, Texas troglobitic water slater mortality from a decrease in water quantity is not anticipated unless spring discharge falls below 1.4 m^3/s (50 cfs) at San Marcos Springs (EAHCP 2020 pp. 4132). Currently, all of the springflow protection measures have been met, and modeling indicates that flows of 1.5 m^3/s (52 cfs) or more as a monthly average will be maintained during a drought of record (EAHCP 2020 p. 469; ICF 2021 p. 9).

Several water quality protection measures have been implemented as part of the EAHCP. The Edwards Aquifer Authority (see *Regulations* below) has implemented a water quality protection program and the City of San Marcos has added regulations to protect water quality in the recharge zone (EAHCP 2020 p. 3–39). The EAHCP has also developed grounds course management plans that include integrated pest management plans and reduce impacts to covered species (EAHCP 2020 pp. 5-19–5-20, 5-37). The most recent water quality report states that San Marcos Springs' water is of high quality with a limited number of detectable compounds (SWCA 2021 p. 74).

Significantly, coal tar sealants, which contribute to polycyclic aromatic hydrocarbons in stormwater runoff (Mahler et al. 2012 entire), were banned by the Edwards Aquifer Authority in 2012 in the recharge zone of the San Marcos ecosystem that is within its jurisdiction (EAA rule §713.703). The City of San Marcos also passed a coal tar ban in 2016 which protects aquifer habitat in the San Marcos River (EAHCP 2020 pp. 5-44–5-45).

Additional Regulations
To protect water quality, there are several laws and regulations that apply to groundwater use in the State of Texas. The Federal Safe Drinking Water Act of 1974, as amended, regulates pollution and sedimentation of public drinking water sources, including the Edwards Aquifer. This legislation mandates enforcement of drinking water standards established by the Environmental Protection Agency. Texas has an extensive program for the management of drinking water by the TCEQ. This includes regulatory programs such as Texas Pollutant Discharge Elimination System, Texas Surface Water Quality Standards, and Total Maximum Daily Load Program. The number of new groundwater contamination cases has decreased in the state since 2002 with nine cases active and three inactive cases currently in Hays County (Texas Commission on Environmental Quality 2022b pp. 8, 11, A-55–A-56, C-43).

Under the authority of the TCEQ, activities that could potentially pollute the aquifer or any hydrologically connected surface stream are regulated through the Edwards Aquifer Protection Program (i.e., "Edwards Rules") to protect existing and potential uses of groundwater according to Texas Surface Water Quality Standards (Title 30, Chapter 213, Texas Administrative Code). The Edwards Rules require a number of water-quality protection measures for new development occurring in the recharge zone and a small portion of the contributing zone of the Edwards Aquifer (e.g., water pollution abatement plan before conducting any construction related or post-construction activities on the recharge zone). The Edwards Aquifer Authority does not have the authority to regulate the majority of the contributing zone (e.g., Bandera, Kerr, and Kendall Counties) where exurban development is increasing (Siglo Group 2022 pp. 13–14).

While the Texas Pollutant Discharge Elimination System program regulates point source pollution discharged to surface waters in Texas, it does not adequately address all sources of water quality degradation, especially non-point source pollution. Although Texas Land Application Permits for discharging effluent are designed to protect the surface waters and underground aquifers, studies have demonstrated there is reduced water quality (i.e., elevated nitrate levels) downstream of permitted sites (Mahler et al. 2011 pp. 34–35; Ross 2011 pp. 11–18). Similar problems could occur if Texas Land Application Permits increased in the southern segment of the Edwards Aquifer. However, the Texas troglobitic water slater occurs at depths that are not expected to be affected by this potential reduced quality.

In addition to these state and federal regulations, a number of local regulations were implemented by the City of San Marcos, City of New Braunfels, Edwards Aquifer Authority, and Texas State University as part of the EAHCP to protect water quality. Cities can regulate pollution at the surface that ultimately impacts groundwater quality. The City of San Marcos maintains a hazardous household waste program and permits septic systems, which prevents pollutants from being introduced into the spring ecosystem (EAHCP 2020 pp. 4-43–4-44, 5-45). Additionally, the City of San Marcos is one of the stakeholders managing the watershed according to a watershed protection plan for the Upper San Marcos River (The Meadows Center for Water and the Environment 2018 pp. ii, 7). This watershed protection plan addresses the impairment of the Upper San Marcos River due to elevated total dissolved solids, and also proactively addresses bacteria, nutrients, sediment, and future growth scenarios for the watershed (The Meadows Center for Water and the Environment 2018 p. 9).

Numerous governmental partners work to maintain springflows and groundwater levels and reduce pumping pressure on the Edwards Aquifer. Implementation of conservation efforts (e.g., the EARIP HCP and land conservation) have maintained quality and quantity of water in the aquifer and thus the best available information indicates the resiliency of the water slater has been maintained.

Cumulative Effects

We note that, by using the SSA framework to guide our analysis of the scientific information documented in the SSA report, we have analyzed the cumulative effects of identified threats and conservation actions on the species. To assess the current and future condition of the species, we evaluate the effects of all the relevant factors that may be influencing the species, including threats and conservation efforts. Because the SSA framework considers not just the presence of the factors, but to what degree they collectively influence risk to the entire species, our assessment integrates the cumulative effects of the factors and replaces a standalone cumulative-effects analysis.

ANALYSIS

The primary factors influencing the Texas troglobitic water slater population's viability are water quantity (i.e., groundwater pumping and development) and water quality (i.e., development and impervious cover). Because there is a lack of demographic data for the Texas troglobitic water slater, and appropriate surrogate species with more life history information were not identified, we relied on observed and assumed habitat conditions and/or parameters to inform the species' current and future conditions.

CURRENT CONDITION

For the Texas troglobitic water slater to maintain viability, its population, or some portion of its population, must be resilient. Several stressors have the potential to affect the species, including groundwater pumping, drought, and water quality degradation. Groundwater pumping, starting in the 1880s, led to decreased water quantity by the 1950s, reducing artesian pressure for springflows (Mace 2019 p. 208). Current conservation, flow protection, and water quantity optimization measures are effective in meeting biological objectives for the covered species under the EAHCP, including the Texas troglobitic water slater, and reducing groundwater withdrawals (National Research Council 2018 p. 109). If sufficient water of adequate quality passes through the recharge zone into the Edwards Aquifer, we anticipate that the Texas troglobitic water slater population and current habitat will be maintained. The Texas troglobitic water slater has survived significant drought periods (including the drought of record). Based on the best available information on the species distribution and biology, we have no indication that the Texas troglobitic water slater's population resiliency has been impacted by groundwater pumping. Furthermore, the historical range of the Texas troglobitic water slater population does not appear to have been impacted by the drought of record at San Marcos Springs. A conservation status assessment of the Texas troglobitic water slater ranked the overall threat impact from all potential threats to the species as low (Hutchins 2018 p. 487).

Most species need multiple resilient populations distributed across the landscape to provide for redundancy. The more populations, and the wider the distribution of those populations, the more redundancy a species will exhibit. Redundancy reduces the risk that a large component of a species' range will be negatively affected by a catastrophic natural or anthropogenic event at a given point in time. The three Texas troglobitic water slater capture sites function as a single population in San Marcos and represent the only known occurrence for the species. It is unknown if the species existed at any historical location that were extirpated or currently exists at any other nearby sites due to a lack of surveys. The Texas troglobitic water slater is a narrow endemic with habitat requirements restricted to a nearby food source. Based on the best available scientific and commercial information, we conclude that the Texas troglobitic water slater currently has a level of redundancy similar to historical levels.

The Texas troglobitic water slater capture sites likely represent one continuous, interbreeding population (Schwartz et al. 2018 pp. 1, 15, 18). Texas troglobitic water slater habitat is deep within the Edwards Aquifer, partially isolated from surface influences and characterized by access to the chemolithoautotrophic organic matter food resources present along the freshwater/saline-water interface. Texas troglobitic water slater adaptive capacity, which would allow them to not only persist in place, but also "shift in space" in response to changes in their environment is unknown (Thurman et al. 2020 p. 521). Currently, the Texas troglobitic water slater is known to occur in one habitat type, and we infer based on hydrology and subterranean biology information that this species is unlikely to live in other habitat types and therefore has a similar level of representation to what the Texas troglobitic water slater had historically. This species is a narrow endemic and, therefore, naturally has limited redundancy and representation.

FUTURE CONDITION

We used a qualitative approach to assess the Texas troglobitic water slater's future condition because of the lack of demographic data for the Texas troglobitic water slater. These future forecasts are then applied to the concepts of the 3 Rs to construct a risk assessment of the future viability of the Texas troglobitic water slater (Smith et al. 2018 p. 306). Sufficient water quantity and quality are the primary needs for this species.

To assess the future viability of the Texas troglobitic water slater, two plausible future scenarios were considered in accordance with the species' primary needs (i.e., sufficient water quantity and quality) to capture the full, plausible risk profile for the species using projections out to 2050 and 2100, where applicable. The upper plausible scenario is an upper limit scenario reflecting the most favorable, plausible future condition for the water slater. The lower plausible scenario reflects the least favorable, but still plausible, future condition for the water slater. We defined and examined two regions called “areas of influence” that likely contribute to groundwater quantity and quality.

Our upper plausible scenario incorporates the lower emissions pathway (Representative Concentration Pathway (RCP) 4.5). Based on current projections of greenhouse gas emissions, air temperature is projected to increase 2.0 to 2.8°C (35.6 to 37°F) by 2050 (Sharif 2018 p. 4; U.S. Global Change Research Program 2018 p. 995), and for this scenario we looked at effects of the lower end of this range (2.0°C (35.6°F)). For land use changes, we used the Integrated Climate and Land-Use Scenarios (ICLUS) HADGEM2-ES modeled scenario using projections under the shared socioeconomic pathway 2 (SSP2; lower population growth). Projections were examined at both areas of influence out to the year 2050 (ICLUS version 2.1.1).

Our lower plausible scenario incorporated effects under the higher emissions pathway (RCP8.5). We used the higher end of the range of temperature increases (2.8°C (37°F)) (Sharif 2018 p. 4; U.S. Global Change Research Program 2018 p. 995). For land use changes, we used projections under shared socioeconomic pathway 5 (SSP5; higher population growth), which result in a considerably larger expansion of developed lands relative to the SSP2. The HADGEM2-ES was used because it projected a highly expansive, increasing trend in urbanization for the two areas of influence for the water slater (Collins et al. 2008 entire; U.S. Environmental Protection Agency 2020 metadata).

In both future scenarios, projected land-use changes occurring over the recharge zone could inhibit opportunities for surface water to enter the aquifer and for enough discharging water to effectively clear anthropogenic contaminants. Longer residence times of contaminants in groundwater and lack of photodegradation of constituents in the aquifer are not well understood and it is uncertain how these changes will affect the Texas troglobitic water slater population into the future. There is no information assessing the environmental tolerance of Texas troglobitic water slaters to contaminants or how degradation in water quality can affect the species. Likewise, there are no appropriate isopod surrogates occupying a similar habitat with more information to compare with the Texas troglobitic water slater at this time. Additionally, while climate change and other anthropogenic influences (e.g., vegetation removal and urbanization) cause the surface to warm, a lag in increased groundwater temperature may occur (Sharp 2010 p. 2; Mahler and Bourgeais 2013 p. 295; Benz et al. 2017 entire; Böttcher and Zosseder 2022 pp. 8, 10–11). For ectothermic animals like the Texas troglobitic water slater, overall vulnerability to climate change will depend on thermal sensitivity and how quickly their buffered environment changes, and we do not have information to inform our future scenarios at this time (Pallarés et al. 2021 p. 487; Delić et al. 2022 p. 2).

The southern segment of the Edwards Aquifer has a great capacity to assimilate and dilute contaminants as massive volumes of water transport these materials through the aquifer (Johnson et al. 2009 p. 44). That assimilative capacity could be exceeded over decades of contaminant loading, with contaminants eventually entering the deeper areas of the aquifer (Johnson et al. 2009 p. 58; Opsahl et al. 2018 p. 58). However, contaminants in younger and shallower groundwater can be diluted over distance and time and "flushed" through discharge points more frequently than older groundwater at a greater depth (Gibert et al. 1994 p. 446; Marmonier et al. 2013 pp. 128–129). Whether contaminants would ever reach concentrations that would impair or kill Texas troglobitic water slaters at either scenario we have assessed is uncertain. Neither is there a consensus if chemical sensitivity is greater or lesser in subterranean or surface fauna (Di Lorenzo et al. 2019 entire; Hose et al. 2022 p. 2206).

Much of the exurban and suburban development in Hays County, along with other surrounding counties, is projected to occur outside of municipal boundaries in unincorporated areas where land use regulations (e.g., restrictions on impervious cover) are non-existent in the contributing zone (Siglo Group 2022 pp. 13–14). In the lower plausible scenarios, exurban expansion and population growth are likely to continue to spread across more rural counties surrounding larger metropolitan areas like Austin, Texas, including Hays County within the Edwards Aquifer recharge zone, impacting groundwater quality through increased impervious cover runoff and over time, leaking or poorly managed septic systems (Berube et al. 2006 pp. 10, 38; Guerra and Debbage 2021 pp. 8, 10; Barkfield 2022 p. 2). Alterations to vegetation, topography, soil permeability, and surface water characteristics due to development affect recharge rates and add potential sources of contamination (Burri et al. 2019 pp. 140–141).

Current water planning does not account for climate change, though climate change will be considered in the upcoming EAHCP. The Edwards Aquifer Authority is committed to improving their HCP and funding was allocated to predict droughts and climate change impacts on the aquifer (Başağaoğlu 2021 unpaginated). Land in Hays County over the recharge zone has been purchased or protected through easements, and partners are committed to purchasing more land in the future, in addition to many other conservation efforts. Even with a drying climate, under both future scenarios, if current management of the southern segment of the Edwards Aquifer continues into the future, aquifer levels should not decline to a level where Texas troglobitic water slater habitat would be impacted.

Overall, the water slater has survived significant drought periods and surrounding urban development, and the population has maintained resiliency. Despite projections in climate change and increases of progressively more urbanized land-use classes, the best available information does not indicate that resiliency, redundancy, and representation of the water slater population would be reduced into the future in either plausible scenario.

FINDING

Regulatory Framework

Section 4 of the Act (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species is an "endangered species" or a "threatened species." The Act defines an endangered species as a species that is "in danger of extinction throughout all or a significant portion of its range," and a threatened species as a species that is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The Act requires that we determine whether any species is an "endangered species" or a "threatened species" because of any one or a combination of the following factors:

> (A) The present or threatened destruction, modification, or curtailment of its habitat or range;
> (B) Overutilization for commercial, recreational, scientific, or educational purposes;
> (C) Disease or predation;
> (D) The inadequacy of existing regulatory mechanisms; or
> (E) Other natural or manmade factors affecting its continued existence.

These factors represent broad categories of natural or human-caused actions or conditions that could have an effect on a species' continued existence. In evaluating these actions and conditions, we look for those that may have a negative effect on individuals of the species, as well as other actions or conditions that may ameliorate any negative effects or may have positive effects.

The Act does not define the term "foreseeable future, which appears in the statutory definition of "threatened species." Our implementing regulations at 50 CFR 424.11(d), as revised in 2019, set forth a framework for evaluating the foreseeable future on a case-by-case basis. The term "foreseeable future" extends only so far into the future as we can reasonably determine that both the future threats and the species' responses to those threats are likely. In other words, the foreseeable future is the period of time in which we can make reliable predictions. "Reliable" does not mean "certain"; it means sufficient to provide a reasonable degree of confidence in the prediction. Thus, a prediction is reliable if it is reasonable to depend on it when making decisions.

It is not always possible or necessary to define the foreseeable future as a particular number of years. Analysis of the foreseeable future uses the best scientific and commercial data available and should consider the timeframes applicable to the relevant threats and to the species' likely responses to those threats in view of its life-history characteristics. Data that are typically relevant to assessing the species' biological response include species-specific factors such as lifespan, reproductive rates or productivity, certain behaviors, and other demographic factors.

Status Assessment

Status Throughout All of Its Range

After evaluating threats to the species and assessing the cumulative effect of the threats under the section 4(a)(1) factors, we found that there are no credible sources or evidence that project a negative impact from environmental or anthropogenic factors directly to the known Texas troglobitic water slater population, nor is there evidence indicating a change to demographic factors historically. The primary driving factors of Texas troglobitic water slater viability are water quantity (i.e., groundwater pumping and development) (Factor A) and water quality (i.e., development and impervious cover) (Factor A). The Texas troglobitic water slater has survived significant drought periods (including the drought of record) and despite the ongoing threats, the population has been regularly observed for over a century. Volumes of groundwater extracted from the aquifer have been reduced since 2008, and groundwater quantity is not currently impacting the species and is not expected to become a stressor because of the current regulations (i.e., Edwards Aquifer Authority and associated Habitat Conservation Plan) in place (Ding and McCarl 2019 pp. 10–11). The absence of long-term declines in aquifer levels suggests that suitable habitat, in terms of water quantity, for the water slater has experienced little change from historical conditions and, in turn, have not declined. It is unlikely that widespread loss or degradation of water-filled subterranean spaces has occurred due to reduced recharge and groundwater pumping. Flow protection measures have sustained the San Marcos Spring system during drought and provided protection for water levels in deeper portions of the Southern segment.

We have no evidence that any groundwater contamination (Factor A) is affecting the species, as there are no instances where degraded water quality was documented discharging from water slater sites. There are 12 wells within the local groundwater contributing area of influence connected to water slater sites. These 12 wells have been sampled sporadically over the last 20 years. The average values for tested contaminants were below the Environmental Protection Agency’s drinking water quality standards. Isopods are generally tolerant to pollutants (e.g., subterranean *Caecidotea recurvata* and riverine *Asellus aquaticus*) (Aston and Milner 1980 pp. 1, 12–13; Simon and Buikema 1997 pp. 398–399). There is limited evidence suggesting persistent and elevated levels of contamination occurs at a local scale around water slater sites.

Finally, direct mortality through expulsion from groundwater wells (Factor E) is occurring, but the species’ benthic lifestyle (making it less susceptible to well entrainment) and likely high reproductive rate result in this mortality being unlikely to affect the population’s current resiliency. Because it is a species that occurs in pore spaces, it is less susceptible to entrainment and expulsion from wells, and species with life history traits like those of the Texas troglobitic water slater are unlikely to be affected by the mortality observed at the groundwater wells where it has been found. Therefore, with the best available scientific and commercial information and our understanding of known uncertainties, the water slater has maintained resiliency, and conditions that support the species (i.e., sufficient water quality and quantity) should continue to be available. The water slater retains the ability to withstand stochastic events, and redundancy and representation remain unchanged from historical conditions. Thus, after assessing the best available information, we conclude that the Texas troglobitic water slater is not in danger of extinction throughout all of its range.

Therefore, we proceed with determining whether the Texas troglobitic water slater is likely to become endangered within the foreseeable future throughout all of its range. The timescale for our future scenarios is from 2022 to 2100, the maximum extent of climate change and land-use projections and species response. The primary driving factors on the Texas troglobitic water slater population's future viability are water quality (i.e., development and impervious cover) (Factor A) and water quantity (i.e., groundwater pumping and development) (Factor A). Increases in development in the areas of influence under both future scenarios would lead to increases in impervious cover, altered recharge rates, and degraded water quality. The lands directly above Texas troglobitic water slater habitat are already developed, although future developments may occur in the areas of influence. Projections indicate that the human populations of Bexar, Comal, Hays, and Kendall Counties will continue to increase over the next three decades (Texas Demographic Center 2021, entire). Land-use projections indicate potential for increases in impervious cover that could degrade water quality and lower recharge capacity for the Southern segment of the aquifer under both future scenarios. We have no information to determine whether contaminants would ever reach concentrations that would impair Texas troglobitic water slater habitat.

Water quantity is expected to remain sufficient for the Texas troglobitic water slater. At the depths at which this species occurs, groundwater extraction and changes in precipitation events due to climate change are not expected to have effects on the water slater's habitat. Future extreme precipitation events under RCP4.5 have the potential to increase groundwater levels in the aquifer via infiltration through the recharge zone (Chakraborty et al. 2021, p. 12). Flow protection measures have sustained the San Marcos Spring system during drought and provide protection for water levels in deeper portions of the Southern segment. Neither future scenario projection points to evidence indicating any threat to the Texas troglobitic water slater population under current groundwater management implementation, and if current management of the Southern segment continues into the future, aquifer levels should not decline to a level where water slater habitat would be affected.

For both the lower and upper plausible future scenarios, we do not have any credible sources or evidence that project a negative impact from environmental or anthropogenic factors directly to the known water slater population, nor is there evidence indicating a negative change to demographic factors historically. We expect that under both future scenarios, resiliency, redundancy, and representation of the species will be maintained into the foreseeable future.

After assessing the best available information, we find that well mortality, groundwater quantity (including reductions through climate change), and groundwater quality are not expected to be significant stressors through 2100 for the species, and we conclude that the Texas troglobitic water slater is not likely to become endangered within the foreseeable future throughout all of its range.

Status Throughout a Significant Portion of Its Range

Under the Act and our implementing regulations, a species may warrant listing if it is in danger of extinction or likely to become so in the foreseeable future throughout all or a significant portion of its range. Having determined that the Texas troglobitic water slater is not in danger of extinction or likely to become so in the foreseeable future throughout all of its range, we now consider whether it may be in danger of extinction or likely to become so in the foreseeable future in a significant portion of its range—that is, whether there is any portion of the species' range for which it is true that both (1) the portion is significant; and (2) the species is in danger of extinction now or likely to become so in the foreseeable future in that portion. Depending on the case, it might be more efficient for us to address the "significance" question or the "status" question first. We can choose to address either question first. Regardless of which question we address first, if we reach a negative answer with respect to the first question that we address, we do not need to evaluate the other question for that portion of the species' range.

We evaluated the range of the Texas troglobitic water slater to determine if the species is in danger of extinction now or likely to become so in the foreseeable future in any portion of its range. The Texas troglobitic water slater is a narrow endemic that functions as a single, contiguous population and occurs within a very small area. The species has been found expelled at only three sites in Hays County, TX, all within 600 m (1,969 ft) of each other, with all three sites connected by groundwater flowpaths. Thus, there is no biologically meaningful way to break this limited range into portions and the threats that the species faces affect the species comparably throughout its entire range. As a result, there are no portions of the species' range where the species has a different biological status from its rangewide biological status. Therefore, we conclude that there are no portions of the species' range that warrant further consideration, and the species is not in danger of extinction or likely to become so in the foreseeable future in any significant portion of its range. This does not conflict with the courts' holdings in *Desert Survivors* v. *U.S. Department of the Interior*, 321 F. Supp. 3d 1011, 1070-74 (N.D. Cal. 2018), and *Center for Biological Diversity v. Jewell*, 248 F. Supp. 3d. 946, 959 (D. Ariz. 2017) because, in reaching this conclusion, we did not apply the aspects of the Final Policy on Interpretation of the Phrase "Significant Portion of Its Range" in the Endangered Species Act's Definitions of "Endangered Species" and "Threatened Species" (79 FR 37578; July 1, 2014), including the definition of "significant" that those court decisions held to be invalid.

Determination of Status

Our review of the best available scientific and commercial information indicates that the Texas troglobitic water slater does not meet the definition of an endangered species or a threatened species in accordance with sections 3(6) and 3(20) of the Act. Therefore, we find that listing the Texas troglobitic water slater is not warranted at this time.

COORDINATION WITH STATES

We invited Texas Parks and Wildlife Department (TPWD) to participate in the SSA development and they were also provided an opportunity to review the draft SSA. TPWD did not participate in SSA development but did provide comments on the report. We incorporated submitted reports and feedback from these comments, including citing new literature and making edits to provide clarity in our assumptions and analyses in the SSA report.

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Date: 11/15/2023

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