Desert Slender Salamander
(*Batrachoseps Major Aridus*)

5-Year Review:
Summary and Evaluation

Habitat photo provided by Elizabeth Gallegos, USGS.
Salamander photo by Mario Garcia-Paris, Spanish National Research Council.

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ACKNOWLEDGEMENTS

This 5-year review is based on the 5-year status report prepared by Anisa Lopez-Ruiz during their 2024 Directorate Fellows Program internship at the Carlsbad Fish and Wildlife Office. To complete this assessment, Anisa conducted a literature review, updated occurrence data, coordinated between the U.S. Fish and Wildlife Service and external partners, assessed current threats to the species, and identified priority research and conservation tasks.

5-YEAR REVIEW

Desert Slender Salamander
[*Batrachoseps Major Aridus* (=*B. Aridus*)]

GENERAL INFORMATION

Species: Desert slender salamander (*Batrachoseps major aridus*), an amphibian subspecies

Date listed under the Endangered Species Act: June 4, 1973

Federal Register citation: U.S. Fish and Wildlife Service 1973 (38 FR 14678)

Classification: Endangered

Recovery Plan: August 12, 1982. Recovery Plan for the desert slender salamander. September 2019, Supplemental Finding for the Recovery Plan for the desert slender salamander (*Batrachoseps major aridus*).

Recovery Priority Number: 6 (high threat, low recovery potential, subspecies)

BACKGROUND

Under the Endangered Species Act of 1973, as amended (Act; 16 U.S.C. 1531 *et seq*.), the U.S. Fish and Wildlife Service (Service), referred to as "we" in this document, maintains lists of endangered and threatened wildlife and plant species (referred to as the List) in the Code of Federal Regulations (CFR) at 50 CFR 17.11 (for wildlife) and 17.12 (for plants). Section 4(c)(2)(A) of the Act requires us to review each listed species' status at least once every 5 years.

Most Recent Status Review: Service 2020. Desert Slender Salamander (*Batrachoseps major aridus*) 5-year review: Summary and Evaluation. Carlsbad Fish and Wildlife Office. 5 pp.

We initiated a status review for the desert slender salamander in 2020. The review was finalized on May 21, 2020, and recommended no change in listing status.

Federal Register Notice Announcing this Status Review: On October 16, 2024, we published a Federal Register notice announcing initiation of the 5-year review of this species, and the opening of a 60-day comment period to receive information (Service 2024a, pp. 83510–83514). We did not receive any comments about Desert slender salamander.

Species Overview and Habitat: Desert slender salamander (*Batrachoseps major aridus*) is a small, subterranean amphibian from the Plethodontidae (lungless salamander) family. Adult desert slender salamanders are less than 102 millimeters [mm; 4 inches (in)] in total length, with a tail length of approximately 48 mm (1.9 in). They live in moist subterranean microhabitats such as crevices and animal burrows, emerging aboveground after rainfall events. Little is known about the species' life history and biology. This rare species is known from two canyons on the lower desert slopes of the eastern Santa Rosa Mountains in Riverside County, California. The population is presumed extant though it has not been observed since 1997.

ASSESSMENT

Information Acquired Since the Last Status Review

We used a species report conducted by a Directorate Fellows Program intern at the Service's Carlsbad Fish and Wildlife Office (CFWO) to inform this 5-year review. We contacted species experts from the California Department of Fish and Wildlife (CDFW) and the U.S. Geological Survey (USGS) to request any data or new information we could consider in our review. Additionally, we conducted a literature search and a review of information in our files.

SUMMARY OF NEW INFORMATION SINCE 2020

Biology

Habitat

Desert slender salamander habitat at known occurrences within Hidden Palm Canyon and Guadalupe Canyon include historically mesic areas, with water supplied by groundwater seepage or seasonal surface water, that supports the persistence of amphibians within an otherwise dry desert environment. Like other *Batrachoseps* species, the desert slender salamander is fully terrestrial and though they require a moist environment, they do not rely on surface water for reproduction (Jockusch *et al.* 2020, p. 25). This trait has likely facilitated its persistence in its historical range.

Water is supplied to Hidden Palm Canyon from an estimated 440 acres [ac; 178 hectares (ha)] subterranean watershed, which reaches the canyon as groundwater seepage (Service 1982, p. 6). At Guadalupe Canyon, the Martinez and Sheep Mountains drain into the northeast flowing Guadalupe Creek as seasonal surface water and perennial groundwater seepage (Duncan and Esque 1986, pp. 2, 6).

At Guadalupe Canyon, the majority of salamanders have been found in organic soils (Duncan and Esque 1986, p. 15). The surface material surrounding Hidden Palm Canyon is exposed bedrock, talus, and coarse-grained sand (Service 1982, pp. 6–7). Rather than soil, porous limestone that covers portions of the canyon wall represents the most important structural habitat component at Hidden Palm Canyon (Service 1982, p. 9). In both cases, desert slender salamanders rely on substrates that retain moisture when other retreats dry out.

The geographic isolation of the two occurrences prevents direct disturbance from outdoor recreation or land development. However, this also makes it difficult to access the sites, so relatively little information has been gained about the status and habitat integrity of these sites over the years since listing.

USGS scientists conducted surveys from 2017 to 2023 and reported that habitat at Hidden Palm Canyon and Guadalupe Canyon appeared much drier than how it was previously described in the 1980s and 1990s, when desert slender salamander was last detected (Backlin and Fisher 2024, pers. comm.). The reason for these drier conditions is uncertain though it may be attributed to climate change and/or geological changes that have reduced the availability of groundwater. A 1985–1986 study of the desert slender salamander occurrence at Guadalupe Canyon emphasized the association of desert slender salamander with broad-leafed plants that create rich soil, retain moisture, and support arthropods (Duncan and Esque 1986, pp. 34–35). The current conditions at the historical localities are drier than when salamanders were last detected, and it is uncertain if the habitat remains suitable.

USGS surveyed for desert slender salamander beyond its known range. Important features for identifying potentially suitable habitat for surveys included rock features that reach the bottom of a canyon and the presence of north facing slopes (Backlin and Fisher 2024, pers. comm.). Further research and survey efforts are needed to identify and confirm suitable habitat for desert slender salamander.

Distribution and Abundance

At the time of listing, *Batrachoseps major aridus* was known from only one occurrence in Hidden Palm Canyon, estimated to be less than 1 ac (0.4 ha) in size (Service 1982, p. 3). In 1981, an additional occurrence was found in Guadalupe Canyon and confirmed to be the desert slender salamander (Giuliani 1981, pp. 1–17; Brame 1981, pers. comm.). At Guadalupe Canyon, desert slender salamanders were found in small, disjunct patches of habitat that totaled approximately 0.5 ac (0.2 ha), with potential habitat estimated to be 1.5 ac (0.6 ha) (Duncan and Esque 1986, p. 36). No abundance data has been collected in Guadalupe Canyon since a 1984–1985 study, which detected 30 salamanders over 15 nights of sampling (Duncan and Esque 1986, pp. 6, 22).

The last detailed study of desert slender salamander at Hidden Palm Canyon occurred in 1977 and 1978 (Bleich 1978, entire). Surveys were conducted four times per month for one year. Typically, 0 to 10 salamanders were found per 100 minutes of survey effort (Bleich 1978, Tables 1–13). Based on length, a large proportion of salamanders detected were juveniles, indicating that the population was reproducing (Bleich 1978, p. 8). Bleich estimated that the population of desert slender salamander at Hidden Palm Canyon was between 133 and 515 individuals (Bleich 1978, p. 9).

Desert slender salamanders have not been seen in Hidden Palm Canyon since 1997 (Nicol 1997, p. 1), although biologists from CDFW performed nearly annual searches for desert slender salamander until 2006 (Konno 2013, pers. comm.).

USGS performed diurnal and nocturnal visual encounter surveys from 2017 to 2019. Six nocturnal and diurnal surveys were conducted at Hidden Palm Canyon, and one diurnal survey was conducted at Guadalupe Canyon (USGS 2019, p. 1). No desert slender salamanders were found during these surveys.

In 2021 and 2023, USGS conducted additional surveys at the two historical occurrences, Hidden Palm Canyon and Guadalupe Canyon, though no salamanders were detected. Surveys were also conducted beyond the known range to encompass the desert regions of Riverside, San Diego, and Imperial Counties, California. The search area expanded beyond previously known habitat in order to evaluate other areas with potentially suitable habitat and discover additional populations. Surveys were conducted at 137 sites across southern California deserts. They found 60 *Batrachoseps* individuals across 26 sites, including sites in the Santa Rosa Mountains and Anza-Borrego Desert.

Some of these salamanders have been determined by morphology to not be desert slender salamander, and others require further analysis to determine whether they represent the listed entity, *Batrachoseps major aridus* (USGS 2023, pp. 1–2). An additional population of *Batrachoseps* salamanders were found around Palm Springs by a Service biologist. Further discussion of these newly discovered salamander is included below in the Occurrence Status section.

Taxonomy

The *Batrachoseps* genus is represented by two subgenera, *Plethopsis* and *Batrachoseps*; the latter consists of five species groups (clades) (Wake 2006, p. 15; Jockusch *et al.* 2012, p. 1). Species in this genus are primarily differentiated at the molecular level as compared to morphological or ecological levels (Wake 2006, pp. 16–19). *Batrachoseps major* is one of eight species belonging to the *B. pacificus* clade which originated in Southern California (Jockusch *et al.* 2020, p. 19). Desert slender salamander, currently recognized as a subspecies of *B. major*, is closely related to a southern phylogeographic unit of *B. major* (Wake 2006, p. 19).

Desert slender salamander is morphologically distinct and retains its distinctive mitochondrial DNA but is only minimally differentiated from *Batrachoseps major* in terms of allozymic similarity (Wake and Jockusch 2000, p. 108). Martinez-Solano *et al*. (2012, p. 147) found that based on mitochondrial DNA, the southern *B. major* species group is composed of six lineages, one of which is desert slender salamander. The study found that desert slender salamander is the most morphologically and ecologically differentiated lineage (Martinez-Solano *et al*. 2012, p. 147). There is no information available regarding the genetic variability of this subspecies because of the limited number of samples available and the poor DNA quality of the preserved specimens.

Occurrence Status

The desert slender salamander has historically been reported from two locations, Hidden Palm Canyon located within the Santa Rosa Mountains and Guadalupe Canyon located in the San Jacinto Mountains National Monument area (Bleich 1978, p. 1; Giuliani 1981, p. 3), and was last observed at Hidden Palm Canyon in 1997 (Table 1). Since then, multiple survey attempts have been conducted to determine the status of the population (see Distribution and abundance section above).

Given the remoteness of the two historical occurrences and the conservation protections in place at each site, which have contributed to the maintenance of suitable habitat for the desert slender salamander, we presume that the populations are extant at the two historical occurrences (Table 1). However, lack of recent observation, along with the drier habitat conditions, also cast doubt on the status of the population at these two historical localities. Although there is no clear threshold at which to declare these populations extirpated, especially considering this is a fossorial species with surfacing behaviors that remain unknown, their status may be reconsidered possibly extirpated in the coming years if there are no future signs of desert slender salamander presence.

During surveys in 2023, USGS detected two salamanders on the south slope of the Santa Rosa Mountains, close to the historical localities of desert slender salamander (USGS 2023, pp. 1–2). Based on gross morphology, the salamanders found at these new locations in the Santa Rosa Mountains may represent a possible new *Batrachoseps major aridus* occurrence (Table 1;

Backlin and Fisher 2024, pers. comm.). Other salamanders found in Anza-Borrego and around Palm Springs are also unique and native *Batrachoseps* populations, but their identity is still unknown. Out of the newly discovered salamanders, the Santa Rosa Mountains salamanders appear to be more like the listed entity, compared to salamanders found in Anza-Borrego and Palm Springs (Backlin and Fisher 2024, pers. comm.).

Preliminary genetic (mtDNA) work suggests that the salamanders from the Santa Rosa Mountains may represent desert slender salamander, but genomics analysis is needed to confirm the identity of these entities (Backlin and Fisher 2024, pers. comm.). At this time, we consider the salamanders in the Santa Rosa Mountains as a potential occurrence. If the Santa Rosa Mountains salamanders are determined to be the listed entity, this may indicate that the distribution of desert slender salamander extends further south on the west facing slope of the Santa Rosa Mountains than previously known and encompass isolated and remote localities in the Santa Rosa Mountains (Figure 1). Further analysis of morphology and genetics is needed to confirm whether individuals from this potential occurrence are desert slender salamander.

Summary

Desert slender salamander is a narrow endemic subspecies, which historically persisted in isolated localities amidst an inhospitable desert climate. One occurrence at Hidden Palm Canyon was known at listing, and an additional occurrence at Guadalupe Canyon has been identified since then. Though salamanders have not been observed for some time, they are difficult to detect and so both occurrences are presumed extant at this time. USGS researchers found salamanders in the Santa Rosa Mountains that appear similar to the listed entity, which we have identified as a potential occurrence. Genomics analysis is needed to determine whether this occurrence represents desert slender salamander. Further research is also needed to investigate the habitat requirements and life history of desert slender salamander, especially to determine when and at what times of year they emerge aboveground.

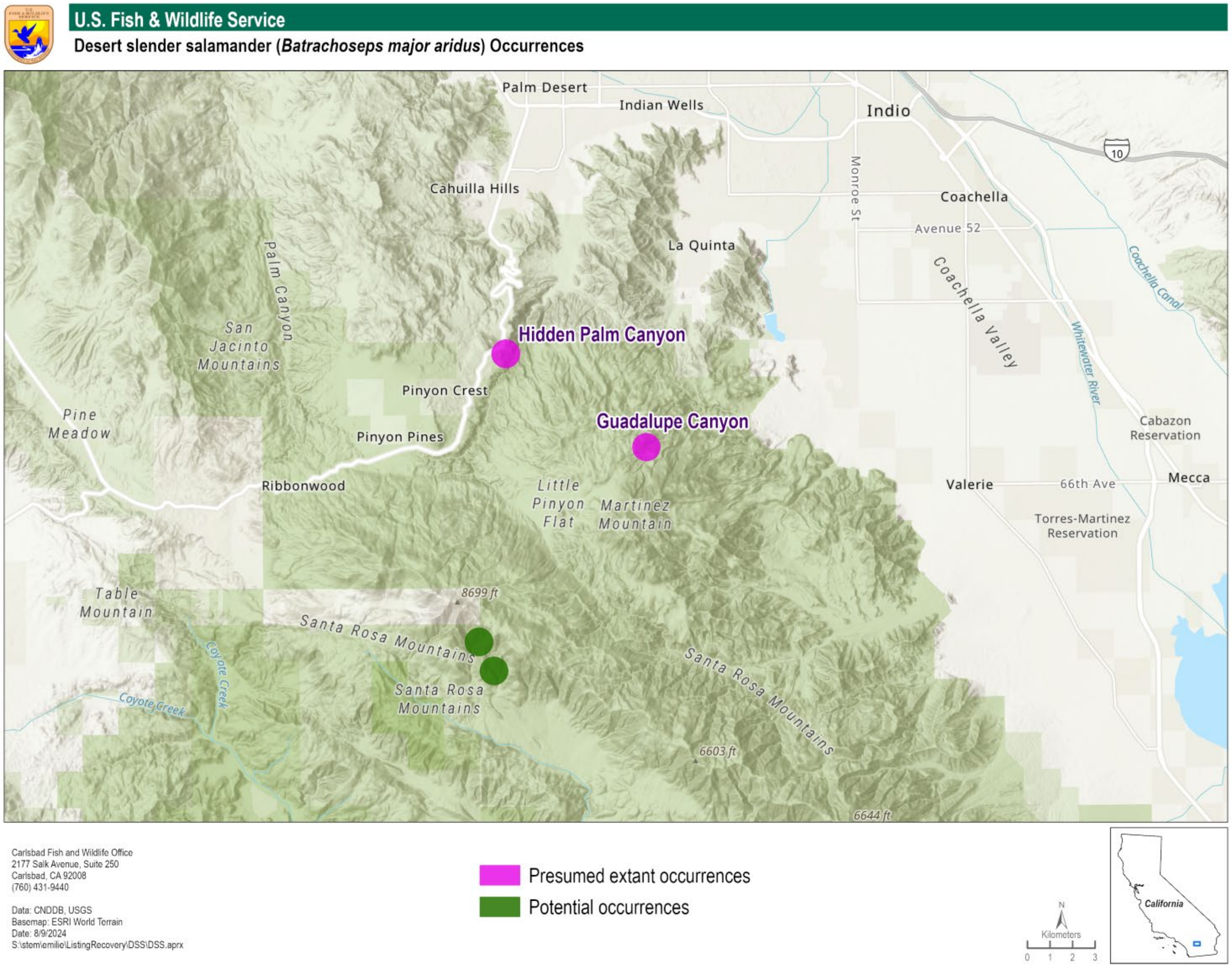

Figure 1. Desert slender salamander occurrences (presumed extant) and potential occurrences detected in the Santa Rosa Mountains by USGS in 2023. Locations of presumed extant and potential occurrences are obscured.

Table 1. Occurrence Table for *Batrachoseps Major Aridus*.

Location Name	Ownership/Conservation Status	Status at Listing	2014 Status	2024 Status	Last Observed	Change Summary since last Review
Hidden Palm Canyon	CDFW/ Hidden Palm Ecological Reserve	Extant	Presumed extant	Presumed extant	1 individual detected in 1997 by CDFW biologist (Nicol 1997, pp. 1–2).	There has been no change in EO or conservation status since 2020. USGS surveyed this site three times during February-March 2021.
Guadalupe Canyon	BLM/Santa Rosa Wilderness Area	N/A	Presumed extant	Presumed extant	30 individuals detected between November 1985 and July 1985 (Duncan and Esque 1986, p. 22).	There has been no change in EO or conservation status since 2020. USGS surveyed this site two times during March 2021 and did not observe the species.
Santa Rosa Wilderness	BLM/Santa Rosa Wilderness Area	N/A	N/A	Potential occurrence	2 individuals detected on April 2, 2023 (USGS 2023, p. 6).	Discovery surveys detected slender salamanders south of the historical locations.

Threats

The 1973 listing rule (Service 1973, p. 14678) did not contain a detailed five-factor analysis identifying threats to the desert slender salamander. The 2014 and 2020 5-year reviews addressed:

Factor A threats (the present or threatened destruction, modification, or curtailment of habitat or range) from erosion, fire, nonnative plants, and groundwater pumping.

Factor C threats (disease or predation) from *Batrachochytrium dendrobatidis.*

Factor E threats (other natural or manmade factors affecting a species' continued existence) from small population size and climate change.

In this review, we discuss small population size as a result from other threats. Otherwise, we have new information about the other six threats (Tables 2, 3).

Table 2. Threats Table for *Batrachoseps Major Aridus* by Locality.

Locality	Threats	Landowner	Conservation protection(s)
Hidden Palm Canyon	Erosion, fire, invasive plants, groundwater pumping, disease, climate change	CDFW	Hidden Palm Ecological Reserve (inaccessible without permit)
Guadalupe Canyon	Fire, invasive plants, disease, climate change	BLM	Santa Rosa Wilderness Area, Santa Rosa and San Jacinto Mountains National Monument. Management Plan does not have specific conservation measures for the species (BLM 2003; pp.2-7, 2-8, 4-14).

Table 3. Magnitude of Threats for *Batrachoseps Major Aridus*.[1]

Threat	Intensity	Exposure	Scope	Magnitude
Factor A: Erosion	L	L	Rangewide	L
Factor A: Fire	M	L	Localized	L
Factor A: Invasive plants	L	L	Localized	L
Factor A: Groundwater pumping	L	L	Localized	L
Factor C: Disease	H	M	Rangewide	H
Factor E: Climate change	M	H	Rangewide	H

[1] L=low, M=medium, H=high

Erosion

The Desert slender salamander Recovery Plan (Service 1982, p. 11) and subsequent 5-year reviews in 2014 (Service 2014, pp. 15–16) and 2020 (Service 2020, p. 2) identified erosion as a threat to the habitat at Hidden Palm Canyon due to sizable storms and the potential modification of watershed hydrology by the construction of Highway 74. Severe storms in September 1976 caused erosion in Hidden Palm Canyon that destroyed the habitat where salamanders were most commonly found (Service 1982, p. 9). Later site visits by CDFW staff in 2006 and 2012 found the lower portion of the wall was washed away (Konno 2013, pers. comm.).

Future habitat destruction due to erosion is expected to be minimal. The limestone substrate present at Hidden Palm Canyon is relatively resistant to erosion. Scouring of the surface of the wash, where the population has been previously found, would not likely affect the interstitial spaces underground where the salamander can retreat. The erosion documented previously may have destroyed the substrate that was most sensitive to erosion, leaving harder substrate that does not erode easily.

While some erosion may continue to change the canyon surface, these changes appear to be a low magnitude threat to desert slender salamander. However, the small population size of desert slender salamander may make them vulnerable to catastrophic erosion events caused by heavy rainfall. In this report, we distinguish erosion from debris flows. Rather than erosion, we consider debris flows, which may be exacerbated by catastrophic fire events and climate change, to be a greater threat to desert slender salamander. Debris flows will be discussed under Fire and Climate Change sections below.

Fire

The 2014 and 2020 5-year reviews identified fire as a threat to the habitat of desert slender salamander. Fire is unlikely to be a source of direct mortality for desert slender salamander because the hot, dry conditions associated with increased fire probability induce the salamanders to retreat underground. The 2014 5-year review concludes that the greatest threat that fire would be associated with is post-fire erosion effects, such as a precipitation event following a wildfire that could lead to debris flows.

Though there have been no recent fires in Hidden Palm Canyon or Guadalupe Canyon, there have been four small fires in the watershed areas around the two historical localities within the past 15 years (Cal-Fire 2022, Fire Perimeters). According to the CalFire Fire Probability for Carbon Accounting map, which estimates the projected annual probability of wildfire from 2021–2050, Guadalupe Canyon is mostly located in a 0.4-0.5 percent fire probability risk, while Hidden Palm Canyon has a <0.25 percent fire probability risk (CalFire 2024, Fire Probability).

These data and estimates correspond with characterizations of vegetation around desert slender salamander habitat. The watershed and adjacent slopes surrounding desert slender salamander habitat are drier and dominated by desert vegetation (Brame 1970, p. 7; Bleich 1978, p. 3; Service 1982, p. 7). The fire return interval for the vegetation association in this area (*Agave deserti* Shrubland Alliance) is characterized as truncated and long, with typically low intensity and moderate severity fires (Sawyer *et al.* 2009, p. 334). The natural intensity and severity of fire in the *Washingtonia filifera* Woodland Alliance found within the canyons is low (Sawyer *et al.* 2009, p. 300). Except for the effect nonnative grasses might have on fire frequency, the composition of the plant community in the surrounding watershed suggests that a fire is unlikely to be carried through this area (Fisher 2013, pers. comm.). Therefore, the risk of fire in the canyon itself appears low.

Knowledge of amphibian responses to wildfire is limited compared to other vertebrates. In a 2011 review, Hossack and Pilliod (p. 131) conclude that direct mortality from fire is a small threat to most healthy populations, although fire, or any stochastic stressor, could pose a more severe threat to small, isolated populations such as the desert slender salamander. Additionally, wildfires may produce cryptic effects in salamanders such as host-specific changes in skin microbiota (Mulla and Hernandez-Gomez 2023, p. 2203). However, the subterranean association of desert slender salamander combined with the low intensity, severity, and probability of fire in the habitat makes direct mortality from fire a low magnitude threat.

Although fire itself does not pose an immediate or severe threat to desert slender salamander, the compounding post-fire effects could greatly disturb its habitat. A fire on the slopes of the canyon followed by a rain event could facilitate habitat degradation from debris flows. Post-fire debris flows have reduced amphibian habitat and nearly extirpated endangered populations in Southern California (Service 2009, p. 9; Backlin *et al.* 2013, p. 162). Although debris flows in the drier desert climate will not likely be as destructive as debris flows that affect mountain habitats with greater vegetative cover and greater precipitation, debris flows have the potential to bury the limited amount of suitable habitat available to desert slender salamander. The threat of fire, rain events, and potential debris flows should continue to be monitored with changing climactic conditions.

Nonnative Invasive Plants

Nonnative plants have been observed on site visits to both Hidden Palm Canyon and Guadalupe Canyon. *Tamarix chinensis* (Saltcedar) has been observed at Hidden Palm Canyon (Service 2009, p. 9) and Guadalupe Canyon in 1984–1985 (Duncan and Esque, 1986, pp. 6, 48). *Tamarix chinensis* was observed again at Hidden Palm Canyon in 2012 (Konno 2013, pers. comm.). The nonnative grass, *Bromus madritensis* subsp. *rubens* (Red brome), has been identified in the habitat surrounding Hidden Palm Canyon. Both species may increase fire frequency (Barrows 1996, p. 1; Cal IPC 2013, p. 1).

Though nonnatives have been reported at both historical localities, these locations are relatively resistant to nonnative plant invasion because there is limited water available. The direct effects of invasive nonnative plants on desert slender salamander are unknown. They may decrease soil water content (Barrows 1996, pp. 1–2), although they may also create suitable habitat for desert slender salamander by providing cool, shaded areas. Although nonnative plants have historically been observed at Hidden Palm Canyon and Guadalupe Canyon, they represent a low magnitude threat to desert slender salamander.

Groundwater Pumping

The 2014 and 2020 5-year reviews describe the threat of increased groundwater pumping in the upper watershed (Service 2014, pp. 19–20; Service 2020, p. 2). While both historical localities are geographically remote with no anticipated threat of development, the habitats may be indirectly impacted by groundwater pumping of the surrounding watershed. Since Guadalupe Canyon is located within the Santa Rosa Wilderness Area, prohibiting any development in the area, groundwater pumping is only considered a threat for Hidden Palm Canyon.

The uphill watershed of Hidden Palm Canyon is the site of approximately 50 homes that appear to have been constructed decades ago. There has been limited development in this area for the past 15 years, with the construction of less than five houses, and no additional development since 2013 (Service 2024b, GIS data). The estimated water usage of this limited number of homes is expected to be low given the size of the watershed (Service 2014, p. 19). Based on the limited development in the Hidden Palm Canyon watershed, groundwater pumping is considered a low magnitude threat.

Disease

The fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*), which causes the infectious disease chytridiomycosis in amphibians, has contributed to declines and extinctions in hundreds of amphibian species and remains a threat to desert slender salamander (Skerratt *et al.* 2007, pp. 1-8; Wake and Vredenburg 2008, p. 11466).

USGS conducted surveys at the two historical localities between 2017–2019 and 2021–2023. Although they did not find desert slender salamander, they found other amphibians at these occurrences, including California treefrog (*Pseudacris cadaverina*) at Hidden Palm Canyon and Guadalupe Canyon, and red-spotted toad (*Anaxyrus punctatus*) at Hidden Palm Canyon. Red-spotted toads detected in the 2017 to 2019 surveys were tested for Bd. The presence of Bd was confirmed at Hidden Palm Canyon with 60 percent (18 of 30 red-spotted toads) testing positive. However, in 2021, one California treefrog from Hidden Palm Canyon and six from Guadalupe Canyon were tested for Bd and *Batrachochytrium salamandrivorans* (Bsal), though neither disease was detected (USGS 2021, p. 5).

Information on susceptibility to Bd-induced mortality or disease transmission in desert slender salamander remains unknown. Cowgill *et al.* (2021, p.1) investigated chytridiomycosis dynamics within two co-occurring salamander species, *Batrachoseps luciae* and *Aneides lugubris*, and found that both species had high Bd-induced mortality rates. This indicates that *Batrachoseps* species like desert slender salamander are highly vulnerable to Bd. Bd infection was positively correlated to intraspecific group size and proximity to heterospecific amphibians (Cowgill *et al.* 2021, pp. 1). With the small population size of desert slender salamander and proximity to other amphibians at historical occurrences, the threat of Bd could be severe. Bd may have already affected desert slender salamander populations in Hidden Palm Canyon and Guadalupe Canyon, considering that Bd was detected in other amphibians in Hidden Palm Canyon. A Bd-related mass mortality event of desert slender salamander would have likely been undetected, since the salamander are cryptic and remote.

The salamander chytrid fungus Bsal is causing mortality of salamanders in Europe, prompting concern that Bsal could be introduced to North American salamanders. Extensive testing of salamanders in North America failed to detect Bsal occurrence, with further modeling indicating that Bsal is "highly unlikely" to occur in amphibians in North America (Waddle *et al.* 2020, pp. 1–4). USGS testing of red-spotted toads at Hidden Palm Canyon also did not detect Bsal in this population. However, laboratory experiments found that lungless salamanders (family Plethodontidae) are particularly vulnerable to Bsal chytridiomycosis, while anuran families also became infected (Gray *et al.* 2023, p. 2). The southwestern United States had a moderate predicted invasion risk score (Gray *et al.* 2023, p. 2). Given these findings, the isolation of historical desert slender salamander occurrences, and the low vagility of *Batrachoseps* species that occupy the surrounding areas, Bsal is not considered a threat at this time.

Climate Change

Climate Change Projections

The 2014 5-year review identified climate change as a threat to desert slender salamander. In 2014, we generally predicted that the southwest United States would become drier, and that extreme events such as heavier storms, heat waves, and regional droughts would become more common (Glick *et al.* 2011, p. 7; Service 2014, p. 29). We also predicted that mean annual temperatures in the Sonoran Desert ecoregion, where desert slender salamander occurs, was expected to increase by 1.8 to 2.4°Celsius [C; 3.2 to 4.3°Fahrenheit (F)] (PRBO 2011, p. 47) and that the number of extremely hot days (above the 95th percentile) was expected to increase by 22 days (Bell *et al.* 2004, pp. 83–85; Service 2014, p. 29).

Boyd Deep Canyon Desert Research Center, University of California Riverside, manages a reserve close to Hidden Palm Canyon and has collected continuous weather data since 1974. We used data from the Agave Hill weather station, located at an elevation similar to Hidden Palm Canyon, to understand the trends in temperature around desert slender salamander occurrences. The average maximum temperature in January is 15.9°C (60.6°F), and the average maximum temperature in July is 35.2°C (95.3°F), with an average increase of 0.04°C (0.07°F) per month for both January and July temperatures (Figure 2). Average maximum temperatures in January and July have increased since 1974 and may be contributing to drier habitat.

We used data from the Pinyon Crest weather station, located in the recharge area for the seep at Hidden Palm Canyon, to understand trends in annual rainfall around desert slender salamander occurrences. Annual average rainfall is around 23.8 cm (9.4 in) (Figure 3).

We relied on data from Cal-Adapt, which used peer-reviewed climate data to build tools to forecast climate change in California (Cal-Adapt 2024). Since desert slender salamander is highly localized, we used Localized Constructed Analogues (LOCA) grid cells as the unit of analysis.

In the area around Hidden Palm Canyon, average temperatures are expected to increase, while average precipitation is expected to increase slightly. Annual average maximum temperature is expected to increase, from a baseline of 24.1°C to 26.4°C (75.4°F to 79.6°F) in the mid-century and 27.2°C (81.0°F) in late century, under RCP4.5 medium emissions scenario (Table 4; Cal-Adapt 2024). Annual average precipitation is expected to increase from a baseline of

10.9 inches to 12.3 inches in the mid-century and 11.7 inches in late century (Table 5; Cal-Adapt 2024).

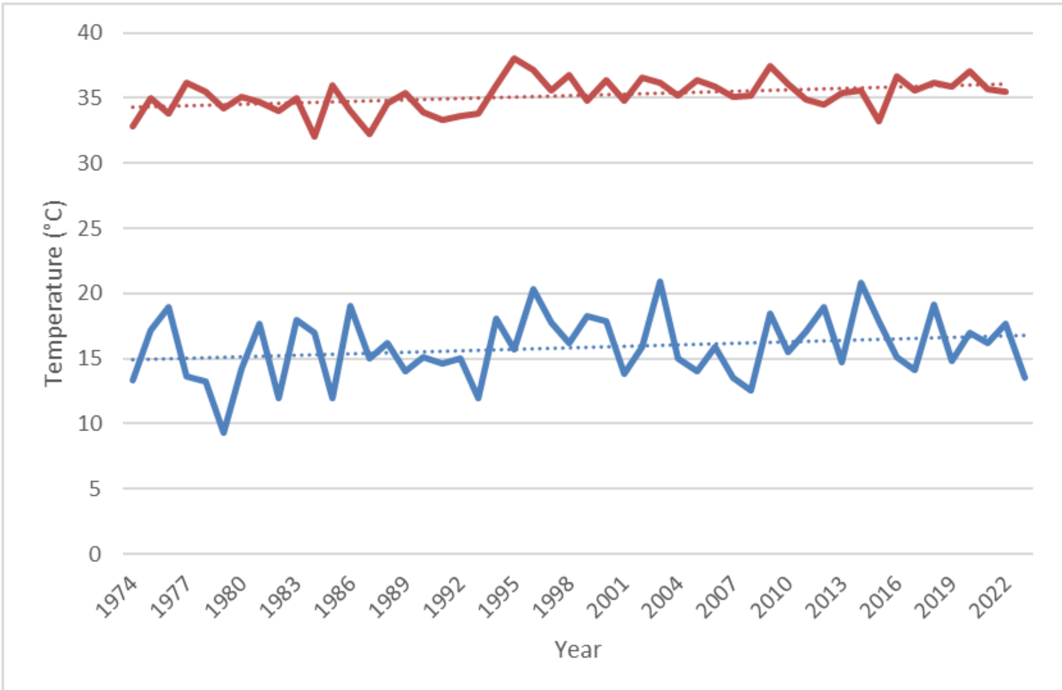

Figure 2. Average Maximum Temperatures (in degrees Celsius) at the Boyd Deep Canyon Desert Research Center Agave Hill Weather Station for the Months of January (blue) and July (red) from 1974 to 2023 (UC NRS 2024, web). Linear trendlines provided.

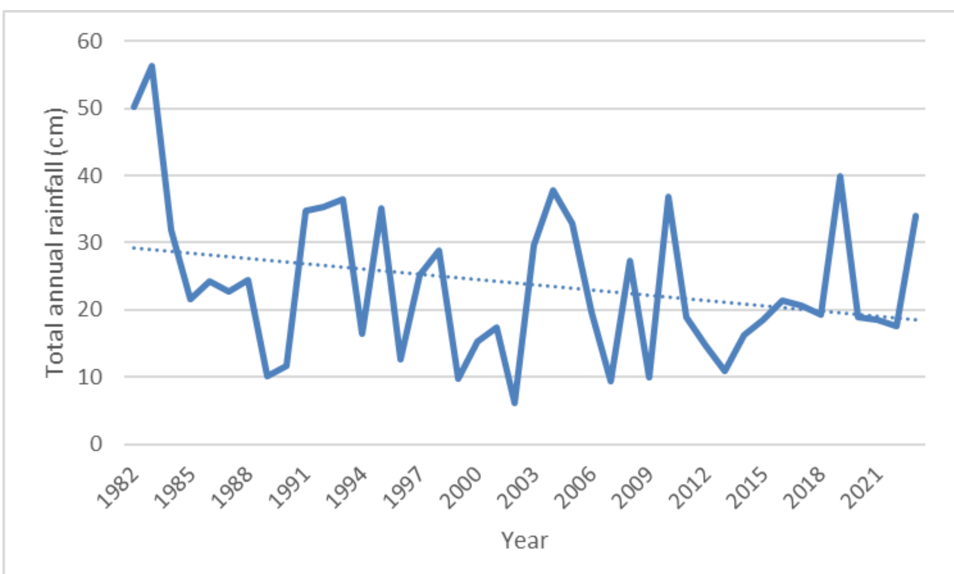

Figure 3. Total Annual Rainfall (in cm) at the Boyd Deep Canyon Desert Research Center Pinyon Crest Weather Station from 1982 to 2023 (UC NRS 2024, web). Linear trendline provided.

Table 4. Projected Annual Average Maximum Temperatures for *Batrachoseps Major Aridus* in Hidden Palm Canyon (LOCA Grid Cell 33.59375, -116.40625).[1,2]

Year Range	RCP4.5 Projected Annual Average Maximum Temperature (30-year Average and Range, Degrees C)	RCP8.5 Projected Annual Average Maximum Temperature (30-year Average and Range, Degrees C)
Historical (1961–1990)	24.1°C (range 22.6-25.7°C)	24.1°C (range 22.6-25.7°C)
Mid-century (2035–2064)	26.4°C (range 24.9-28°C)	27°C (range 25.3-29.4°C)
End of century (2070–2099)	27.2°C (range 25.7-28.8°C)	28.8°C (range 26.5-30.9°C)

[1] The values are the average of projections from four priority models (CanESM2, CNRM-CM5, HadGEM2-ES, MIROC5) during the mid-century (2035-2064) and end-of-century time period (2070-2099).

[2] Data from Cal-Adapt (2024).

Table 5. Projected Annual Average Precipitation *Batrachoseps Major Aridus* in Hidden Palm Canyon (LOCA Grid Cell 33.59375, -116.40625).[1,2]

Year Range	RCP 4.5 Projected Annual Average Precipitation (30-year Average and Range, Inches)	RCP 8.5 Projected Annual Average Precipitation (30-year Average and Range, Inches)
Historical (1961–1990)	10.9 (range 2.1-31.4)	10.9 (range 2.1-31.4)
Mid-century (2035–2064)	12.3 (range 1.6-33.1)	11.8 (range 1.0-36.4)
End of century (2070–2099)	11.7 (range 2.4-47.0)	13.7 (range 1.4-44.1)

[1] The values are the average of projections from four priority models (CanESM2, CNRM-CM5, HadGEM2-ES, MIROC5) during the mid-century (2035-2064) and end-of-century time period (2070-2099).

[2] Data from Cal-Adapt (2024).

Annual averages may obscure seasonal variation and climate extremes. Pierce *et al.* (2013) used downscaled global climate models to estimate seasonal changes in temperature and precipitation in California. While warming is expected year-round, it is particularly pronounced in summer months, with the warmest historical July temperatures being cooler than the projected future mean (Pierce *et al.* 2013, pp. 844–855). In southeastern California, spring and fall precipitation is projected to decrease, while summer rainfall is expected to increase as the North American monsoon intensifies (Pierce *et al.* 2013, pp. 851, 855). These projections agree with the estimates from Cal-Adapt (Tables 3, 4).

Potential Response of Species

Amphibians are generally sensitive to environmental changes due to their life history traits. Although little is known about the life history and biology of the desert slender salamander specifically, its small population size, isolated habitat and limited dispersal ability restrict its ability to adapt to new climate conditions. Desert slender salamander may not be able to shift its range in response to climate change. The small population size hinders the ability of the population to respond to a mass mortality event that may result from climate extremes; this may also represent low adaptive capacity that could reduce the species' ability to adapt to changing environmental conditions.

Elevated temperature and evaporative water loss should be considered when evaluating the projected physiological stress on amphibians. Evaporative water loss is a thermal regulatory mechanism for amphibians, so that increased evaporative water loss helps lower body temperature (Lertzman-Lepofsky *et al.* 2020, p. 2). A combination of rising temperatures and decreased moisture may create conditions that exceed thermal and hydric physiological limits. Presumably, desert slender salamander possess physiological and behavioral (e.g., retreating to subterranean burrows) adaptations to relatively high temperatures and decreased precipitation given their historical range in desert climates. However, we cannot determine whether climate change projections will exceed their physiological limits because these limits are unknown. Even if climate projections do not exceed certain thermal and hydric limits, the energetic strain of maintaining metabolic functions in warmer temperature may come at the cost of weakened immune defenses and increase strain on cardiovascular tissues (Rollins-Smith and Le Sage 2023, pp. 2–3).

The stress of unprecedented high temperatures in the summer may be mediated by increased precipitation; the additional moisture could allow salamanders to increase evapotranspiration to cool down without risking desiccation. Although summer precipitation and temperature are both expected to increase, the combination of higher summer temperatures and drought conditions or reduced groundwater seepage would threaten the survival of desert slender salamander populations. The increases in summer rainfall may also exacerbate flooding and debris flows that disturb desert slender salamander habitat.

Although desert slender salamanders are not likely to shift their range or adapt through rapid selection, they may be able to adapt through plasticity. Species can respond to climate change by reducing their body size, which could be the result of either plasticity in growth or selection for smaller size. A study of *Plethodon* species, which belong to the same family as desert slender salamander, found that some species demonstrated reductions in body size. These reductions are likely indicative of plastic growth, as salamanders increase their metabolism to adapt to a changing climate, rather than rapid genetic changes through selection (Caruso *et al.* 2014, pp. 1751, 1758). These findings illustrate how desert slender salamander may be able to adapt to climate change through plastic growth.

Increased temperature may also have reproductive effects on the desert slender salamander. Early warming might cue breeding earlier in the year (Carey and Alexander 2003, p. 111; Corn 2005, p. 61), potentially increasing the susceptibility of individuals to temperature drops that are more common early in the season. However, at least some salamander species appear to require a latency period and long temperature lags (several warmer days in a row) to cue breeding (Bernard and Greenwald 2023, p. 1), which protects the species from breeding too early. The effects of increased temperature on the breeding phenology of desert slender salamanders are unknown.

Climate change may alter host-pathogen interactions, which may be harmful or beneficial for an amphibian host (Blaustein *et al.* 2010, p. 296). *Bd* is known to grow best within a particular temperature range [4–25°C (39–77°F)] (Piotrowski *et al.* 2004, p. 9), with pathogenicity (ability to cause disease) and virulence (degree of magnitude caused by the disease) diminishing at elevated temperatures [31.8°C (91ºF)] (Longcore *et al.* 1999, p. 223). Projected average maximum temperatures in the mid and late century exceed this threshold (Table 3), which may reduce the threat of *Bd.* Changes in climate can also result in changes in the ranges of pathogens or pathogen vectors (Blaustein *et al.* 2010, p. 296). Climate change may also result in changes in amphibian behavior, immune system strength, and phenology that disrupt existing host-pathogen interactions (Blaustein *et al.* 2010, pp. 295–298). Because there is no information on which pathogens affect desert slender salamander, we are unable to predict how climate change will affect disease ecology.

It is difficult to predict the effects of climate change on desert slender salamander because so little is known about the species' physiology, breeding phenology, and disease ecology. Climate change may also alter host-pathogen interactions and breeding phenology. Importantly, increased temperatures may reduce the threat of *Bd.* We project that the stress of unprecedented high temperatures in summer months will be mitigated to some degree by increased precipitation, although drought conditions in the summer would be a serious concern. The subterranean habit of desert slender salamander may also allow the salamander protection from the harshest effects of high temperature and extreme precipitation. However, heat stress and drier conditions may lead to sublethal effects, which, combined with other threats such as disease, may lead to decreased fitness, lower breeding success, and mortality.

Summary of Threats

In 2020, we recommended that the status of desert slender salamander remain unchanged due to continued threats affecting the species. In this review, we updated our threats analysis and provided new information related to the distribution and abundance of the desert slender salamander. Currently, disease and climate change present the greatest threats to desert slender salamander, and the remaining threats are low in magnitude (Tables 2, 3).

Conclusion

Desert slender salamander is only known from two localities in Riverside County and has not been detected since 1997 in Hidden Palm Canyon and since 1985 in Guadalupe Canyon. The habitat at these historical localities appears much drier than in the decades when salamanders were last detected and thus may no longer be suitable habitat. Though multiple survey efforts have not detected salamanders at the two sites, we continue to presume that these occurrences remain extant. We recommend that surveys at these sites continue, and that the status of these occurrences should be reconsidered if there are further negative survey results.

Since 2020, USGS has conducted surveys for desert slender salamander across Southern California deserts beyond its known range. They detected two salamanders in nearby sites in the Santa Rosa Mountains, which may represent new desert slender salamander occurrences, but further morphological and genetic analysis is required to determine the identity of these individuals.

New information from survey efforts does not substantially alter the species' status or the results of our five-factor analysis in the previous review. Therefore, we conclude that the desert slender salamander remains a federally endangered subspecies and recommend no change in status at this time.

RECOMMENDATIONS FOR FUTURE ACTIONS

We recommend that the following actions be completed over the next 5 years to manage threats to *Batrachoseps major aridus* and aid in recovery efforts. We recognize that conservation of this species will require cooperation and coordination with partners.

1. Conduct additional surveys at Hidden Palm Canyon and Guadalupe Canyon to determine whether the habitat is suitable, and the populations remains extant.

2. Continue surveys at potentially suitable habitat in Santa Rosa Mountains and other areas in Southern California.

3. Fill knowledge gaps related to species life history, ecology, and habitat needs. Specifically, determine when and how often desert slender salamander must surface from subterranean spaces to inform more effective survey techniques and understand threats.

4. Conduct genomic analysis of *Batrachoseps* individuals detected in Santa Rosa Mountains to confirm whether they represent a new occurrence for the species.

5. Evaluate impacts of climate change through drought and extreme precipitation events on habitat suitability.

6. Continue to monitor for *Batrachochytrium dendrobatidis* (Bd) and *Batrachochytrium salamandrivorans* (Bsal) within the species range.

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