Pecos gambusia
(Gambusia nobilis)
5-Year Status Review:
Summary and Evaluation

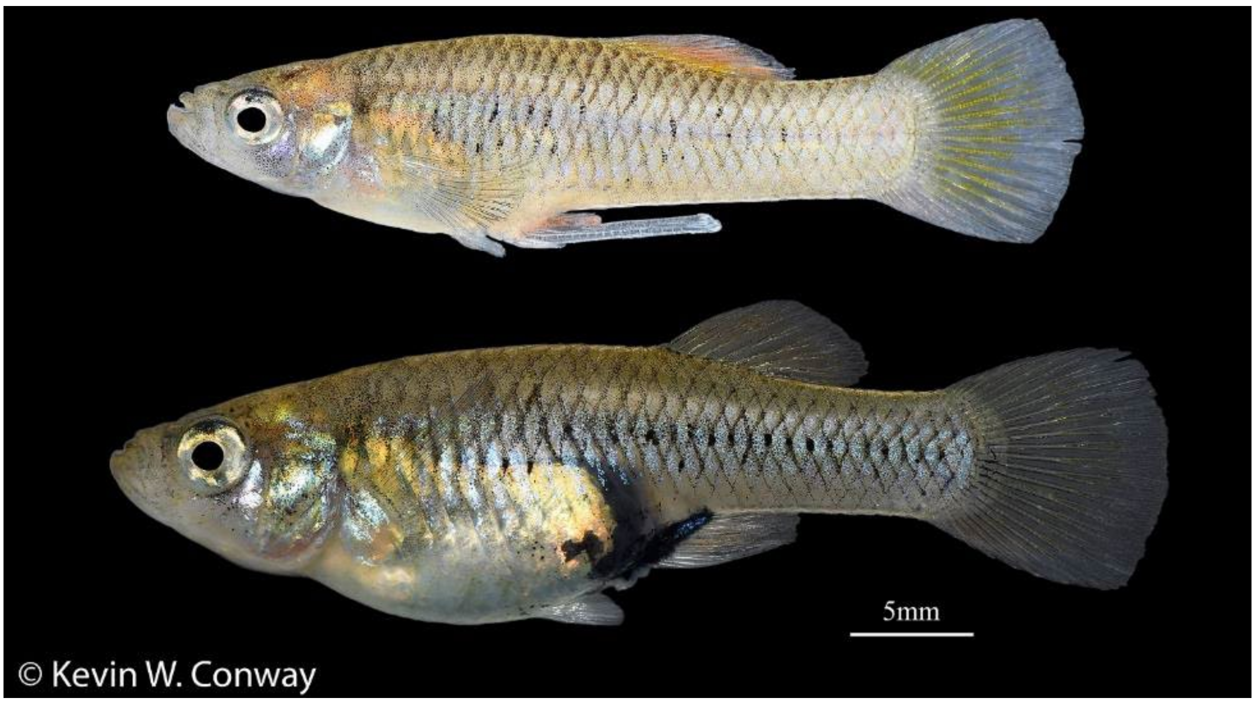

Image: Male (top) and female (bottom) Pecos gambusia. Photo copyright Kevin W. Conway, Texas A&M University.

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
Austin, Texas
July 24, 2025

5-YEAR REVIEW

Species reviewed: Pecos gambusia (*Gambusia nobilis*)

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Pecos gambusia (*Gambusia nobilis)*

1.0 GENERAL INFORMATION

1.1 Reviewers:

Lead Regional or Headquarters Office:
Gary Pandolfi, Recovery Biologist, Southwest Regional Office, Albuquerque, New Mexico

Lead Field Office:
Maritza Mallek, Fish and Wildlife Biologist, Austin Ecological Services Field Office, Austin, Texas

Cooperating Field Office(s):
Sarah Yates, Fish and Wildlife Biologist, New Mexico Ecological Services Field Office, Albuquerque, New Mexico

Mike Montagne, Project Leader, Texas Fish and Wildlife Conservation Office, San Marcos, Texas

Nate Caswell, Project Leader, New Mexico Fish and Wildlife Conservation Office, Albuquerque

Carl Jacobsen, Refuge Biologist, Bitter Lake National Wildlife Refuge, Roswell, New Mexico

Cooperating Regional Office(s):
Not Applicable

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service or USFWS) is required by section 4(c)(2) of the Endangered Species ESA (ESA) to conduct a status review of each listed species once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing as endangered or threatened is based on the species' status considering the five threat factors described in section 4(a)(1) of the ESA. These same five factors are considered in any subsequent reclassification or delisting decisions. In the 5-year review, we consider the best available scientific and commercial data on the species and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

The U.S. Fish and Wildlife Service (Service) conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.12) as required by section 4(c)(2)(A) of the Endangered Species Act (16 U.S.C. 1531 et seq.). The Service provides notice of status reviews via the *Federal Register* and requests new information on the status of the species (e.g., life history, habitat conditions, and threats). Data for this status review were solicited from interested parties through a *Federal Register* notice announcing this review on January 11, 2023 (88 FR 1602). This review was conducted by the Austin Ecological Services Field Office and considered both new and previously existing information from federal and state agencies, non-governmental organizations, academia, and the public. The primary sources of information used in this analysis included information from the recovery plan, the 2018 Five-Year Status Review, peer-reviewed articles, agency reports, and other documents available in the Austin Ecological Services Field Office files. We engaged with staff from Texas Parks and Wildlife Department (TPWD), specifically those from the agency's Inland Fisheries and State Parks (i.e., Balmorhea State Park) Divisions. We also engaged with Service employees affiliated with various programs and divisions, including but not limited to the New Mexico Ecological Services Field Office, the Texas Fish and Wildlife Conservation Office (FWCO), the New Mexico FWCO, Bitter Lake National Wildlife Refuge (NWR). Finally, we engaged with staff from The Nature Conservancy (TNC), the Middle Pecos Groundwater Conservation District, and researchers from universities with expertise in the species. Comments received were evaluated and incorporated as appropriate.

1.4 Background:

1.4.1 FR Notice citation announcing initiation of this review:

88 FR 1602: January 11, 2023

1.4.2 Listing history:

<u>Original Listing</u>
FR notice: 35 FR 16047
Date listed: October 13, 1970
Entity listed: Pecos gambusia (*Gambusia nobilis*)
Classification: Endangered

1.4.3 Associated Rulemakings:

Not applicable

1.4.4 Review History:

A five-year status review for the Pecos gambusia was approved in July 2018. This was the first five-year review completed for the species. The recommendation resulting from the review was that no change was warranted to the classification of the species as Endangered.

1.4.5 Species' Recovery Priority Number at start of 5-year review:

11

1.4.6 Recovery Plan or Outline

Name of plan or outline: Pecos Gambusia Recovery Plan
Date issued: November 16, 1981
Dates of previous plans/amendment or outline, if applicable: Not applicable

2.0 REVIEW ANALYSIS

Section 4 of the ESA (16 U.S.C. 1533) and its implementing regulations (50 CFR part 424) set forth the procedures for determining whether a species meets the definition of "endangered species" or "threatened species." The ESA 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 ESA requires that we determine whether a species meets the definition of "endangered species" or "threatened species" due to any of the five factors described below.

Section 4(a) of the ESA describes five factors that may lead to endangered or threatened status for a species. These include: 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.

The 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 assessing whether a species meets either definition, we must evaluate all identified threats by considering the expected response of 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 Service recommends 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 in the foreseeable future.

2.1 Distinct Population Segment (DPS) policy (1996):

Not applicable; the Pecos gambusia is not listed as a DPS.

2.2 Updated Information and Current Species Status

2.2.1 Biology and Habitat

2.2.1.1 New information on the species' biology and life history:

New information is available on the tendency of Pecos gambusia to mate with congeners (i.e., other fish species in the same genus) and conspecifics (i.e., other Pecos gambusia). Based on the results from a genetics study conducted at Balmorhea State Park using individuals collected in 2015 and 2016, it appears that male Pecos gambusia are unlikely to successfully mate with female largespring gambusia (*G. geiseri*) (Rodriguez 2017, p. 48). However, male largespring gambusia appear to successfully mate with female Pecos gambusia. In general, Pecos gambusia males appear to prefer conspecific females, even when largespring gambusia females are more abundant than Pecos gambusia females (Rodriguez 2017, p. 49). This may explain the persistence of Pecos gambusia; that is, why the species has not been replaced by a hybrid swarm (Rodriguez 2017, p. 49). Similarly, an earlier study evaluating the hybridization potential between Pecos gambusia and western mosquitofish using individuals collected from 2007 to 2009 found that both male and female Pecos gambusia preferred to mate with conspecifics (Swenton 2011, p. 211). These studies provide evidence that although hybrids of Pecos gambusia with both largespring gambusia and western mosquitofish (*G. affinis*) occur, Pecos gambusia continue to persist even when they occupy the same habitats as these congeners and when introgression occurs.

An analysis of age structure was completed on the Pecos gambusia populations within the San Solomon and Clark Hubbs Ciénegas at Balmorhea State Park using data collected from 2009 to 2012 (Hargrave et al. 2013, p. 2). Pecos gambusia were observed to have 3 distinct age classes in the San Solomon and Clark Hubbs Ciénegas at the time the study was conducted (Hargrave et al. 2013, pp. 11–12). The researchers suggest that only age 1 individuals are reproductive in these ciénegas (Hargrave et al. 2013, pp. 11–12). Growth was also monitored through the first summer, and the report indicates that young-of-year Pecos gambusia in these populations born in the spring grow 25 millimeters (mm) (0.98 inches (in)) from summer to winter (Hargrave et al. 2013, p. 11).

During the same research period, the diet of Pecos gambusia was investigated through gut content analysis of captured Pecos gambusia from the San Solomon and Clark Hubbs Ciénegas (Hargrave et al. 2013, pp. 12, 19). Pecos gambusia in the San Solomon Cienega consumed mostly algae, which comprised ~75% of the stomach contents of the fish examined (Hargrave et al. 2013, p. 13). Also present in these Pecos gambusia were benthic invertebrates and terrestrial insects (Hargrave et al. 2013, p. 13). Stomach contents did not vary across or within years of the study (Hargrave et al. 2013, p. 13). Pecos gambusia in the Clark Hubbs Cienega ate a smaller proportion of algae (~45%) and a higher proportion of benthic invertebrates and terrestrial insects (~50%) compared to the San Solomon Cienega (Hargrave et al. 2013, p. 19). Stomach contents of Pecos gambusia in the Clark Hubbs Cienega were increasing in algae consumption over time (Hargrave et al. 2013, p. 19).

Diet overlap between Pecos gambusia and largespring gambusia was assessed in both Balmorhea State Park ciénegas. Diet overlap in the San Solomon Cienega was high, averaging 80%, and appeared to be increasing over the course of the study period (Hargrave et al. 2013, p. 18). In the Clark Hubbs Cienega, diet overlap ranged from 13% in December of 2009 to 76% in August of 2012, averaging 62%, but exhibiting no temporal trend (Hargrave et al. 2013, p. 24). Based on the gut content and diet overlap results, Hargrave et al. suggested that Pecos gambusia, as well as the other fishes present in the ciénegas at Balmorhea State Park, may be limited by resource availability since they all rely on aquatic invertebrates (2013, p. 27).

Another research study examined competition between Pecos gambusia and largespring gambusia and how changes to flow impact that competition (Delaune and Hargrave 2014, p. 3). In the wild, largespring gambusia are far more abundant than Pecos gambusia (Delaune and Hargrave 2014, p. 2). In addition, where spring flows are higher, the ratio of the two species is about 1:1, but when flows are low, the ratio becomes skewed in favor of largespring gambusia (Delaune and Hargrave 2014, p. 16). Observations from the wild also indicate that Pecos gambusia appear to cluster near spring outlets (Delaune and Hargrave 2014, p. 17). The authors hypothesized that spring flow rates present in the wild may be an important factor influencing the ratio of Pecos gambusia to largespring gambusia (Delaune and Hargrave 2014, pp. 2–3). An experimental mesocosm was used to measure competition in a controlled environment, with growth rates used as the metric by which competition was assessed (Delaune and Hargrave 2014, pp. 8–12). Competition between the species was evaluated under high and low flow scenarios (Delaune and Hargrave 2014, pp. 5–7). By comparing growth in each species under different flow treatments, the authors concluded that Pecos gambusia outcompetes largespring gambusia under high flow scenarios, but that they exert equal competitive pressures on one another under low flow scenarios (Delaune and Hargrave 2014, pp. 17–18). Flow is likely not the only factor influencing the relative abundance and density of these two species when they co-occur, but given trends towards decreased flow in wild habitats, may be a very important one (Delaune and Hargrave 2014, pp. 19–21), particularly given the fact that flows tend to be declining for all extant Pecos gambusia populations.

A number of behavior studies on Leon Springs pupfish (*Cyprinodon bovinus*) by members of the Itzkowitz Lab from Lehigh University aimed to investigate interactions between Leon Springs pupfish and Pecos gambusia (Paciorek et al. 2014, pp. 527–528; Black et al. 2016, entire; Snekser et al. 2017, pp. 86–87; Snekser and Itzkowitz 2022, pp. 143–144). However, these studies omit an analysis of western mosquitofish, which co-occurs with Pecos gambusia in places where Leon Springs pupfish is also present. Because the studies were conducted visually, we suggest that while their findings may apply to the two gambusia species in combination, they do not provide information on Pecos gambusia specifically.

2.2.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, birth rate, seed set, germination rate, age at mortality, mortality rate, etc.), or demographic trends:

Diamond Y Preserve

Since the last five-year review was completed in 2018, TPWD and TNC have also conducted Pecos gambusia monitoring surveys. For the period 2021–2023, minnow traps were used to conduct surveys at Diamond Y, Karges, and Euphrasia Springs on TNC's Diamond Y Preserve. Table 1, Table 2, and Table 3 show the results from that effort. No putative hybrids were recorded, but Pecos gambusia and western mosquitofish can hybridize, so some hybrids may be present at very low levels (U.S. Fish and Wildlife Service 1983, p. 14; The Nature Conservancy 2023, pp. 11, 16).

The analysis of that data also evaluated the relative abundance of these species and Leon Springs pupfish (The Nature Conservancy 2023, p. 11). Pecos gambusia comprised a widely varying proportion of the trapped fishes at the Diamond Y Spring over the study period, but consistently comprised a large majority of the trapped individuals at Karges (~60–80%) and Euphrasia (~85–100%) Springs (The Nature Conservancy 2023, p. 11).

There appeared to be some correlation between flows and the relative abundance of Pecos gambusia compared to western mosquitofish, with Pecos gambusia being more dominant under higher flows (The Nature Conservancy 2023, p. 16). Both flows and sampling results were more consistent over time at

Karges and Euphrasia Springs, while the reduction in flows at the Diamond Y Spring was associated with an increase in the abundance and density of western mosquitofish (The Nature Conservancy 2023, pp. 11, 16). The report also notes that Pecos gambusia are no longer present at the confluence of Diamond Y Draw and Leon Creek due to the drying of that habitat, marking a decline to zero of Pecos gambusia abundance in this area (The Nature Conservancy 2023, p. 16).

Table 1. Results from minnow trap sampling at Diamond Y Spring from 2021 to 2023. We include data for both Pecos gambusia and western mosquitofish because the two species compete with one another and are capable of producing hybrid offspring. Data from The Nature Conservancy (2023, p. 11). The sampling effort on July 25, 2022 had lower trap hours because low flows in Diamond Y Spring necessitated modifications to the survey protocol. Fewer traps were set, and locations were adjusted. CPUE refers to catch per unit effort; the unit of effort in this case is trap hours.

Date	Trap Hours	Pecos gambusia	Pecos gambusia CPUE	Western mosquitofish	Western mosquitofish CPUE
11/11/2021	45.77	2	0.04	0	0.0
4/27/2022	60.57	25	0.41	8	0.1
7/25/2022	20.53	45	2.19	275	13.4
11/2/2022	48.68	5	0.10	0	0.0
2/27/2023	57.17	35	0.61	10	0.2
5/2/2023	62.33	7	0.11	51	0.8

Table 2. Results from minnow trap sampling at Karges Spring from 2021 to 2023. We include data for both Pecos gambusia and western mosquitofish because the two species compete with one another and are capable of producing hybrid offspring. Data from The Nature Conservancy (2023, p. 11). CPUE refers to catch per unit effort; the unit of effort in this case is trap hours.

Date	Trap Hours	Pecos gambusia	Pecos gambusia CPUE	Western mosquitofish	Western mosquitofish CPUE
11/12/2021	34.92	388	11.11	18	0.5
4/27/2022	55.92	57	1.02	0	0.0
7/26/2022	63.62	229	3.60	5	0.1
11/3/2022	59.58	245	4.11	11	0.2
2/28/2023	57.23	265	4.63	1	0.0

Table 3. Results from minnow trap sampling at Euphrasia Spring in 2022 and 2023. We include data for both Pecos gambusia and western mosquitofish because the two species compete with one another and are capable of producing hybrid offspring. Data from The Nature Conservancy (2023, p. 11). CPUE refers to catch per unit effort; the unit of effort in this case is trap hours.

Date	Trap Hours	Pecos gambusia	Pecos gambusia CPUE	Western mosquitofish	Western mosquitofish CPUE
4/26/2022	8.37	100	11.95	0	0.0
7/26/2022	7.88	78	9.89	0	0.0
11/3/2022	10.15	86	8.47	10	1.0
2/28/2023	10.93	116	10.61	6	0.5

San Solomon Spring System

The 2018 five-year status review reported that the distribution of Pecos gambusia within the San Solomon Spring System included Phantom Lake Spring and refugium; San Solomon Springs, which are the water source for the pool and ciénegas within Balmorhea State Park; Giffin Spring pool and outflow; and East Sandia Spring pool and outflow (U.S. Fish and Wildlife Service 2018, pp. 16–19). Monitoring of this system has occurred fairly consistently over the last 15 years. A series of efforts spanning 2009 to 2013 (Hargrave et al. 2013, pp. 7–8), 2014 to 2015 (Hargrave 2017, pp. 12–17), and 2017 to 2018 (Norris et al. 2022, pp. 43–52) collected data to estimate metrics including population size, density, and CPUE (fish per hour) for Pecos gambusia and its primary competitor within this spring system, largespring gambusia. We compiled the data across all years and present a summarized version of the results for Pecos gambusia in Table 4, Table 5, and Table 6. Note, because we compiled this data across reports completed by different people and funding sources, and with sometimes different aims, some of the results are inconsistent across studies. Specifically, some studies reported standard deviations and some reported 95% confidence intervals, and we report the available information in Tables 4 and 5 accordingly.

Table 4. Density estimates for Pecos gambusia monitoring using seining as the methodology for the period 2009–2018. Here we reproduce point estimates for density (number of fish per one square meter) and either the 95% confidence intervals (data from 2009–2013) or standard deviations (data from 2014–2018) for these estimates from three studies for six San Solomon Spring System localities. Additional context is available in the original reports or papers (Hargrave et al. 2013, pp. 7–8, 28–30; Hargrave 2017, p. 12; Norris et al. 2022, pp. 48–52). An em-dash (—) indicates that no data were reported for that event.

Monitoring Dates	San Solomon Ciénega	Clark Hubbs Ciénega	Refuge Canal	Phantom Lake Spring	East Sandia Spring	Giffin Spring
March 2009	0.5 ± 0.1	—	2.1 ± 1.0	—	—	—
July 2009	2.3 ± 2.7	—	6.2 ± 2.8	—	—	—
Dec 2009	1.2 ± 2.0	0.2 ± 0.1	—	—	—	—
April 2010	1.5 ± 1.0	<0.1 ± 0.1	—	—	—	—
July 2010	0.9 ± 0.6	0.5 ± 0.3	—	—	—	—
Dec 2010	0.6 ± 0.4	2.7 ± 0.6	—	—	—	—
March 2011	0.5 ± 0.4	2.9 ± 1.8	—	—	—	—
Aug 2011	2.2 ± 0.9	4.2 ± 1.1	—	—	—	—
Jan 2012	1.2 ± 0.5	2.3 ± 1.0	—	—	—	—
April 2012	0.4 ± 0.2	1.5 ± 0.8	—	—	—	—
Aug 2012	1.8 ± 0.6	4.1 ± 3.4	—	—	—	—
Dec 2012	1.3 ± 0.7	3.3 ± 2.4	—	—	—	—
April 2013	0.6 ± 0.5	1.1 ± 1.4	—	—	—	—
Summer 2014	1.1 ± 0.8	2.9 ± 0.5	—	0.7 ± 1.0	2.4 ± 1.5	5.3 ± 2.5
Winter 2014	0.8 ± 1.8	1.1 ± 1.5	—	0.0 ± 0.0	0.2 ± 1.0	3.2 ± 1.1
Summer 2015	3.2 ± 2.2	5.5 ± 4.3	—	0.5 ± 1.0	1.4 ± 1.1	7.7 ± 5.3
Winter 2015	0.8 ± 1.0	0.5 ± 1.5	—	0	0.1 ± 1.0	2.8 ± 2.0
March 2017	0.2 ± 29.9	0.8 ± 14.8	0.4 ± 22.6	6 ± 159.1	—	—
June/July 2017	0.5 ± 75.1	1.7 ± 34.6	1.5 ± 138.6	9.5 ± 225.3	—	—
Sept 2017	1 ± 122.3	3 ± 53	2.2 ± 19.1	—	—	—
Dec 2017	0.4 ± 66.8	4.1 ± 25.5	1.4 ± 110.3	9.4 ± 116	—	—
April 2018	0.4 ± 100.2	1.5 ± 84.9	0.7 ± 26.2	—	—	—
June 2018	0.3 ± 51.3	1.6 ± 112.4	1.0 ± 2.1	6.8 ± 178.9	—	—
Sept 2018	0.2 ± 22.5	1.7 ± 25.5	1.1 ± 21.2	—	—	—
Dec 2018	0.1 ± 20.4	1.3 ± 55.9	0.8 ± 93.3	—	—	—

Table 5. Population size estimates for Pecos gambusia monitoring using seining as the methodology for the period 2009–2018. Here we reproduce point estimates for density (number of fish per square meter) and either the 95% confidence intervals (data from 2009–2013) or standard deviations (data from 2014–2018) for these estimates from three studies for four San Solomon Spring System localities. Additional context is available in the original reports or papers (Hargrave et al. 2013, pp. 7–8, 28–30; Hargrave 2017, p. 12; Norris et al. 2022, pp. 48–52). An em-dash (—) indicates that no data were reported for that event.

Monitoring Dates	San Solomon Ciénega	Clark Hubbs Ciénega	Refuge Canal	Phantom Lake Spring
March 2009	332.9 ± 311.0	—	1,232.9 ± 584.4	
July 2009	1,456.2 ± 1751.3	—	3,680.3 ± 1,666.0	—
Dec 2009	762.1 ± 1,263.1	211.9 ± 91.6	—	—
April 2010	939.2 ± 637.1	28.6 ± 24.4	—	—
July 2010	570.9 ± 417.1	408.6 ± 280.6	—	—
Dec 2010	401.1 ± 278.6	2,357.8 ± 561.7	—	—
March 2011	333.6 ± 228.5	2,556.8 ± 1,606.0	—	—
Aug 2011	2,023.5 ± 500.2	4,568.2 ± 2,134.5	—	—
Jan 2012	823.5 ± 250.2	2,111.0 ± 1,235.6	—	—
April 2012	325.5 ± 222.2	1,865.4 ± 1,346.2	—	—
Aug 2012	1,955.5 ± 1,800.1	4,454.8 ± 3,956.1	—	—
Dec 2012	910.1 ± 490.0	2,920.5 ± 2,124.0	—	—
April 2013	420.2 ± 350.5	973.5 ± 1,239.0	—	—
March 2017	839.7 ± 5,947	760.7 ± 1,137.8	418.3 ± 1,414.3	621.9 ± 1,755.6
June/July 2017	2,025.1 ± 14,954.1	1,573.1 ± 2,654.9	1,438.7 ± 8,662.8	975.4 ± 2,816.8
Sept 2017	4,554 ± 24,351.8	2,799.1 ± 4,063.7	2,127.4 ± 1,193.3	—
Dec 2017	1,916.4 ± 13,304.8	3,796.2 ± 1,950.6	1,306.1 ± 6894.9	968.9 ± 1,279.7
April 2018	1,817.6 ± 19,942.4	1,403.3 ± 6,501.9	647.9 ± 1,635.3	—
June 2018	1,541 ± 10,211.6	1,484.5 ± 8,615	933.6 ± 132.6	704.9 ± 1,974.1
Sept 2018	1,086.6 ± 4,479.7	1,595.3 ± 1,950.6	1,051.0 ± 1,325.9	—
Dec 2018	474.2 ± 4,065.4	1,159.5 ± 4,280.4	734.7 ± 5,834.1	—

Table 6. Catch per unit effort for Pecos gambusia monitoring using seining as the methodology for the period 2017–2018. Here we reproduce estimates of catch per unit effort in terms of fish captured per ten minutes and standard deviations from four San Solomon Spring System localities. Additional context is available in the original reports (Norris et al. 2022, pp. 48–52). An em-dash (—) indicates that no data were reported for that event.

Monitoring Dates	**San Solomon Ciénega**	**Clark Hubbs Ciénega**	**Phantom Lake Spring**	**East Sandia Spring**
March 2017	3.5 ± 3.7	12 ± 0	22.9 ± 32.3	3.5 ± 5.5
June/July 2017	3.3 ± 4.3	7.9 ± 6.7	36.5 ± 31.1	1.3 ± 1.3
Sept 2017	5.5 ± 8.7	13.6 ± 5.3	—	8.7 ± 2.8
Dec 2017	20.9 ± 64.5	13.6 ± 9.9	34.3 ± 44.2	26.4 ± 15
April 2018	6.1 ± 13	16.8 ± 24.6	—	—
June 2018	5 ± 4.7	18.4 ± 9.8	28.3 ± 6.1	3.9 ± 4.6
Sept 2018	2.3 ± 3.9	10.2 ± 12.6	—	6.2 ± 3.8
Dec 2018	2.6 ± 4.1	17.7 ± 25.6	—	9.7 ± 4.2

With respect to density, Pecos gambusia densities were highest in Giffin and Phantom Lake Springs. Densities fluctuated more in the larger ciénegas at Balmorhea State Park (Clark Hubbs and San Solomon Ciénegas). Each locality was estimated to contain populations in the low thousands, with large confidence intervals or standard deviations around these values. Point-in-time estimates fluctuate within and across years, which is common for this methodology and species.

Of some concern is the relative difference between density, CPUE, and estimated population size for Pecos gambusia compared to largespring gambusia. Within Balmorhea State Park, the canal, Clark Hubbs Ciénega, and San Solomon Ciénega all contained many times more largespring gambusia than Pecos gambusia, regardless of the measurement (Norris et al. 2022, pp. 48–52). The difference was often an order of magnitude, and the report states that at all three of these locations, largespring gambusia was the most abundant species collected (Norris et al. 2022, pp. 48–53). Largespring gambusia is a strong competitor against Pecos gambusia, especially when spring influence is lessened, so the magnitude and dominance of largespring gambusia in this system is a factor negatively influencing Pecos gambusia viability (Echelle and Echelle 1980, pp. 46–47; Delaune and Hargrave 2014, pp. 16–21).

The most important change to Pecos gambusia populations in the San Solomon Spring System area is the total loss of the Phantom Lake Spring population due to the drying of a constructed *in situ* refugium immediately adjacent to the cave that was sustained through a system of pipes and electrical pumps. Staff from the Texas Fish and Wildlife Conservation Office (FWCO), TPWD, and researchers from the Texas A&M University system visited the refugium in February 2023 and confirmed the loss of the Pecos gambusia population there (Montagne 2023, pp. 1–2).

Blue Spring

No research into or sampling designed to assess abundance, population trends, or demographics of Pecos gambusia has been conducted at this location since the previous five-year review was approved in 2018.

Bitter Lake National Wildlife Refuge

Beginning in the winter of 2018, the regional refuge system inventory and monitoring staff collaborated with the refuge biologist at Bitter Lake NWR to create a sampling protocol to survey Bitter Creek twice a year. This was intended to be a pilot program, and some changes were made to the protocol as staff implemented and learned from it. Table 7 and Table 8 summarize the results for Pecos gambusia sampling, but we note that dating to at least the 1980s, western mosquitofish was known to occupy the lowest portion of Bitter Creek (Brooks and Wood 1988, pp. 21–26). Figure 1 depicts sampling locations. Staff conducting the surveys did not always have extensive field fish identification experience, and so an unknown number of the Pecos gambusia reported from some of the sites (Table 7) could be western mosquitofish. In addition, with the exception of a minority of traps set during 2018, the surveys were all conducted using minnow traps with a ¼ inch-mesh size. This mesh size is sufficiently large to allow virtually all male and juvenile gambusia escape from the traps. For this reason and due to other potential issues with the data, we do not purport to analyze the results in great detail. However, because the data are unpublished and would be otherwise unavailable, we reproduce them here. We also received minnow trap data from the New Mexico Department of Game and Fish (NMDGF), but since it contained only counts and used traps with ¼-inch mesh (Patten 2023, entire), we do not reproduce those data here.

Table 7. Results from minnow trap sampling at Bitter Lake NWR from 2018 to 2024 at sites BCLE1, BCLE3, BCMP1, BCMP4, and BCMP5. To interpret site codes, “BC” refers to Bitter Creek, “MP” refers to Middle Perennial”, and “LE” refers to Lower Ephemeral. An em-dash (—) means that the location was not sampled on that date. See also Figure 1 for a map of sampling locations. All trapped gambusia were assumed to be Pecos gambusia, but some captured individuals could have been western mosquitofish or hybrids. CPUE refers to catch per unit effort; the unit of effort in this case is trap hours.

Sampling Date	**BCLE1**		**BCLE3**		**BCMP1**		**BCMP4**		**BCMP5**	
	Count	CPUE	Count	CPUE	Count	CPUE	Count	CPUE	Count	CPUE
Winter 2018	0	0.0	0	0.00	1	0.00	0	0.00	3	0.01
Summer 2018	—	—	166	3.81	—	—	5	0.12	871	20.42
Winter 2019	0	0.0	0	0.00	1	0.01	1	0.01	4	0.02
Summer 2019	—	—	22	0.89	8	0.70	14	1.34	9	0.92
Winter 2020	0	0.0	0	0.00	2	0.01	8	0.05	8	0.05
Summer 2020	—	—	—	—	67	6.76	43	3.98	27	2.39
Winter 2021	0	0.00	0	0.00	4	0.03	56	0.37	9	0.06
Summer 2021	5	0.45	39	3.32	147	11.19	33	2.19	40	2.42
Winter 2022	0	0.00	0	0.00	1	0.01	1	0.01	0	0.00
Summer 2022	0	0.00	11	0.81	58	4.24	99	7.30	129	9.45
Winter 2023	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Summer 2023	2	0.34	21	1.94	114	7.57	87	5.88	46	3.03
Winter 2024	0	0.00	0	0.00	0	0.00	1	0.01	6	0.04

Table 8. Results from minnow trap sampling at Bitter Lake NWR from 2018 to 2024 at sites BCMP7, BCMP11, BCMP13, BCMP15, and BCMP16. BCMP stands for "Bitter Creek Middle Perennial." An em-dash (—) means that the location was not sampled on that date. See also Figure 1 for a map of sampling locations. All trapped gambusia were assumed to be Pecos gambusia, and the presence of western mosquitofish or hybrids is unlikely (Davenport 2004a, p. 2). CPUE refers to catch per unit effort; the unit of effort in this case is trap hours.

Sampling Date	BCMP7		BCLMP11		BCMP13		BCMP15		BCMP16	
	Count	CPUE	Count	CPUE	Count	CPUE	Count	CPUE	Count	CPUE
Winter 2018	233	1.14	1	0.00	69	0.34	17	0.08	81	0.41
Summer 2018	603	9.44	555	10.62	986	18.08	446	9.03	138	2.70
Winter 2019	91	0.54	3	0.02	47	0.27	32	0.19	48	0.28
Summer 2019	36	3.93	17	2.18	147	23.27	65	12.54	42	9.77
Winter 2020	89	0.54	107	0.74	212	1.26	8	0.05	8	0.05
Summer 2020	156	12.63	106	6.84	137	9.63	52	3.78	50	3.75
Winter 2021	447	2.93	94	0.61	28	0.18	14	0.09	24	0.16
Summer 2021	28	1.58	60	3.14	2	0.10	75	3.67	173	8.20
Winter 2022	58	0.35	15	0.09	14	0.09	0	0.00	5	0.03
Summer 2022	11	0.79	16	1.19	70	5.32	52	3.98	48	3.72
Winter 2023	66	0.42	30	0.19	3	0.02	0	0.00	6	0.04
Summer 2023	137	8.98	117	7.09	129	8.06	181	11.72	—	—
Winter 2024	385	2.36	31	0.21	0	0.00	2	0.01	3	0.02

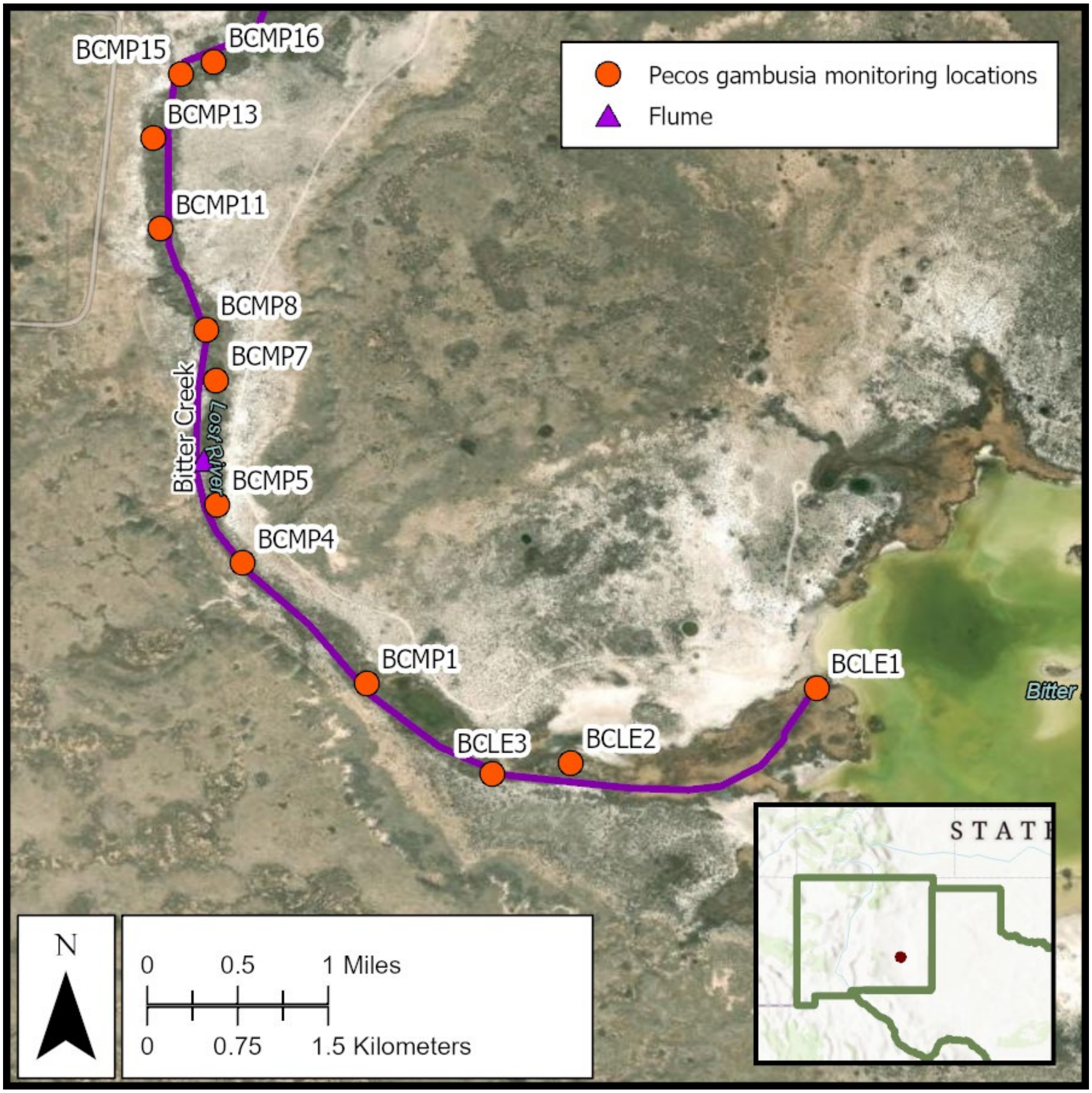

Figure 1. Sampling locations, depicted with orange circles for Pecos gambusia along Bitter Creek on the Bitter Lake National Wildlife Refuge near Roswell, New Mexico. The sampling locations are abbreviated, where "BC" stands for "Bitter Creek," "MP" stands for "Middle Perennial," and "LE" stands for Lower Ephemeral. Numbers are not sequential because sampling locations are used for purposes other than Pecos gambusia work; the ones shown were used consistently for Pecos gambusia minnow trap sampling from 2018–2024. The purple triangle denotes the location of the flume on Bitter Creek.

Summary

Pecos gambusia rarely live more than three years in the wild, and are capable of producing large numbers of offspring (Bednarz 1979, p. 217; Swenton and Kodric-Brown 2012, pp. 670–677; Hopkins and Kodric-Brown 2015, p. 1841). Sampling Pecos gambusia and other small-bodied desert fishes sufficiently to obtain high quality population estimates is challenging, and the detection of trends in density and population estimates is extremely difficult (U.S. Fish and Wildlife Service 1981, p. 11; Maunder and Punt 2004, pp. 155–156). While the available data preclude definitive statements about the trends in Pecos gambusia population size or demographics at any of the localities where they remain extant, habitat loss and alteration in these ecosystems have been extensive enough across the 2018–2024 period of review that there is concern about declining trajectories and increased vulnerability to the species as a result of these changes. We discuss these aspects in greater detail later in the review. That said, significant investments in monitoring occurred over that time frame for three of the four populations, and researchers did not report any concerns with age structure, sex ratios, body condition, or survival rates (Hargrave et al. 2013, entire; Hargrave 2017, entire; Norris et al. 2022, entire; Johnson and Tobler 2024, entire). Where habitat persists, densities and abundances are adequate to maintain the species over time. However, Pecos gambusia appear to be vulnerable to rapid decline if habitat conditions deteriorate.

Overall, the abundance of Pecos gambusia at the species level is declining. This is due primarily to declines in abundance associated with habitat loss and modification across the species' range, which will be discussed in more detail in Section 2.2.1.6. Habitat alteration at all sites under study, where it leads to conditions more conducive to the success of congeners (either western mosquitofish or largespring gambusia), has also led to downward pressure on Pecos gambusia abundance. Pecos gambusia populations associated with the San Solomon Spring System and Balmorhea State Park, with the notable exception of Phantom Lake Spring, are currently stable and exhibit unsurprising seasonal variation in which total abundance increases in the spring and summer and decreases in the winter (Norris et al. 2022, pp. 89–90).

2.2.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Texas

Genetic studies focusing on the Pecos gambusia populations in Texas were completed in the early 2020s (Bretzing-Tungate 2023, p. 39; The Nature Conservancy 2023, p. 7). Fin clips were collected from Pecos gambusia at three sites within the Diamond Y Preserve (i.e., Diamond Y, Karges, and Euphrasia Springs) and at three sites within the San Solomon Spring System (i.e., Clark

Hubbs Ciénega, Phantom Lake Spring, and East Sandia Spring) (Bretzing-Tungate 2023, pp. 42–43).

With respect to genetic diversity, the Pecos gambusia at Clark Hubbs Ciénega and East Sandia Spring had the most robust and healthy levels of genetic diversity, while Phantom Lake Spring had the lowest levels (Bretzing-Tungate 2023, pp. 51–52). The Diamond Y Preserve populations had lower genetic diversity in terms of heterozygosity than the San Solomon Spring populations, but they also had higher allelic richness (Bretzing-Tungate 2023, p. 52). Evidence of genetic drift within the three populations at the Diamond Y Preserve was also detected (Bretzing-Tungate 2023, p. 52). The level of drift is substantial enough that Bretzing-Tungate (2023, p. 53) suggested that these populations "are at risk of collapse." Effective population size estimates based on the genetic analyses were possible for three of the sampled localities and are reproduced in Table 9.

Table 9. Effective population size estimates with lower and upper 95% confidence intervals done using a jackknife method, as well as point estimates for all three contemporary Pecos gambusia populations. Data reproduced from Bretzing-Tungate (2023, p. 65).

Locality	**Lower**	**Point**	**Upper**
East Sandia Spring	444.7	470	501
Clark Hubbs Ciénega	903.1	956	970
Phantom Lake Spring	1.4	2.2	4.5

Bretzing-Tungate (2023, pp. 48–49) also reviewed hybridization rates between Pecos gambusia and either western mosquitofish or largespring gambusia. That analysis found that six of the 195 Pecos gambusia analyzed for hybrid detection were hybrids (Bretzing-Tungate 2023, pp. 48–49). One Pecos gambusia x western mosquitofish hybrid was detected at the Diamond Y Spring pool, two Pecos gambusia x largespring gambusia hybrids were detected at East Sandia Springs, and three Pecos gambusia x largespring gambusia hybrids were detected at Phantom Lake Spring (Bretzing-Tungate 2023, pp. 48–49). The detected hybrids included both F1 hybrids and backcrosses between "pure" individuals and F1 hybrids, indicating low levels of hybridization present in the Texas populations (Bretzing-Tungate 2023, pp. 48–49). The study further demonstrated evidence that historical mtDNA introgression of the western mosquitofish genome into Pecos gambusia has occurred at the Diamond Y Preserve (Bretzing-Tungate 2023, p. 51).

New Mexico

Swenton (2011, p. 5) studied the genetics and hybridization rates of Pecos gambusia with western mosquitofish from 2006–2011 in New Mexico. Pecos gambusia and western mosquitofish have been documented to co-occur in some of the waters at Bitter Lake NWR since the 1940s (Swenton 2011, p. 107). Pecos gambusia were collected from four sites on the Refuge thought to only contain non-introgressed Pecos gambusia (Swenton 2011, p. 108). For these four localities, observed heterozygosity was low, which the author suggests is due to drift associated with geographic isolation (Swenton 2011, pp. 117–118). Localities with Pecos gambusia across the Refuge that are not obviously hydrologically connected are characterized by low diversity within populations and high differentiation among populations (Swenton 2011, p. 118). This is likely due not only to the isolation of the species from other populations within the Pecos River basin, but also due to introductions consisting of low numbers (a few dozen) of individuals and bottleneck events associated with changing water quantity and quality (Swenton 2011, pp. 118–119). The presence of highly differentiated populations among the populations on the Refuge should be considered before translocations or reintroductions are conducted, because such actions could impact the existing genetic diversity and related adaptive capacity (Swenton 2011, p. 118).

During the same period, *Gambusia* species (i.e., Pecos gambusia, western mosquitofish, and potential hybrids) were collected from five sites within the Refuge where Pecos gambusia–western mosquitofish hybrids are thought to occur (Swenton 2011, p. 108). Although introgression was detected, overall rates of hybridization appear to be low—less than 30% (Swenton 2011, pp. 117–120). Most of the observed hybrids were backcrosses of a F1 hybrid with a pure individual (Swenton 2011, p. 120). Despite the relatively low rates of detected hybridization, the fact that none of the four putative "pure" sites were confirmed to be free of western mosquitofish or Pecos gambusia–western mosquitofish hybrids is a concern (Swenton 2011, p. 137). That said, Swenton (2011, pp. 121–122) notes that pre- and post-mating isolating mechanisms, in conjunction with ecological differentiation, reduce the hybridization potential between the two species.

Reviewing older literature, we note that as long ago as the late 1980s, Pecos gambusia and western mosquitofish were simultaneously observed in Bitter Creek and Sinkhole 20, indicating sufficient barriers to hybridization to maintain the two species as separate species for decades (Brooks and Wood 1988, pp. 21–26). Taken together, the long history of sympatry between Pecos gambusia and western mosquitofish and the recent studies showing hybridization at consistently low levels indicates that, while hybridization remains a stressor to the species, it has not caused declines or extirpations of Pecos gambusia from any of the sites in New Mexico.

Summary

There is new information but no significant change in Pecos gambusia genetics since the previous five-year review was published in 2018. Pecos gambusia has in the past and can in the future hybridize with both western mosquitofish and largespring gambusia in most of the places it is extant (Bretzing-Tungate 2023, p. 51). The most recent available data suggests that levels of gene flow between Pecos gambusia and either largespring gambusia or western mosquitofish continue to be low (Swenton 2011, pp. 117–122; The Nature Conservancy 2023, p. 7). While these levels were low enough to preclude immediate concerns, their existence makes continued genetic monitoring necessary to ensure hybridization does not become a more significant threat in the future (The Nature Conservancy 2023, p. 7).

2.2.1.4 Taxonomic classification or changes in nomenclature:

There have not been any new publications or reports concerning the taxonomic classification or nomenclature of the Pecos gambusia since the previous five-year review was approved in 2018.

2.2.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, pollinator availability, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species within its historic range, etc.):

Diamond Y Preserve

Pecos gambusia were present throughout the upper and lower watercourse within the Diamond Y Preserve at the time of the previous status review in 2018 (U.S. Fish and Wildlife Service 2018, p. 19). They remain present in both of these watercourses as of 2025, but the spatial extent of occupancy has declined as a result of drying. Habitat that was once available and wet year-round (i.e., perennial) may now be dry seasonally or when drought conditions are present (Figure 2). The upper watercourse was 1.5 kilometers (km) (0.9 miles (mi)) long and drained into a marshy area characterized by springs and seeps that formed a wetland occupied by the species (U.S. Fish and Wildlife Service 2018, p. 19). Currently, the upper watercourse has been fragmented as a result of declining spring flows and the subsequent drying of aquatic habitat.

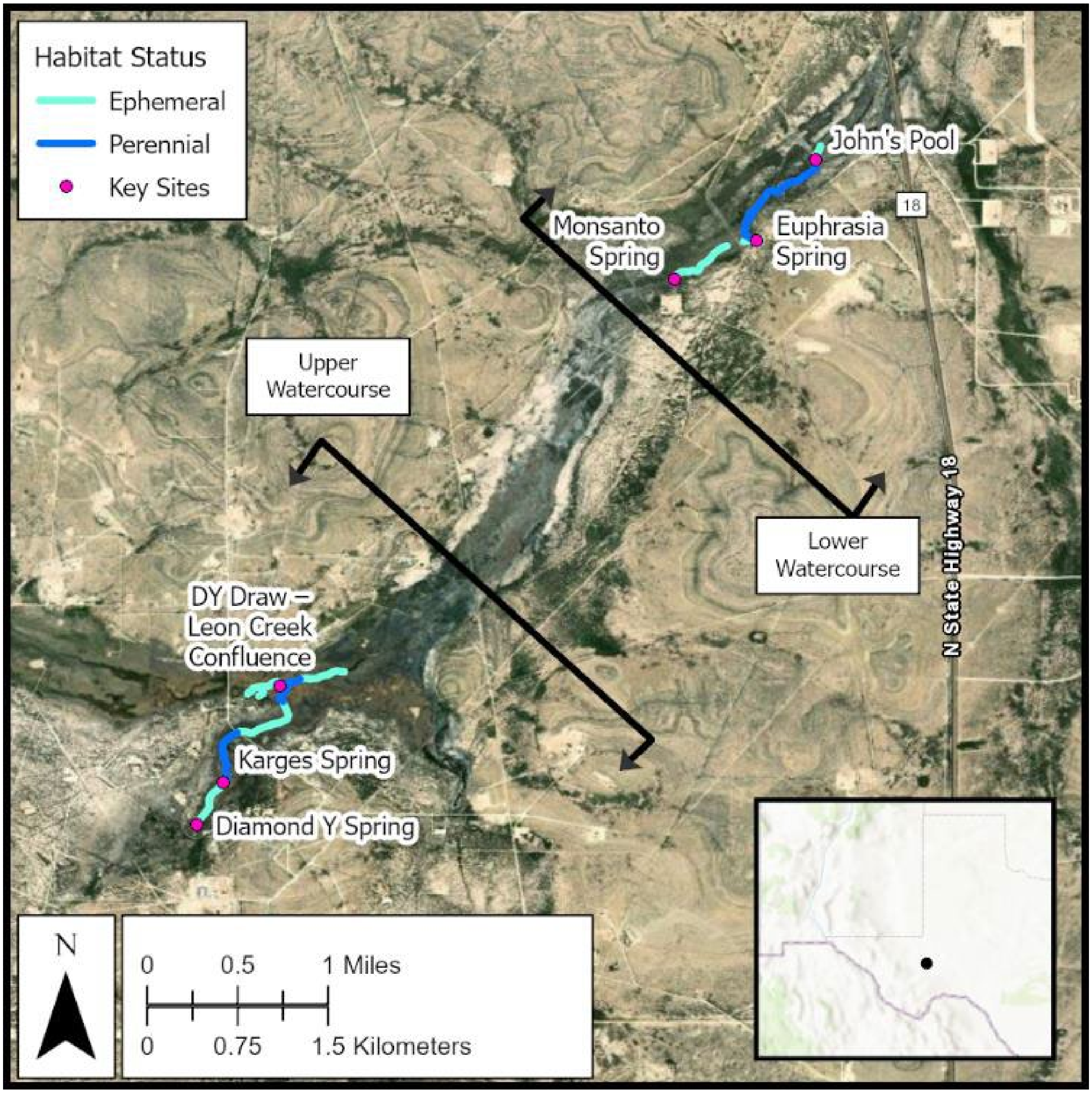

Figure 2. Diamond Y Preserve showing upper and lower watercourses. Key sites are depicted as bright pink circles and are labeled. In the last decade, portions of these watercourses that were perennial have dried and are now ephemeral and are subject to drying either seasonally or in times of drought. Ephemeral aquatic habitats are not reliable habitat for Pecos gambusia. Ephemeral waters are shown with a bright blue-green line, while perennial waters are shown with a dark blue line. Overall, the map illustrates that a significant reduction in perennial waters has occurred.

In 2018, the Diamond Y Spring pool dropped sufficiently low to cease discharging into its outlet channel for the first time, and other significant portions of the upper watercourse dried up (The Nature Conservancy 2023, pp. 9–12, 16, 27; Smith 2024b, p. 2). This phenomenon has occurred every summer since, and the outflow is dry for long portions of the summer each year (The Nature Conservancy 2023, pp. 9–12, 16). Pecos gambusia can use wetted habitat seasonally, but must retreat to the spring pools during annual drying events (The Nature Conservancy 2023, p. 16).

After the watercourse between the Diamond Y Spring and Karges Spring dried in 2018, TNC staff walked the habitat in the upper watercourse and found that the spring now called Karges Spring contained numerous Pecos gambusia and provided outflow to a channel approximately 300 m (984 ft) in length (The Nature Conservancy 2023, p. 12; Smith 2024b, p. 2). This channel ceases to flow when it intersects a private road, where there is a collapsed culvert (The Nature Conservancy 2023, p. 27; Smith 2024b, p. 1). The channel becomes impounded and pools up above the road. This section of the upper watercourse is still reliably perennial, and represents a stronghold for the species and its habitat within the Diamond Y Preserve (Smith 2024b, p. 2). The remainder of the draw to the confluence with Leon Creek is subject to drying and no longer supports Pecos gambusia year-round (The Nature Conservancy 2023, pp. 9–12, 16, 27; Smith 2024b, p. 1).

San Solomon Springs System

When the last five-year review was conducted in 2018, it was reported that Pecos gambusia could be found in association with San Solomon Spring and the waters of Balmorhea State Park (including the pool, the canals inside the Park, the ciénegas, and the canals leaving the Park), East Sandia Spring, Giffin Spring, and Phantom Lake Spring (U.S. Fish and Wildlife Service 2018, pp. 16–19). We have updated the current range for this review and denote species presence at each of the springs in the system in Figure 3.

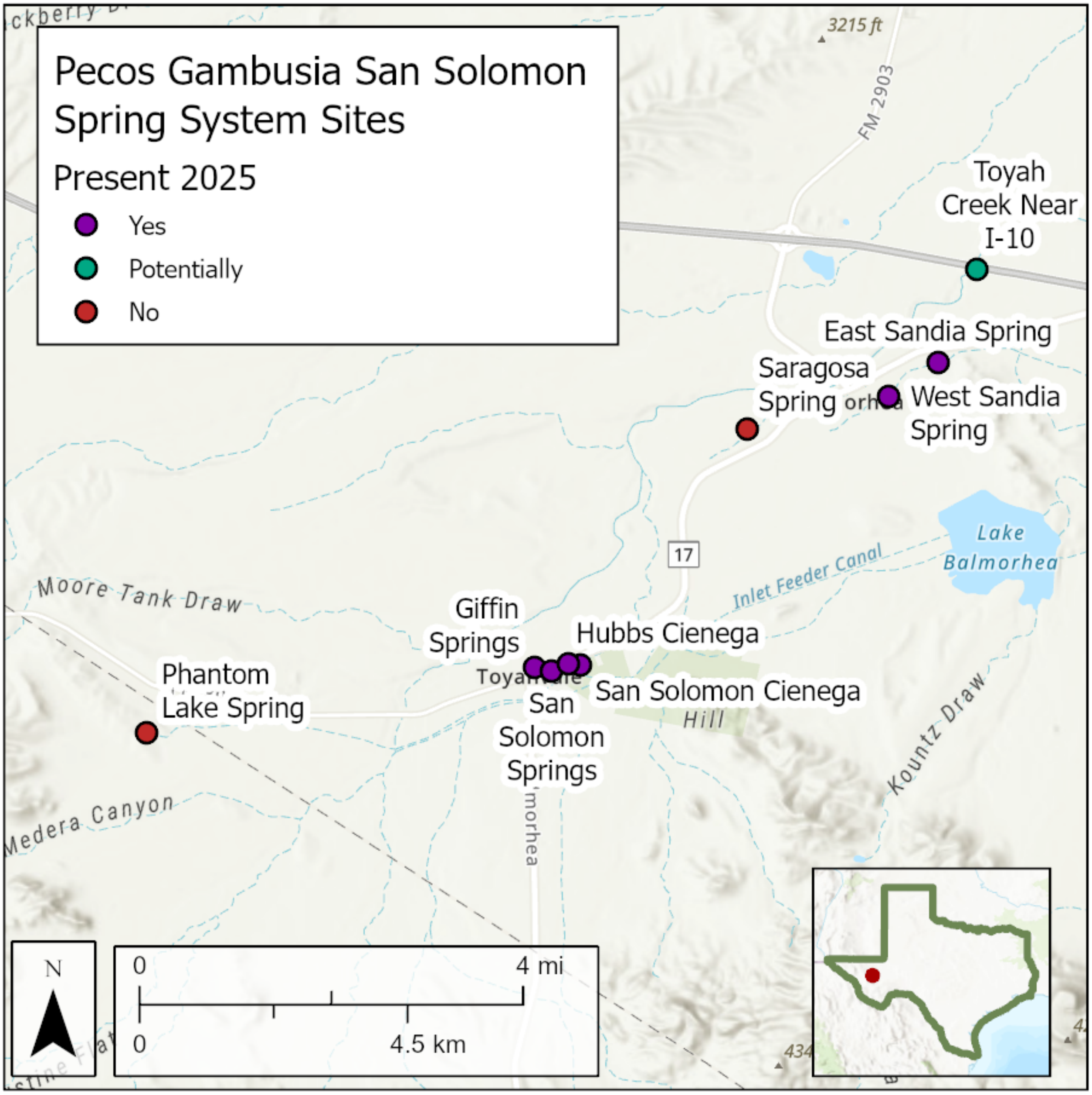

Figure 3. Springs and ciénegas known to have supported Pecos gambusia. This image includes sites historically and currently occupied. The presence of Pecos gambusia at each location as of 2024 is depicted by color: red indicates that Pecos gambusia are not present (Phantom Lake Spring, Saragosa Spring), teal indicates that Pecos gambusia are potentially present (Toyah Creek near I-10), and purple indicates that Pecos gambusia are present (East and West Sandia Springs, Giffin and San Solomon Springs, Hubbs and San Solomon Ciénegas). Pecos gambusia are also found in low abundance in the irrigation canal system from Balmorhea State Park to Balmorhea Lake.

As of 2025, Pecos gambusia remain extant within spring-fed habitats at Balmorhea State Park, including the pool, the outflow canal from the pool, the San Solomon Ciénega, the Clark Hubbs Ciénega, and the outflow canals leaving the Park (Hargrave et al. 2013, pp. 7–8, 28–30; Hargrave 2017, p. 12; Norris et al. 2022, pp. 48–52). In East Sandia Spring, Pecos gambusia were detected in 2014–2015, 2017–2018, 2021, 2023, and 2025 (Hargrave 2017, p. 12; Texas Parks and Wildlife Department 2021a, p. 11; Norris et al. 2022, p. 52; Texas Parks and Wildlife Department 2024b, p. 10; Casarez 2025, p. 1). Giffin Spring was sampled in 2014 and 2015 and Pecos gambusia were consistently detected (Hargrave 2017, p. 12). They were observed again on an early 2025 sampling trip (Casarez 2025, p. 1)

Pecos gambusia have been extirpated from the Phantom Lake Spring refugium (Montagne 2023, pp. 1–2). A major restoration of the refugium was conducted from 2010 to 2012 (Texas Fish and Wildlife Conservation Office 2012, pp. 2–9). Monitoring from October 2012 found that both juvenile and adult Pecos gambusia were present, indicating successful colonization of the new habitat (Texas Fish and Wildlife Conservation Office 2012, p. 10). Additional monitoring took place from 2014 to 2018 that indicated that Pecos gambusia were continuing to persist in relatively stable numbers within the reconstructed refugium (Table 4 and Table 5). In early 2022, power to the pumps maintaining this refugium was turned off, which led to the refugium drying, likely in a matter of weeks (Montagne 2023, pp. 1–2). A visit to the property in February of 2023 confirmed that the refugium was totally dry and that Pecos gambusia would soon be extirpated from this locality (Montagne 2023, pp. 1–2). TPWD staff were present for that visit and reported collecting seven individuals from the inside of the cave entrance (Texas Parks and Wildlife Department 2024b, p. 10). These fish were emaciated and some of them appeared to be hybrids with largespring gambusia (Texas Parks and Wildlife Department 2024b, p. 10).

The 2018 review discussed the uncertainty in the status of West Sandia Spring (U.S. Fish and Wildlife Service 2018, pp. 18–19). TPWD staff visited this location in 2021 as part of the San Solomon Springs biomonitoring project, and detected Pecos gambusia using seine hauls and dip nets. We therefore conclude that the species is present here. That review also discusses Toyah Creek as an intermittent tributary (U.S. Fish and Wildlife Service 2018, p. 16). However, we are not aware of any attempts to sample that location and ascertain whether Pecos gambusia persist there. Therefore, as with Comanche Springs pupfish (*Cyprinodon elegans)*, the lack of observations since 1990 combined with the lack of survey effort lead us to denote this locality as "potentially present," with surveys needed to confirm the status of this watercourse and its fish community (Garrett and Price 1993, pp. 14–16).

Blue Spring

No new information about the presence of Pecos gambusia at this locality has become available since the previous five-year review was approved in 2018. We presume that Pecos gambusia continue to occur at this location because we are not aware of any significant changes to the habitat in recent years (U.S. Fish and Wildlife Service 2018, p. 13).

The last five-year review stated that the captive population at Living Desert State Park near Carlsbad, New Mexico was extirpated in the 1990s (U.S. Fish and Wildlife Service 2018, p. 15). In order to verify this, since the captive population was initially founded with individuals from Blue Springs, researchers collected samples of gambusia species from the Park in spring 2025 (Tobler 2025, p. 1). After an initial review of their morphology, it is unlikely that these are Pecos gambusia, but vouchers were taken and genetic testing will be done later this year (Tobler 2025, p. 1). Results should provide a more definitive conclusion as to the status of this captive population.

Bitter Lake National Wildlife Refuge

When the last five-year review was conducted in 2018, it was reported that Pecos gambusia could be found in Sinkholes 7, 9, 27, 31 (Sago Spring), 37 (Lake St. Francis), Bitter Creek near Dragonfly Spring, and the Unit 5 Spring Ditch (U.S. Fish and Wildlife Service 2018, p. 11). We have updated the current range for this review and denote species presence at each site in the system in Figure 4, Figure 5, and Figure 6.

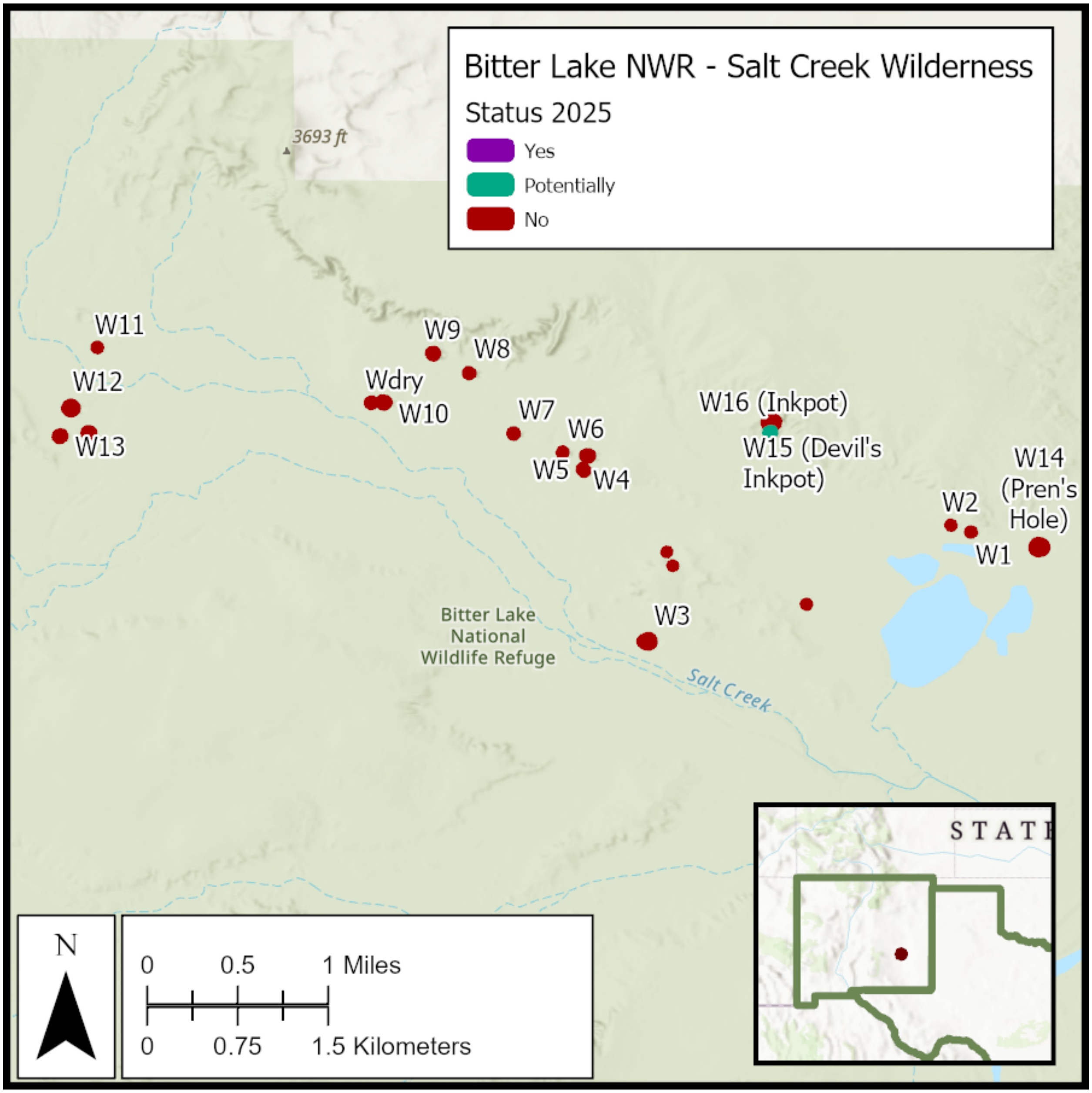

Figure 4. Sinkholes in the Salt Creek Wilderness area on Bitter Lake National Wildlife Refuge. Sinkhole locations from internal Refuge files. Of these sinkholes, only one is thought to potentially be occupied by Pecos gambusia: Inkpot.

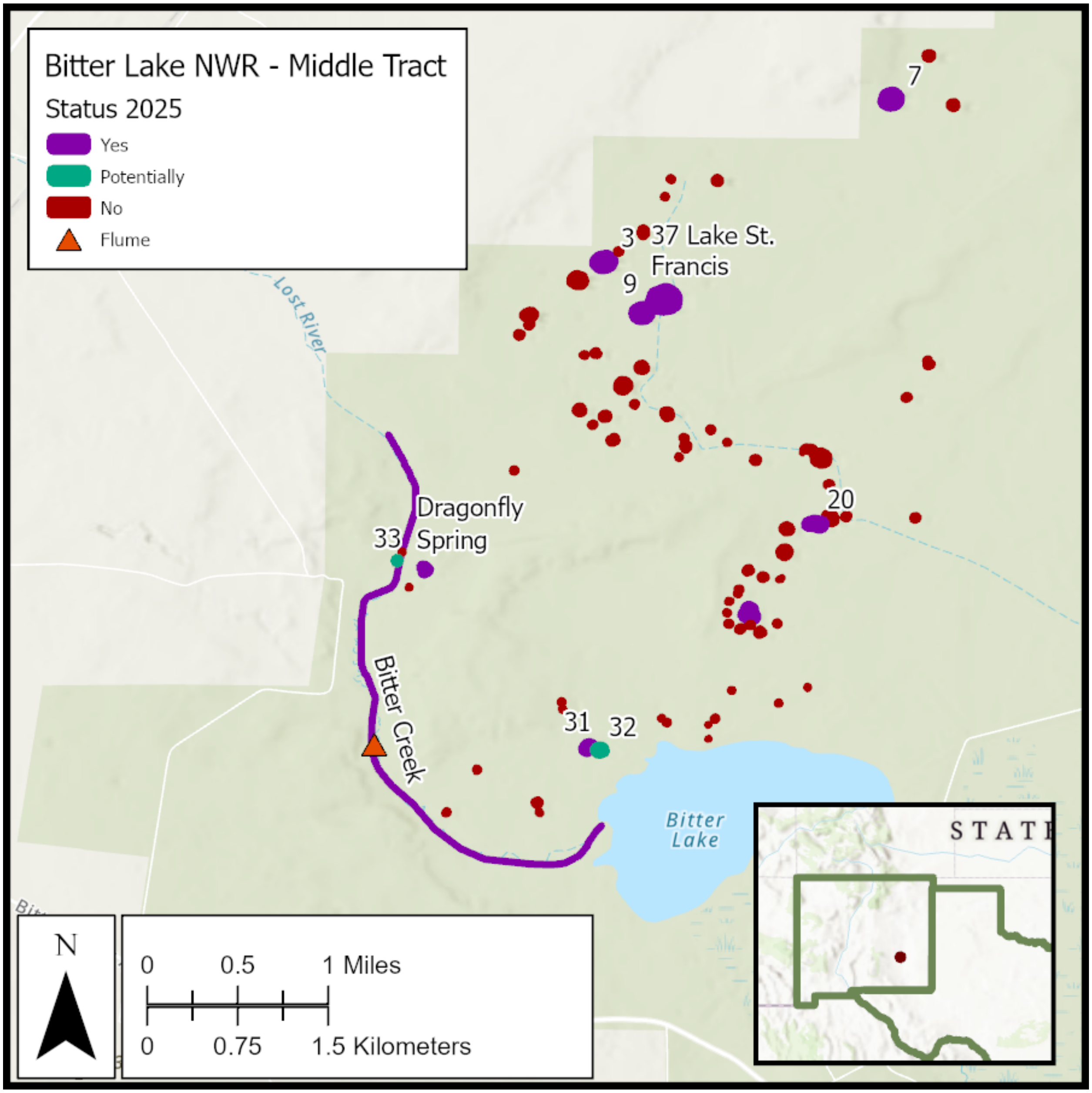

Figure 5. Sinkholes and streams on the Middle Tract of Bitter Lake National Wildlife Refuge, not including the waterfowl management units. Sinkhole locations from internal Refuge files. Presence of Pecos gambusia in a given waterbody is denoted by color: purple for present (Bitter Creek, Sinkholes 3, 7, 9, 20, 27 North and South, 31, and 37 [also called Lake St. Francis]), teal for potentially present (Sinkholes 32, 33), and maroon for not present. Most sinkholes do not contain Pecos gambusia. In addition, sinkholes and streams where Pecos gambusia are present or potentially present are labeled. The orange triangle identifies the location of the flume on Bitter Creek.

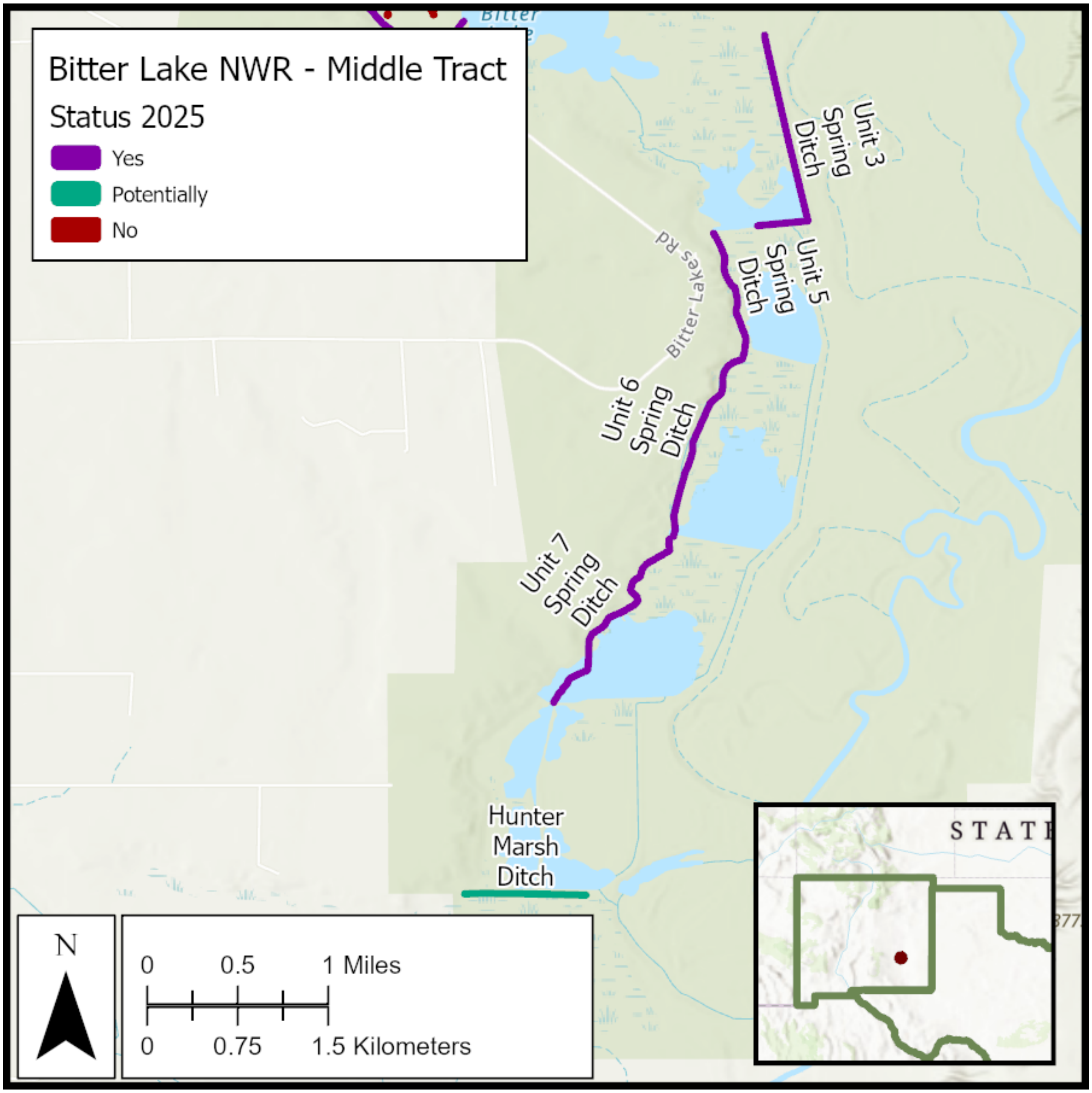

Figure 6. Waterfowl management units and their associated spring ditches on the Middle Tract of Bitter Lake National Wildlife Refuge. Presence of Pecos gambusia in a given waterbody is denoted by color. Purple indicates present, and teal indicates potentially present.

Within the Salt Creek wilderness, sampling is inconsistent. The previous five-year review identified Inkpot as a historical locality, but suggested the species was not present in 2018 (U.S. Fish and Wildlife Service 2018, p. 11). Pecos gambusia were stocked at Inkpot in 1973 (Bednarz 1975, p. 5), captured during sampling in 1995 and 1999 (Hoagstrom 1995, p. 1; Watts 2004, p. 5), then not detected in surveys in 2002 and 2004, to the surprise of surveyors (Davenport 2004b, p. 7; Watts 2004, p. 5). No recent surveys of Inkpot have occurred and so the status of Pecos gambusia there is uncertain.

Sampling is more frequent and done by different groups within the Middle Tract, and so more data is available to determine the spatial distribution of Pecos gambusia there. We compiled stocking and survey data using memos and reports from 1975–2024 (Bednarz 1975; Echelle and Echelle 1980; U.S. Fish and Wildlife Service 1981; 2018; Bouma 1984; Brooks and Wood 1988; Hoagstrom 1995; Hoagstrom and Brooks 1999; Davenport 2004a; 2004b; Watts 2004; Swaim 2008; Johnson and Tobler 2024) and concluded that Pecos gambusia continue to occupy sinkholes 3, 7, 9, 20, 27 North, 27 South, 31, and 37 (also known as Lake St. Francis). Pecos gambusia are also found in Bitter Creek and in spring-influenced habitat along Units 3, 5, 6, and 7. We consider the species potentially present in sinkholes 32, and 33 due to conflicting survey reports (Bouma 1984, pp. 42–43; Hoagstrom and Brooks 1999, p. 33; Watts 2004, pp. 4–5; Swaim 2008, p. 25; Johnson and Tobler 2024, p. 4).

There has been some confusion about the presence or absence of western mosquitofish from Bitter Creek. Western mosquitofish were reported in the lower portion of Bitter Creek in the 1980s (Brooks and Wood 1988, pp. 21–26). Surveyors in 2004 discussed the flume on Bitter Creek as a dividing point below which western mosquitofish were present in the creek, and above which only Pecos gambusia were present (Davenport 2004b, p. 2; 2004a, pp. 1–2). The reports are unclear on how the flume would be a barrier, though it may be due to the increased flow at that location, or it may coincidentally mark a shift in habitat from more to less influenced by spring flows. Given the low flows in recent years, it seems unlikely that flow rate remains a barrier to the movement of western mosquitofish into the upper portion of Bitter Creek (Jacobsen 2025b, p. 1). In 2024, western mosquitofish was captured along with Pecos gambusia, affirming their continued presence in Bitter Creek (Bean 2024, p. 1).We highlight the presence of western mosquitofish in Bitter Creek in this review to clarify and document that both species are present.

The State of New Mexico provided raw data accumulated during Pecos pupfish surveys, which cover the period 2018–2022 (Patten 2023, p. 1). These data corroborate our findings of Pecos gambusia occupancy of Sinkholes 7 and 20, Lake St. Francis, Bitter Creek, and the Unit 5 Spring Ditch (Patten 2023, p. 1). The dataset also includes observations of Pecos gambusia from 2020 and 2021, indicating that Pecos gambusia are sometimes present in Hunter Marsh, but western mosquitofish is dominant there and so Pecos gambusia persistence is questionable, having not historically been documented in this location (Hoagstrom and Brooks 1999, pp. 41–42; Davenport 2004a, p. 5; 2004b, pp. 3–4; Swenton 2011, p. 108; Patten 2023, p. 1; Johnson and Tobler 2024, p. 3; Jacobsen 2025a, p. 1).

Some uncertainty continues to persist with respect to where on the Refuge, if anywhere, Pecos gambusia exist as the only gambusia species present; that is, no western mosquitofish co-occur. We have evidence that western mosquitofish is currently present or has been observed since 1975 in Bitter Creek, sinkholes 3, 7, and 20, the spring ditches, and at Hunter Marsh (Bednarz 1975, p. 7; Bouma 1984, p. 105; Davenport 2004b, entire; 2004a, entire; Watts 2004, entire; Johnson and Tobler 2024, pp. 3–6). Sites where western mosquitofish have not been documented include Sinkholes 9, 27 N&S, 31, and 37 (Lake St. Francis), although a genetic analysis including Sinkhole 27S found introgression within the Pecos gambusia individuals examined (Swenton 2011, pp. 119–121, 136–139).

Compared to the distribution identified in the 2018 status review, we find that Pecos gambusia currently are found in one additional sinkhole (i.e., 20) and a larger portion of Bitter Creek than described in that document. Pecos gambusia also appear to be co-occurring with western mosquitofish in the spring ditches associated with some of the waterfowl management units. These, in addition to our identification of three other sinkholes and Hunter Marsh as potentially containing Pecos gambusia, are a minor update to the distribution within the Refuge and represent a refinement of our description of the species' presence rather than an expansion that took place on the ground. Overall, the spatial distribution has been stable on the Refuge over the past several years.

Summary

The 2018 five-year review stated that there had not been any significant changes in spatial distribution or trends in spatial distribution since the species was listed in 1970. The overall distribution of Pecos gambusia in terms of its occupancy of four spring systems in Texas and New Mexico has not changed since the previous five-year review. However, important contractions in the extent of occupied habitat within the Diamond Y Preserve and San Solomon Springs System populations have occurred within the last several years. In addition, the decline in spatial distribution includes a decline in redundancy with the loss of the Phantom Lake Spring refugium. Overall, this represents a continuation of the decline in spatial distribution for the species that was present at the time of the previous five-year status review.

2.2.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

<u>Diamond Y Preserve</u>

Habitat Availability

Declining spring flows are a major threat to Pecos gambusia (U.S. Fish and Wildlife Service 2013b, pp. 11–13). Reductions in spring flow have led to very low water levels and frequent drying in both the upper and lower watercourses, significantly reducing the total available habitat for the species (see Section 2.2.1.2). The main Diamond Y headwater spring pool stopped discharging into its outlet channel in summer 2018, and in recent years has flowed at very low discharge volumes (Freese and Nichols, Inc. 2020a, pp. 1–36; Smith 2024b, p. 2). Each year in the late spring or early summer, the water level begins to drop, decreasing the available habitat in the middle of the breeding season, and disconnecting that pool from Karges Pool by drying up the channel connecting the two pools (Mallek 2023, pp. 1, 6–8; McKinney et al. 2024, pp. 30–35). Figure 7 plots field data associated with this loss of water and habitat. Figure 8 shows the Diamond Y Spring pool at normal and low water levels.

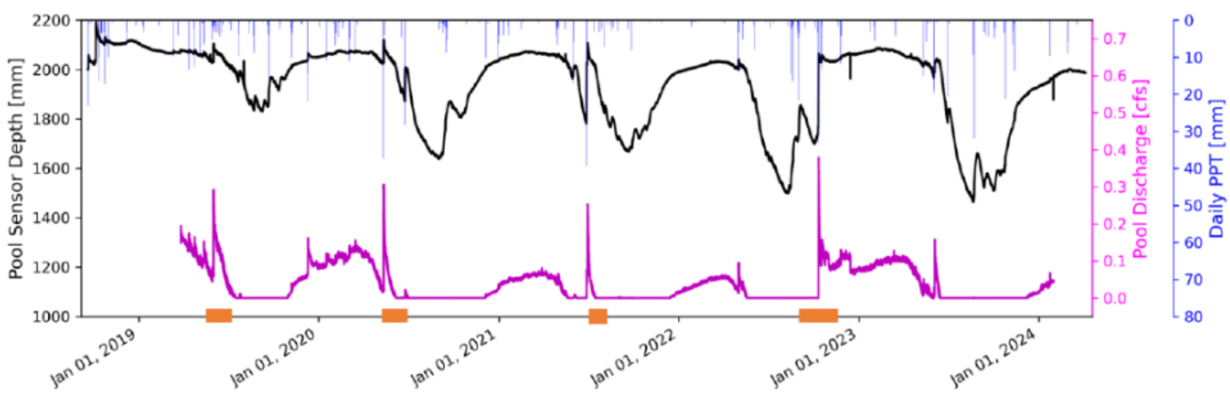

Figure 7. Monitoring data from the Diamond Y Spring pool station covering the period from late 2018 through April 2025. The black line at the top shows the sensor depth, while the pink line at the bottom shows the pool discharge in cubic feet per second. Flat lines are a good proxy for periods when there was no overflow. This figure is reproduced from McKinney et al. (2024, p. 31, Figure 3.9).

Figure 8. Photos of the Diamond Y Spring pool. Photo on top shows the pool full enough to spill into its outflow and was taken on May 23, 2023. Photo on bottom shows the pool very low, such that connectivity with the outflow has been lost. This photo was taken on July 27, 2022.

Beginning in 2017, TNC has funded the collection of continuous, long-term measurements of spring pool level, discharge, and water quality for Diamond Y, Karges, and Euphrasia Springs (McKinney et al. 2024, p. 3). This was in part a response to declining water levels in the Diamond Y Spring pool and decreasing stability in the surface water connection between the Diamond Y and Karges Spring pools (McKinney et al. 2024, pp. 9–10). Preliminary observations were reported for the data collected into 2024 (McKinney et al. 2024, pp. 29–37). Data collected so far indicates that the depth of the Diamond Y Spring pool varies within each year by up to several hundred millimeters, generally having the greatest depth in late spring, and the lowest depth in late summer (Figure 9; McKinney et al. 2024, p. 30).

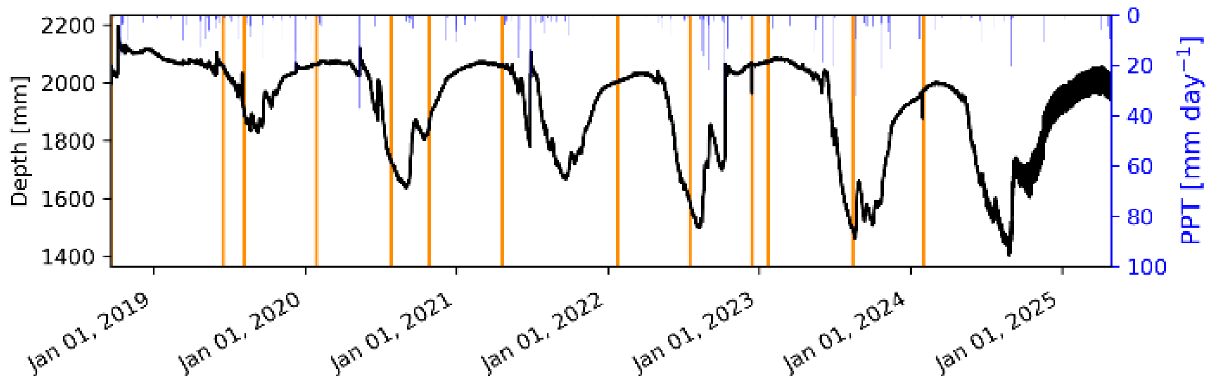

Figure 9. Depth of Diamond Y Spring pool from late 2018 through April 2025 (Smith 2025b). Water levels decline each year during the summer months, and the change in depth between winter and summer has been increasing each year.

The fact that the Diamond Y Spring pool's decrease in spring discharge and water levels occurs regularly each year in late spring suggests that groundwater pumping for irrigation may be affecting spring flow, since groundwater pumping for oil and gas production is not as seasonal in nature (McKinney et al. 2024, p. 30). In recent years, the spring pool has reached its lowest pool depth values in August, declining to 1,400–1,500 mm (55–59 in) in 2022, 2023, and 2024 (McKinney et al. 2024, p. 32; Smith 2024a).

A flume in the outlet channel of the Diamond Y Spring pool measures flow rates during periods when there is sufficient spring flow to fill the pool and sustain an outlet flow (McKinney et al. 2024, pp. 32–35). That is, the pool level must be over 2,000 mm deep or discharge cannot be measured via the flume (McKinney et al. 2024, pp. 32–34). Based on the data from late 2018 to early 2024, discharge from the pool varies seasonally and is impacted by precipitation events (McKinney et al. 2024, p. 32). The lowest values are recorded in summer, when the outflow channel has dried every year since 2018, and the highest values are recorded as brief pulses of 0.3–0.4 cubic feet per second (ft^3/sec) following significant precipitation (McKinney et al. 2024, p. 32). In late spring, recorded discharge averages about 0.1–0.2 cfs (McKinney et al. 2024, p. 32).

In comparison, the depth of the Karges and Euphrasia Spring pools are much less variable. The depth of Karges Spring pool is very consistent, generally staying within a 50 mm (2 in) range, regardless of the depth of the Diamond Y Spring pool, discharge through the outlet channel, or precipitation (McKinney et al. 2024, pp. 35–37). One potential explanation for the contrast is that Karges Spring flow comes from a different source than the Diamond Y Spring flow (McKinney et al. 2024, p. 35). Another is that the Karges Spring, being somewhat lower in elevation than the Diamond Y Spring, has not (yet) been affected by the same factor that is lowering the Diamond Y Spring flow (McKinney et al. 2024, p. 35). The data from the Euphrasia Spring pool suggest that its depth falls in between the Diamond Y Spring pool and Karges Spring pool; it varies by up to 200.0 mm (7.9 in) (McKinney et al. 2024, pp. 38–39). Figure 10 and Figure 11 show the plotted depth values for Karges and Euphrasia Springs.

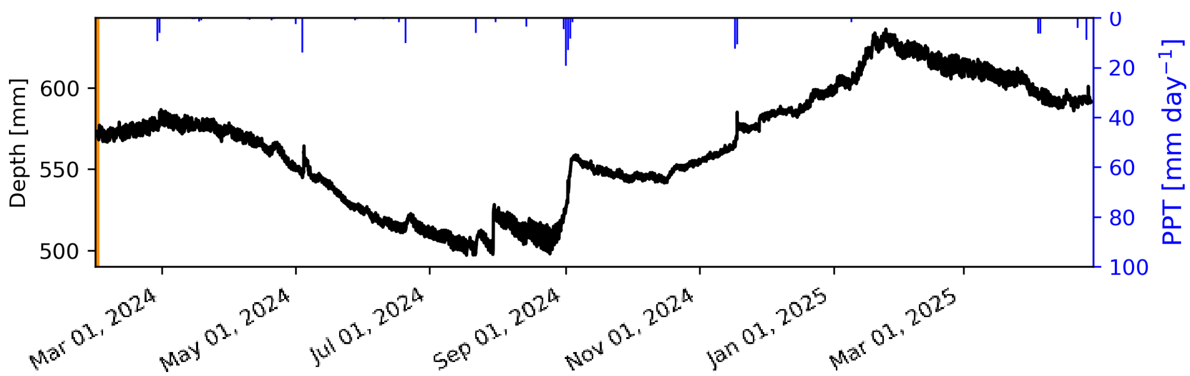

Figure 10. Depth of Karges Spring pool from April 2024 through April 2025 (Smith 2025b).

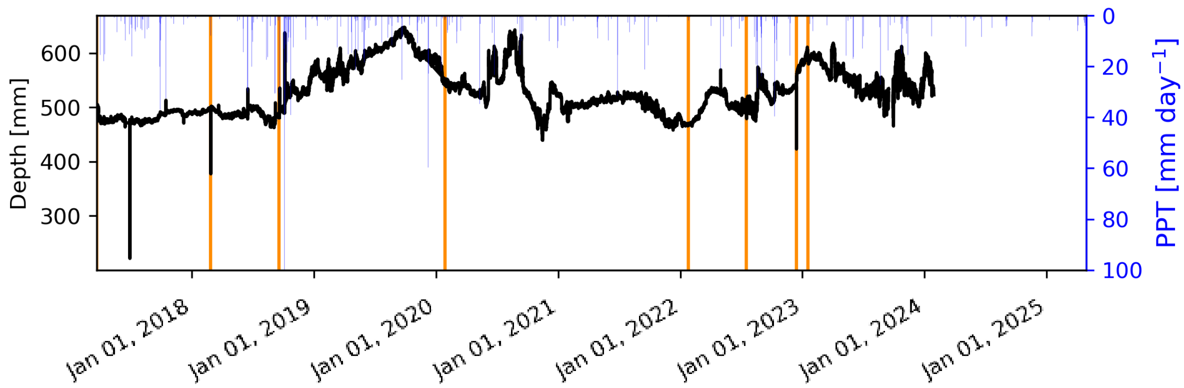

Figure 11. Depth of Euphrasia Spring pool from late 2017 through January 2024 (Smith 2025b).

Declines in groundwater impact have resulted in the loss of surface water habitat outside the spring pools as well. Significant drying of formerly perennial habitat in both the upper and lower watercourses has occurred, leading to reductions in habitat availability as discussed in section 2.2.1.5. Figure 12, taken from TNC's 2023 report, highlights these reductions. In the upper watercourse, the most important losses in habitat availability are those of the confluence of Diamond Y Draw with Leon Creek, and the watercourse below the dirt road above the confluence. In the lower watercourse, the primary loss of habitat is the loss of the Monsanto Pools and the connected watercourse along them, which were all above Euphrasia Spring and its outflow (The Nature Conservancy 2023, pp. 10, 12, 16, 27).

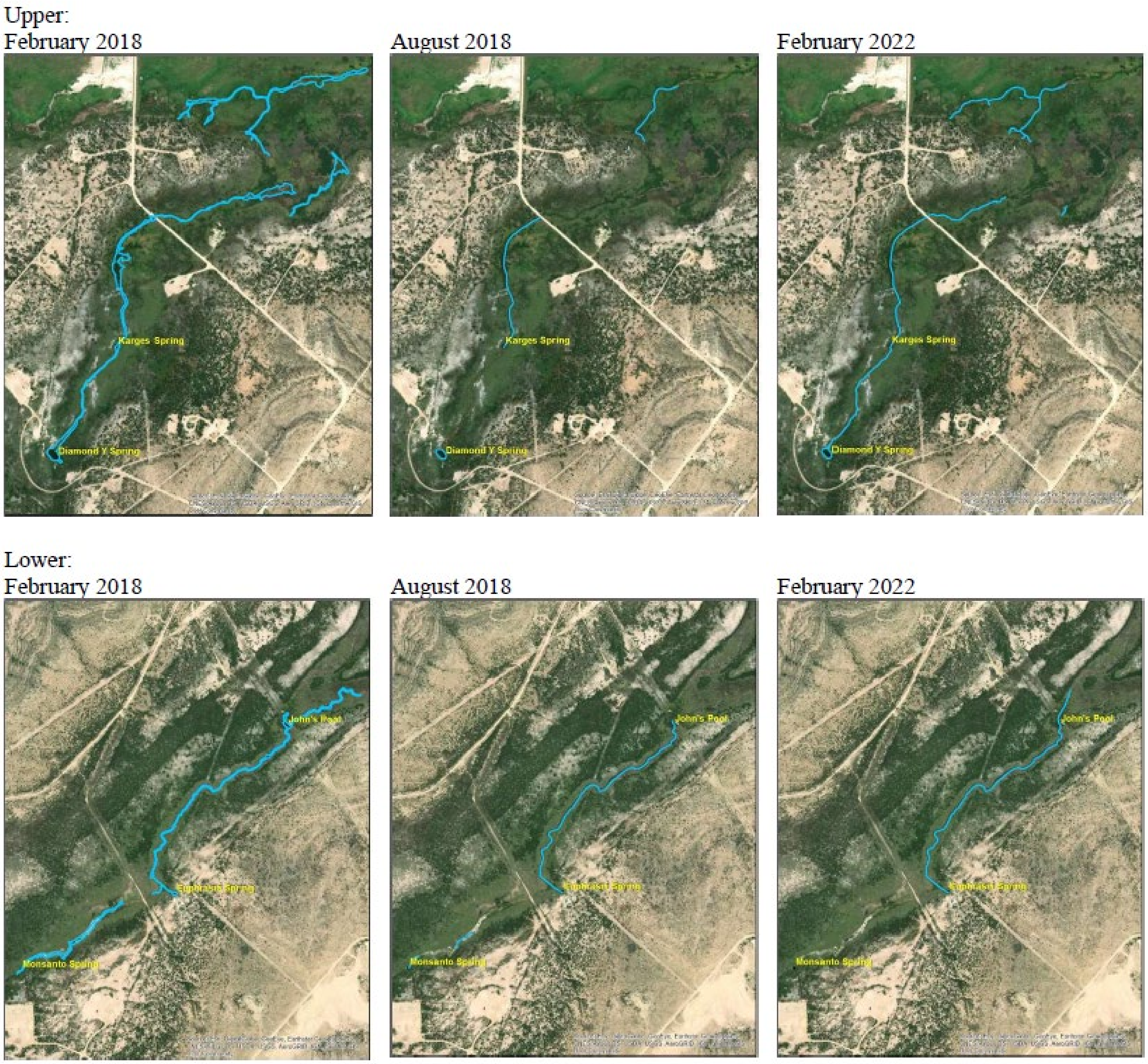

Figure 12. Extent of flow at Diamond Y Spring Preserve in the upper and lower watercourses in February 2018, August 2018, and February 2022. Flow was mapped as polygons in February 2018 and as lines in August 2018 and February 2022. The bright blue lines represent surface water habitat. In the upper three images, Diamond Y Spring and Karges Spring are labeled in yellow. In the lower three images, Monsanto Spring, Euphrasia Spring, and Johns Pool are labeled in yellow. Image reproduced from The Nature Conservancy (2023, p. 27).

Habitat Quality

Some water quality data is available from the draft report commissioned by The Nature Conservancy (McKinney et al. 2024, pp. 27–37). Within the Diamond Y Spring pool, conductivity is typically about 7,000 microsiemens per centimeter (µS/cm), but this increases to about 10,000 µS/cm when the pool level is at the lower part of its range (McKinney et al. 2024, p. 30). Within the Karges Spring pool, conductivity has ranged from about 7,000–7,400 µS /cm (McKinney et al. 2024, p. 36). Water temperature at that location ranges from a low of about 14° C (57° F) in winter to a high of about 20–22° C (68–72° F) in summer (McKinney et al. 2024, p. 35). In the lower watercourse at Euphrasia Spring, conductivity measurements appear unreliable, with values initially measured in the 8,000–15,000 µS /cm range from 2019 to 2021, then spiking to over 60,000 µS /cm in late 2021 to early 2022, dropping to 7,500 µS /cm in spring 2022 and to 500 µS /cm in August (McKinney et al. 2024, pp. 38–39). Similarly, temperature readings at this site were initially very stable around 20° C (68° F) from March 2017 to summer 2020, then became increasingly variable (McKinney et al. 2024, pp. 38–39). It is unknown whether the changes are real or an error, but the researchers suspected that feral hog activity was a factor and the sensor at this location was discontinued in January 2024, pending a resolution to the feral hog impacts (McKinney et al. 2024, pp. 38–39).

Feral hogs were not mentioned in the 2018 five-year status review, but were present on the Diamond Y Preserve in 2011 (Allan 2011, p. 2). Wallows were observed along both the upper and lower watercourses, including in Euphrasia Spring itself (Allan 2011, p. 2). Feral hog activity continued to degrade habitat by increasing sedimentation and decreasing pool depths for the next several years. Increasing hog activity throughout the decade led to the loss of almost all marsh vegetation from the lower watercourse and significant sedimentation, especially near wallows (The Nature Conservancy 2023, p. 2). These impacts are thought to have caused the extirpation of the other endangered fish found on the Preserve, Leon Springs pupfish (*Cyprinodon bovinus*), from the lower watercourse (The Nature Conservancy 2023, pp. 2, 10). In 2019, TNC was awarded funding from the National Fish and Wildlife Foundation to initiate invasive hog control (The Nature Conservancy 2023, p. 1). Efforts focused on aerial shooting in 2022, and although few hogs were taken, it was effective, temporarily, as harassment, as evidenced by recovering vegetation observed in 2023 (The Nature Conservancy 2023, pp. 1–2, 15). Unfortunately, after this project ended no further feral hog harassment or prevention efforts (e.g., fencing) were initiated, and in early 2023 severe impacts to Euphrasia and Karges Springs were discovered by TNC staff (Smith 2025a, p. 1). TNC reported an intent to complete emergency interventions to exclude the feral hogs from the waters inhabited by endangered species (Smith 2025a, p. 1).

A plausible secondary effect of low flows is increased siltation of the Diamond Y Spring pool substrate because flows are not sufficiently strong to push out sediment and maintain a cleaner gravel bottom (Brune 1981, p. 37; Dewson et al. 2007, pp. 404–406). In addition, if large amounts of sediment present on the substrate or as part of it are stirred up due to high intensity rain events or hog activity, this can cause a temporary degradation of water quality (e.g., increased turbidity, decreased dissolved oxygen) that can harm Pecos gambusia (U.S. Environmental Protection Agency 2015a, unpaginated; 2015b, unpaginated; Helcel et al. 2018, p. 4).

As discussed in the previous five-year status review, water quality in the Diamond Y Spring Preserve is at risk of degradation due to activities associated with oil and gas development (U.S. Fish and Wildlife Service 2018, pp. 31–32). Intense oil and natural gas activity occurs within and adjacent to the Preserve. Problems with illegal dumping of materials such as produced water are an issue in oil and gas producing areas (Mulder 2015, unpaginated; newswest9.com 2015, unpaginated). The injection of brines into wells for brine disposal or secondary recovery presents an opportunity for water contamination (Ashworth 1990, p. 31; Scanlon et al. 2020, p. 3515; Karanam et al. 2024, pp. 7–8). Such wells can introduce chemical contaminants to surface or groundwater, and the high salinity of the brines can increase aquatic salinity (Houston et al. 2019, pp. 30–33). Improperly or inadequately cased oil and gas wells are another source of potential contamination to both surface and groundwater; older wells are riskier because, as they age, they may fail and contaminate groundwater (Ashworth 1990, pp. 30–31). Contaminants found in water wells include brine, dissolved hydrocarbons, oil on water, and dissolved natural gas (Boyer 1986, p. 308). Pipelines present another potential route of contamination; they may contain oil, gas, or brines; leaks or ruptures to pipelines can allow these materials to enter underground aquifers (Ashworth 1990, p. 31). In addition, surface spills of oil, brines, or other materials such as drilling mud have contaminated waterways in the past (U.S. Fish and Wildlife Service 2013b, pp. 13–15).

We used data from S&P Global's Enerdeq Browser to identify wells and pipelines within 1.0, 3.0, and 5.0 kilometers (km) (0.6, 1.8, and 3.1 miles [mi]) of the perennial habitats in the upper and lower watercourses (S&P Global 2024a; 2024b). We summarize the results of all wells, regardless of status, in Table 10. Table 11 shows these values for the wells, classified into active, inactive, and unknown status, within the 5.0 km (3.1 mi) buffer. Fifteen new wells have been drilled within 5.0 km (3.1 mi) of the habitat since the last five-year status review was prepared in 2018 (S&P Global 2025d). Table 12 shows the total calculated length of all natural gas pipelines within these buffer distances. The very large pipeline sums are due to the presence of a natural gas refinery within 1.0 km (0.6 mi) of the springs.

Table 10. Wells associated with oil and gas production in the vicinity of the Diamond Y perennial watercourses by type of well. The cumulative number of wells within 1 km, 3 km, and 5 km of those areas is shown. For example, the two gas wells within 1 km are also included in the count of gas wells within 3 km and 5 km. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2024a; 2024b).

Well Classification	**1 km**	**3 km**	**5 km**
gas well	2	21	40
oil well	16	72	127
injection	5	24	55
suspended	0	0	1
plugged gas well	2	14	31
plugged oil well	20	84	160
dry hole	4	31	59
abandoned	4	24	50
dry w/gas shows	0	5	6
dry w/oil shows	1	15	28
dry w/oil and gas shows	0	1	4
drilling in progress	0	2	2
Total	**54**	**291**	**563**

Table 11. Wells associated with oil and gas production within 5 km of the Diamond Y and Karges Spring pools by well status. Wells with an attribute of "<Null>" in the geospatial layer are labeled "Undefined" in this table. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2024a; 2024b).

Well Classification	Active	Inactive	Undefined
gas well	32	6	2
oil well	93	22	12
injection	22	17	16
suspended	0	0	1
plugged gas well	1	28	2
plugged oil well	3	99	58
dry hole	2	10	47
abandoned	0	0	50
dry w/gas shows	0	5	1
dry w/oil shows	0	17	11
dry w/oil and gas shows	0	0	4
drilling in progress	0	0	2
Total	**153**	**204**	**206**

Table 12. Total length of pipelines, in kilometers in the vicinity of the Diamond Y and Karges Spring pools, calculated using the GCS North American 1983 coordinate system. The cumulative length of pipelines within 1 km, 3 km, and 5 km of those two springs is shown. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2024a; 2024b).

Well Classification	1 km	3 km	5 km
Natural Gas	252.1	451.9	574.3
Crude Oil	0	8.8	8.8

We used Railroad Commission of Texas loss report data to evaluate spills from oil and gas production operation in Pecos County for the period 2013–2024 (Railroad Commission of Texas 2013; 2014; 2015; 2016; 2017; 2018; 2019; 2020; 2021; 2022; 2023; 2024). We evaluated the entire county because the spills data was not consistently available at more precise locations. Spills are reported to the Railroad Commission of Texas each year; since 2013, this value has ranged from 0 to 22 spill events per year. The pattern over time and the type of liquid spills (typically crude oil) is shown in Figure 13.

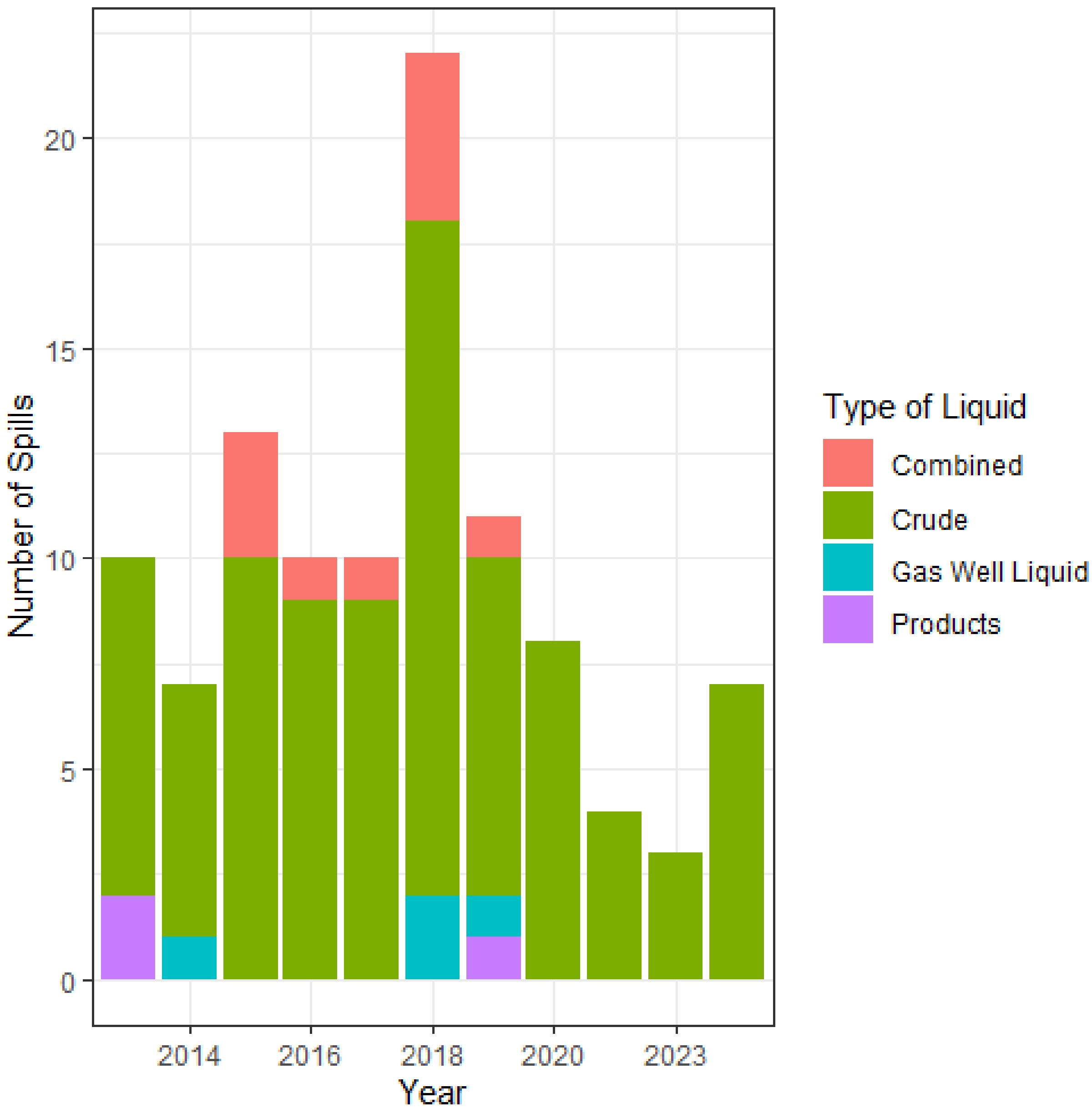

Figure 13. Number of spills per year from 2013 to 2024 in Pecos County, Texas, based on information reported to and made available by the Texas Railroad Commission. Colors denote type of liquid spilled; most spills are from crude oil.

San Solomon Springs System

Habitat Availability

Declining spring flows are a major threat to Pecos gambusia (U.S. Fish and Wildlife Service 2015, p. 6). As discussed above, declines in spring flows lead to declines in aquatic habitat. The loss of some localities (e.g., Phantom Lake Spring) has already occurred due to declining spring flows. Discharge data from

San Solomon springs at Balmorhea State Park is available irregularly from 1920 to the present (Norris et al. 2022, p. 18; U.S. Geological Survey 2025c). A comparison of discharge is presented in Table 13 and recorded data are displayed in Figure 14. Discharge has declined steadily over time, including within the last decade. San Solomon Springs has never been documented to cease flowing (U.S. Fish and Wildlife Service 2013a, pp. 18–19; Norris et al. 2022, p. 16).

Table 13. Discharge data for the USGS gage “San Solomon Spgs at Toyahvale, TX - 08427500” (U.S. Geological Survey 2025c). This table is adapted from (Norris et al. 2022, p. 18) and presents the minimum, maximum, mean, and median values for stream discharge in cubic feet per second (ft^3/sec) from the USGS gage. The values for the periods 1920–1936, 1931–1933, 1941–1965, 1965–1986, and 2001–2016 are reproduced from the baseline biomonitoring report for the San Solomon springs area (Norris et al. 2022, p. 18). The values for the period 2017–2018 are also extracted from that report (Norris et al. 2022, p. 73). Values for the period 2017–2025 were sourced from USGS water data and obtained using the dataRetrieval package in R (DeCicco 2021; R Core Team 2025; U.S. Geological Survey 2025c).

Years	**Mean ft^3/sec**	**Median ft^3/sec**	**Min ft^3/sec**	**Max ft^3/sec**
1920-1936	34.4	34.3	26.5	40.6
1931-1933	40.2	36	30	17
1941-1965	33.6	30.5	26	71
1965-1986	29.9	28.4	17.6	83.2
2001-2016	25.9	25.5	13	46.9
2017–2018	26.5	26.1	20.5	32.7
2017–2025	22.1	21.5	6.94	35.2

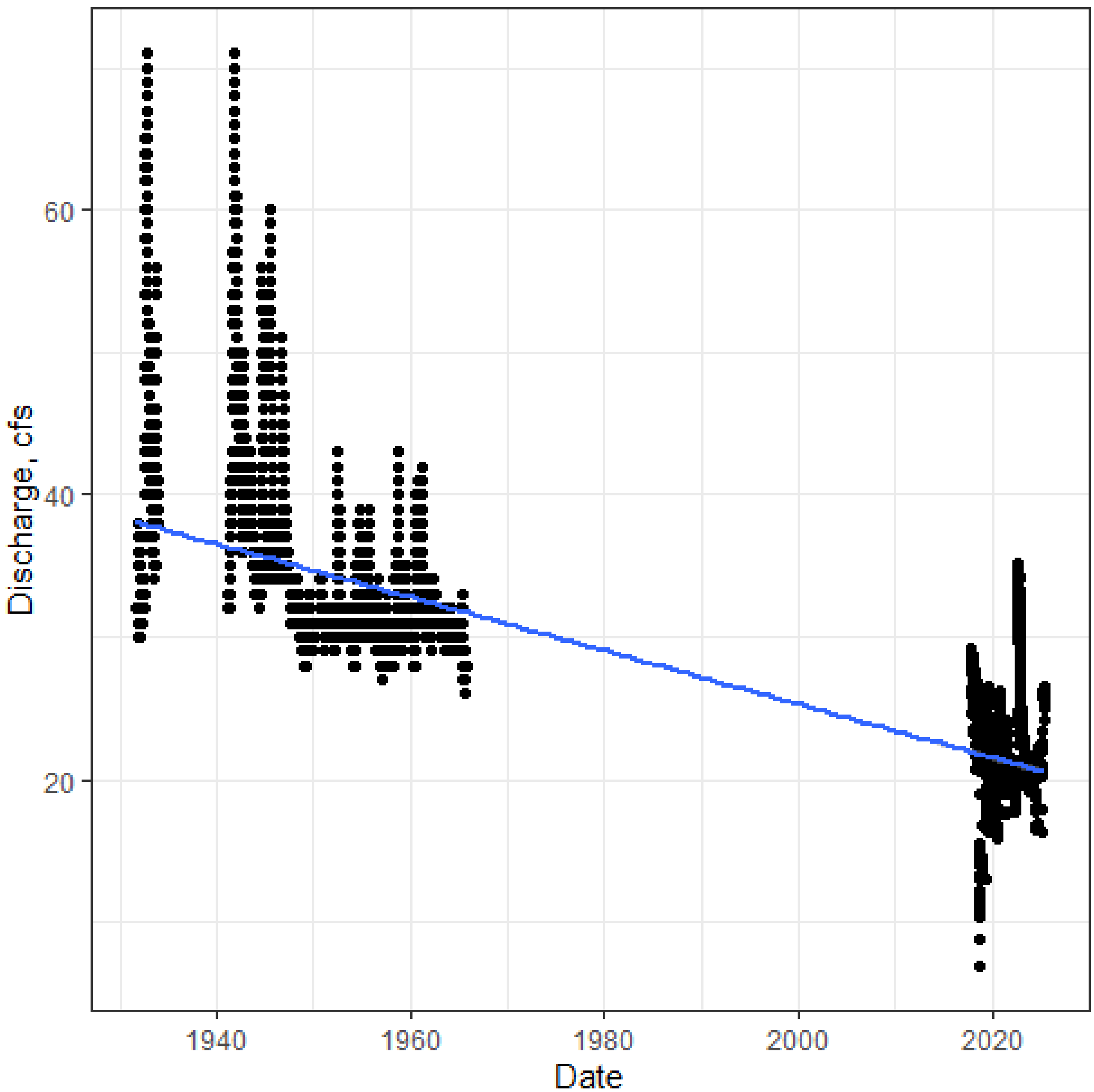

Figure 14. Discharge data for the USGS gage "San Solomon Spgs at Toyahvale, TX - 08427500." Individual measurements are shown as points denoting the mean cubic feet per second (y-axis, cfs) of flow for each day for the period 1931–2025 (Note, data were not available for all intermediate time periods.). The blue line indicates the average change over time based on a simple linear regression. The data used to create this plot were sourced from USGS water data and obtained using the dataRetrieval package in R (DeCicco 2021; R Core Team 2025; U.S. Geological Survey 2025c).

Discharge data from Giffin Spring is available from 1931–1933 and from 2002–present (U.S. Geological Survey 2025b). Summary statistics for the discharge data are presented in Table 14, and recorded data are displayed in Figure 15. Discharge has declined at this spring over time, but the rate of change is smaller than for San Solomon Springs. Like San Solomon Springs, Giffin Spring has never been documented to cease flowing (U.S. Fish and Wildlife Service 2013a, pp. 18–19; Norris et al. 2022, p. 16).

Table 14. Discharge data for USGS gage "Giffin Spgs at Toyahvale, TX - 08427000" (U.S. Geological Survey 2025b) This table presents the minimum, maximum, mean, and median values for stream discharge in cubic feet per second (ft^3/sec) from the USGS gage for the periods 1931–1933 and 2002–2025. Summary data in the final row were sourced from USGS water data and obtained using the dataRetrieval package in R (DeCicco 2021; R Core Team 2025; U.S. Geological Survey 2025b).

Years	Mean ft^3/sec	Median ft^3/sec	Min ft^3/sec	Max ft^3/sec
1931-1933	4.8	4.8	3.6	6.1
2002–2024	4.0	4.0	0.74	12.3

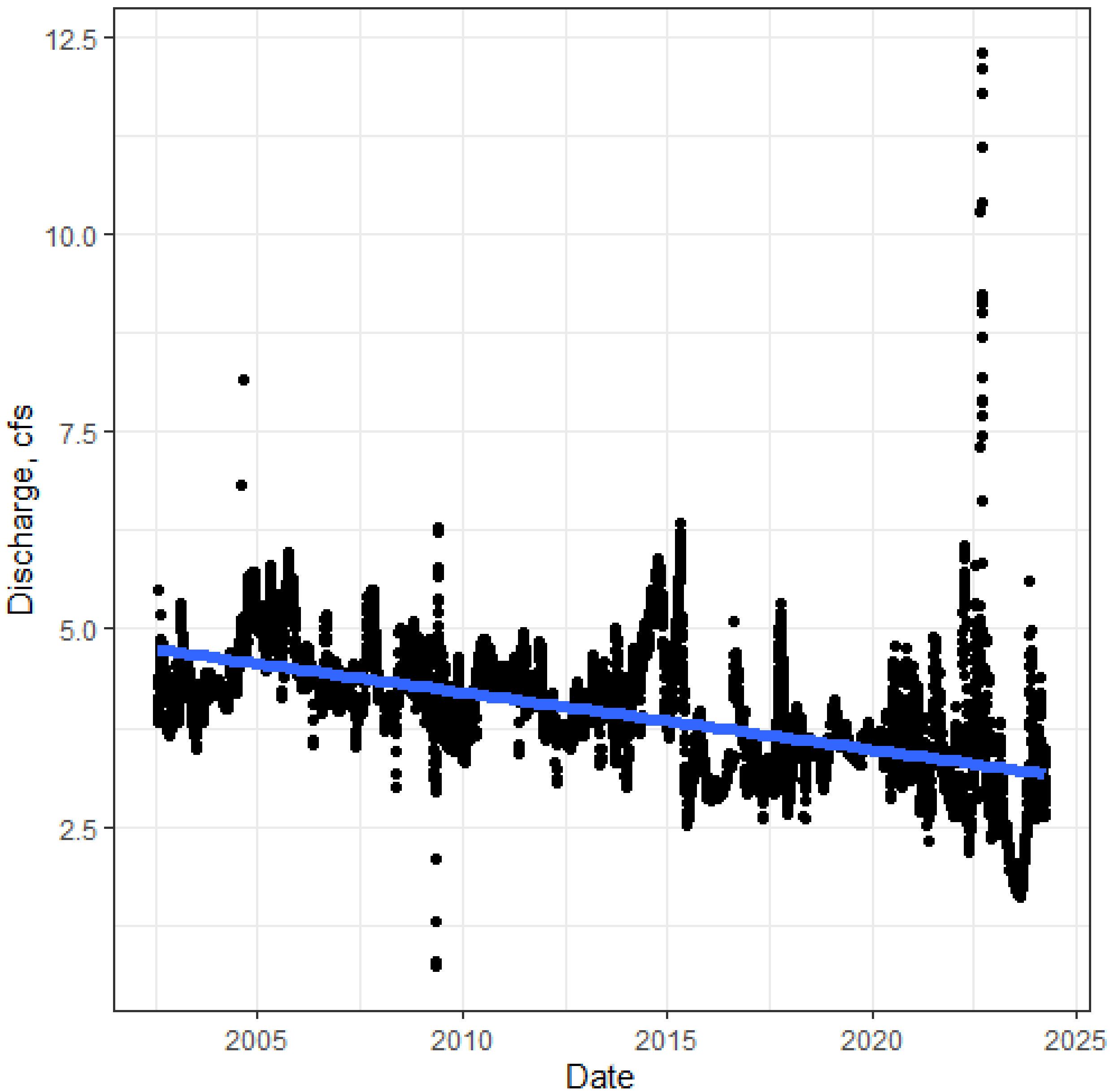

Figure 15. Discharge data for USGS gage "Giffin Spgs at Toyahvale, TX - 08427000." Individual measurements are shown as points denoting the mean cubic feet per second (y-axis, cfs) of flow for each day for the period 2002–2025. The blue line indicates the average change over time based on a simple linear regression. The data used to create this plot were sourced from USGS water data and obtained using the dataRetrieval package in R (DeCicco 2021; R Core Team 2025; U.S. Geological Survey 2025b).

East Sandia Spring has declined since European settlement in the area, but its flows are too low to support a gage and so that data is unavailable (U.S. Fish and Wildlife Service 2013a, pp. 18–19; Norris et al. 2022, p. 16). There is no evidence that it has ceased to flow (U.S. Fish and Wildlife Service 2013a, pp.

18–19; Norris et al. 2022, p. 16). As far of the same effort described above for the Diamond Y Preserve, TNC has funded the collection of continuous, long-term measurements of spring pool level and water quality for East Sandia Spring (McKinney et al. 2024, p. 3). Like at Euphrasia Spring, the sensors also had some issues leading to questionable data, which are described in detail in the report (McKinney et al. 2024, pp. 20–21). The full span of sensor depth data are shown in Figure 16. Much of the spring pool has a relatively shallow depth, although it is several feet deep in the middle. Overall, this spring pool is relatively stable and more influenced by precipitation events than others in the system. West Sandia Spring has also declined, and has been observed to cease flowing during drought (U.S. Fish and Wildlife Service 2013a, pp. 18–19; Norris et al. 2022, p. 16).

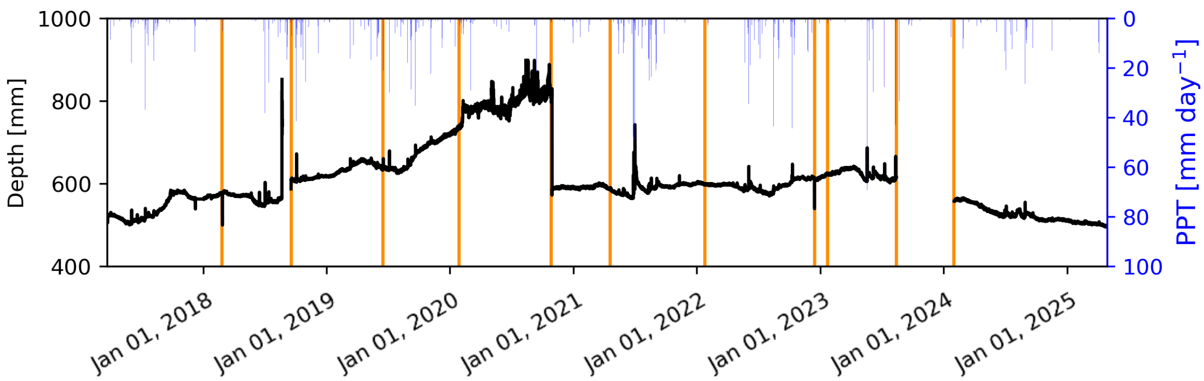

Figure 16. Depth of East Sandia Spring pool from March 2017 through April 2025 (Smith 2025b).

In a 2004 Biological Opinion, Toyah Creek was described as an intermittent tributary (U.S. Fish and Wildlife Service 2004, p. 16). Its intermittency was presumably due to groundwater pumping and decreased stream flows, because in the 1930s it was perennial for four spring-fed miles near Balmorhea (White et al. 1941, p. 86). No improvement in conditions at this location have been reported, indicating that the population at this location continues to be at a high risk of extirpation due to stream drying.

The refugium at the mouth of the cave at Phantom Lake Spring and the Pecos gambusia living in it were lost in the first half of 2022. In November 2021, the Bureau of Reclamation requested Service concurrence on a determination that transferring the land parcel containing the cave and spring to the surrounding landowner would be not likely to adversely affect the Pecos gambusia (Faler 2021, entire). The Austin Ecological Services Field Office issued a concurrence letter in January 2022 (U.S. Fish and Wildlife Service 2022, entire).

The Bureau of Reclamation signed over the property deed on February 18, 2022, and it was officially recorded on March 14, 2022 (Bachus 2024, p. 1). The Bureau of Reclamation notified the landowner that it would be necessary to claim the electric utility account if the pumps were to remain functional, and were told by the landowner that this would take place (Bachus 2024, p. 1). The agency closed their account with the electric company around that time and paid the last bill on April 22, 2022 (Bachus 2024, p. 1).

In early May, a staff member with the Bureau of Reclamation contacted the Texas FWCO to inform them that based on their camera feed, the pumps that maintain the refugium were not functioning (Montagne 2022a, p. 1). We infer that the electricity had been shut off between when the land transfer was finalized and when this notice was received. The Texas FWCO project leader and a Bureau of Reclamation staff member both attempted to contact the landowner and ranch manager (Montagne 2022a, p. 1). In a conversation in late spring 2022, the landowner stated that he had told his ranch manager to turn off the electricity to the pump system (Montagne 2024, p. 1). Based on that information and the history of the site, the Service determined in early June that the refugium dried up by the time that conversation took place (Montagne 2022b, p. 1). This status was confirmed via a site visit in February 2023 (Montagne 2023, pp. 1–2, Figures 17 and 18).

Figure 17. Phantom Lake Spring in February 2018. Photo by U.S. Fish and Wildlife Service staff.

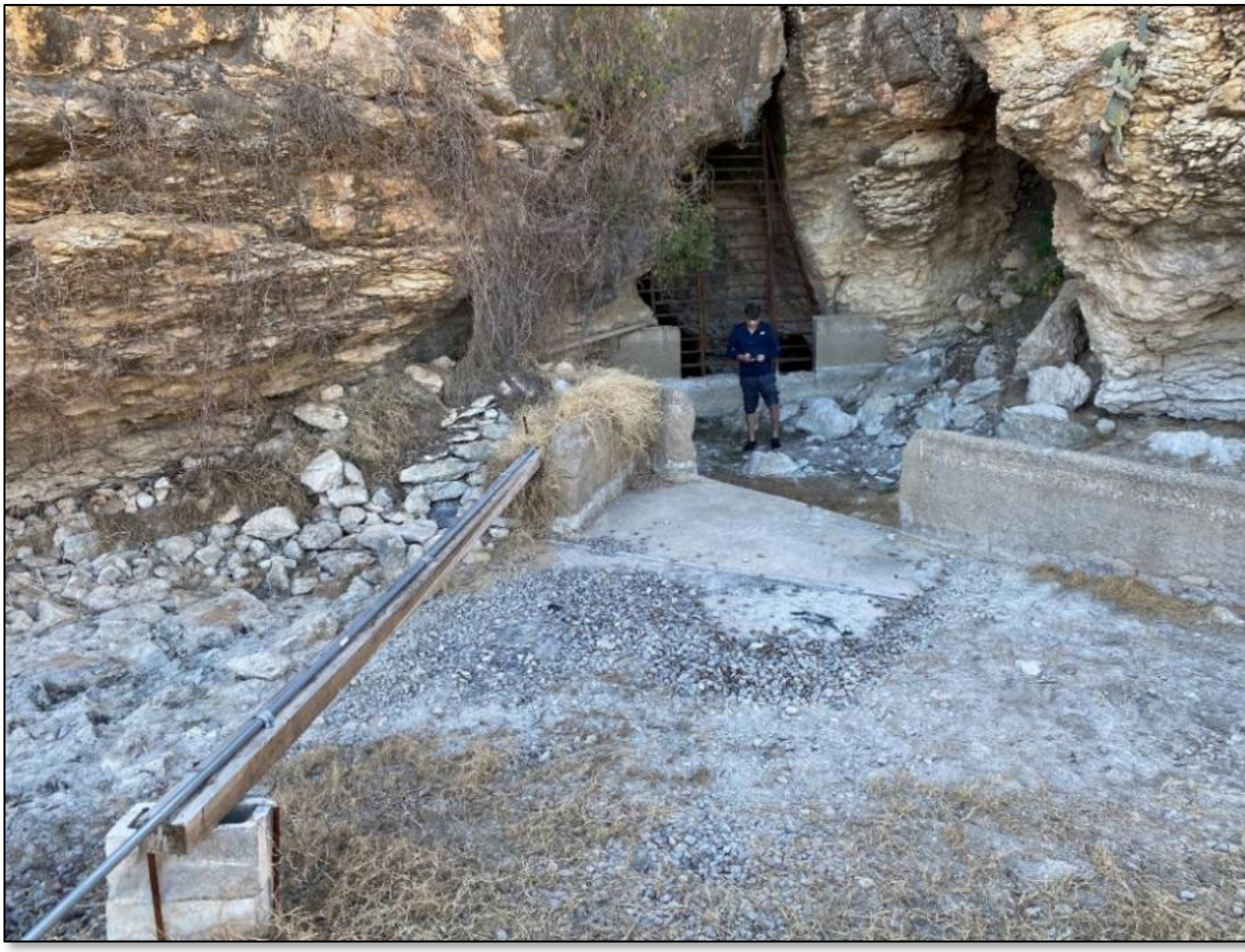

Figure 18. Phantom Lake Spring in February 2023 after the pumps that maintained the water levels in the refugium were turned off. The site has been dewatered and the image reflects the current status quo for the site. Photo by Mike Montagne, U.S. Fish and Wildlife Service.

Habitat Quality

In 2018, TPWD developed recommendations for baseline monitoring of water quantity and quality parameters as well as aquatic fauna of the San Solomon Spring System, which includes San Solomon Spring (underlying the swimming pool at Balmorhea State Park), Giffin Spring, East and West Sandia Springs, and Phantom Lake Spring (Texas Parks and Wildlife Department 2018, entire). Sampling efforts conducted by that agency and partners (e.g., Service and Texas State University) took place from 2017 to 2018 (Norris et al. 2022, pp. 41–42). Water quality of sampled springs was generally of good quality with few detectable contaminants (Norris et al. 2022, pp. 77–89). The San Solomon and Clark Hubbs Ciénegas tended to have higher water temperatures, pH, dissolved oxygen, and percent cover of filamentous algae (Norris et al. 2022, p. 62). East and West Sandia springs have lower water temperatures and higher specific conductivity than San Solomon and Phantom Lake springs (Norris et al. 2022, p. 75). The data from The Nature Conservancy's project at East Sandia Spring agrees with this determination, and additionally demonstrates that the water quality there fluctuates more, at least in terms of conductivity and water temperature, than the San Solomon and Giffin Springs (McKinney et al. 2024, pp. 20–23). Finally, though conditions are not reportedly as severe as on the Diamond Y Preserve, the Sandia Springs Preserve, where both East and West Sandia Springs are located, has also been experiencing feral hog activities since at least January 2022 (McKinney et al. 2024, p. 24).

We repeat the analysis of oil and gas facilities and spills completed above here for the San Solomon Springs System. We used data from S&P Global's Enerdeq Browser to identify wells and pipelines within 1.0, 3.0, and 5.0 km (0.6, 1.8, and 3.1 mi) of the sites shown in Figure 3 (S&P Global 2025a; 2025f). We summarize the results of all wells, regardless of status, in Table 15. Table 16 shows these values for the wells, classified into active, inactive, and unknown status, within the 5.0 km (3.1 mi) buffer. Five new wells have been drilled within 5.0 km (3.1 mi) of the habitat since the last five-year status review was prepared in 2018 (S&P Global 2025d). Table 17 shows the total calculated length of all natural gas pipelines within these buffer distances.

Table 15. Wells associated with oil and gas production in the vicinity of the San Solomon Spring System by type of well. The number of wells within 1 km, 3 km, and 5 km of those areas is shown. The cumulative number of wells within 1 km, 3 km, and 5 km of those areas is shown. For example, the two gas wells within 1 km are also included in the count of gas wells within 3 km and 5 km. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2025a; 2025f).

Well Classification	**1 km**	**3 km**	**5 km**
gas well	2	3	9
oil well	0	1	1
plugged gas well	0	0	1
plugged oil well	0	1	2
dry hole	1	11	20
abandoned	1	2	4
dry w/gas shows	0	0	1
dry w/oil shows	0	0	1
drilling in progress	0	0	5
Total	**4**	**18**	**44**

Table 16. Wells associated with oil and gas production within 5 km of the San Solomon Spring System by well status. Wells with an attribute of "<Null>" in the geospatial layer are labeled "Undefined" in this table. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2025a; 2025f).

Well Classification	Active	Inactive	Undefined
gas well	9	0	0
oil well	1	0	0
plugged gas well	0	1	0
plugged oil well	0	2	0
dry hole	0	2	18
abandoned	0	0	4
dry w/gas shows	0	0	1
dry w/oil shows	0	0	1
dry w/oil and gas shows	0	0	1
drilling in progress	0	0	5
Total	**10**	**5**	**29**

Table 17. Total length of pipelines, in kilometers in the vicinity of the San Solomon Spring System, calculated using the GCS North American 1983 coordinate system. The cumulative length of pipelines within 1 km, 3 km, and 5 km of those two springs is shown. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2025a; 2025f).

Well Classification	1 km	3 km	5 km
Natural Gas	8	12	36

We used Railroad Commission of Texas loss report data to evaluate spills from oil and gas production operation in Pecos County for the period 2013–2024 (Railroad Commission of Texas 2013; 2014; 2015; 2016; 2017; 2018; 2019; 2020; 2021; 2022; 2023; 2024). We evaluated the entire county because the spills data was not consistently available at more precise locations. Spills are reported to the Railroad Commission of Texas each year; since 2013, this value has ranged from 1 to 95 spill events per year. The pattern over time and the type of liquid spills (typically crude oil) is shown in Figure 19.

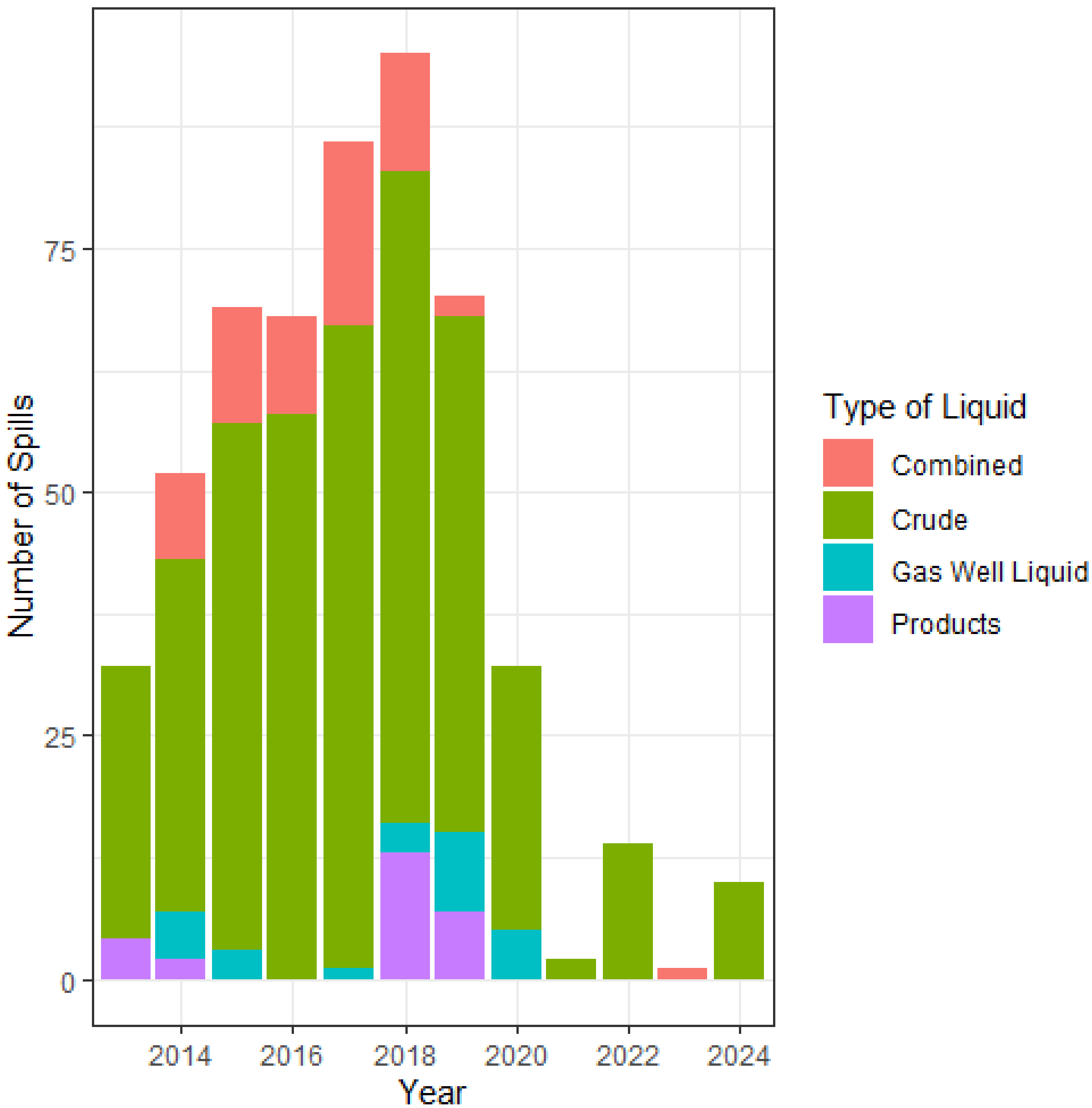

Figure 19. Number of spills per year from 2013 to 2024 in Reeves County, Texas, based on information reported to and made available by the Texas Railroad Commission. Colors denote type of liquid spilled; most spills are from crude oil.

<u>Blue Springs</u>

Habitat Availability

No new information about habitat availability for Pecos gambusia at this locality has been published since the previous five-year review was approved in 2018.

Discharge data from Blue Springs is available from 2000–present (U.S. Geological Survey 2025a). Summary statistics for the discharge data are presented in Table 18 and recorded data are displayed in Figure 20. Discharge has been very consistent over time, and we are not aware of any records of these springs ceasing to flow.

Table 18. Discharge data for USGS gage “Blue Springs Above Diversions NR Whites City, NM - 08405450” (U.S. Geological Survey 2025a). This table presents the mean, median, minimum, and maximum values for stream discharge in cubic feet per second (ft^3/sec) from the USGS gage for the period 2000–2025. These data were sourced from USGS water data and obtained using the dataRetrieval package in R (DeCicco 2021; R Core Team 2025; U.S. Geological Survey 2025a).

Years	**Mean ft^3/sec**	**Median ft^3/sec**	**Min ft^3/sec**	**Max ft^3/sec**
2000–2025	10.7	10.2	3.4	57

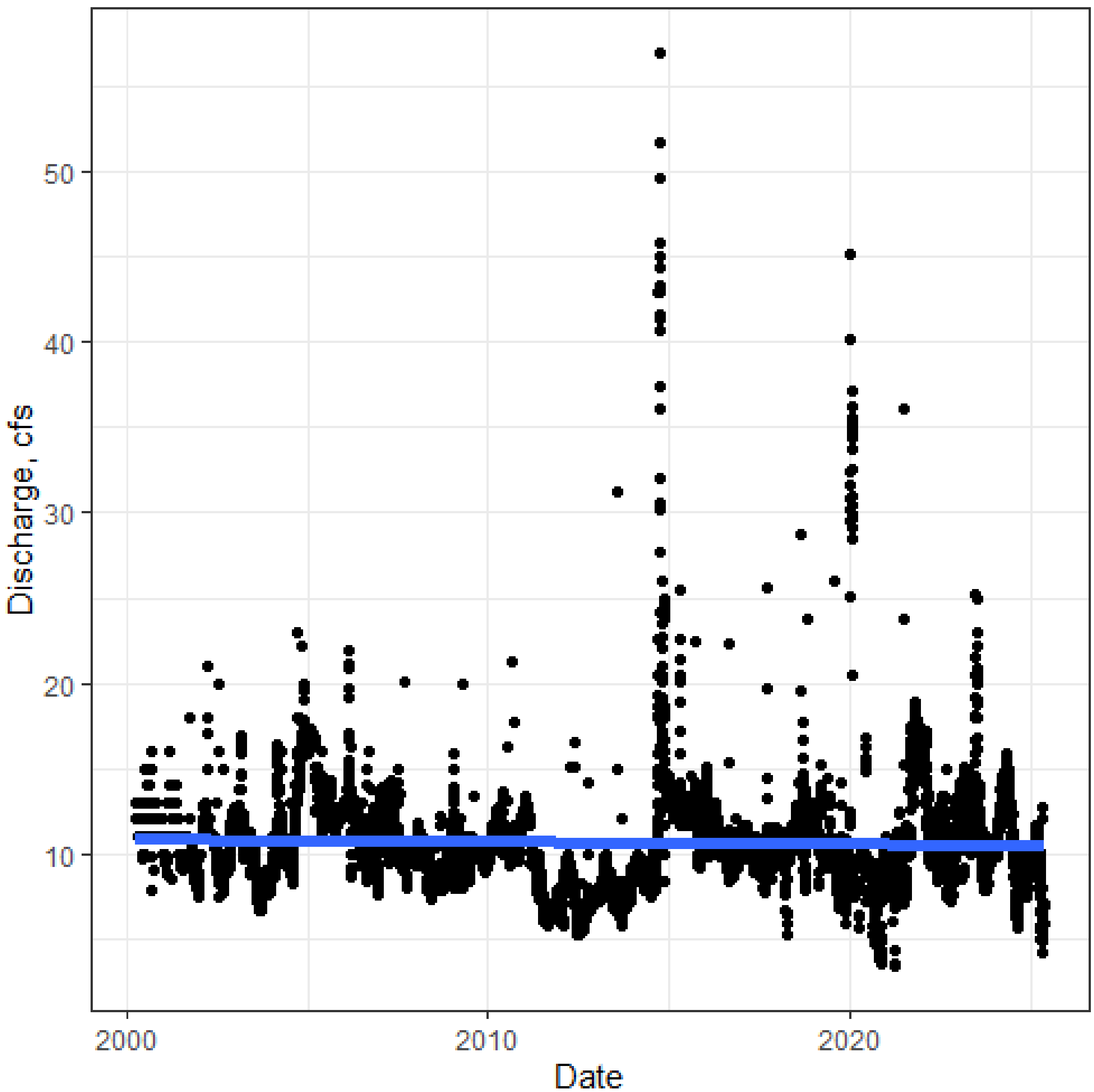

Figure 20. Discharge data for USGS gage "Giffin Spgs at Toyahvale, TX - 08427000." Individual measurements are shown as points denoting the mean cubic feet per second (y-axis, cfs) of flow for each day for the period 2000–2025. The blue line indicates the average change over time based on a simple linear regression. The data used to create this plot were sourced from USGS water data and obtained using the dataRetrieval package in R (DeCicco 2021; R Core Team 2025; U.S. Geological Survey 2025a).

Habitat Quality

We repeat the analysis of oil and gas facilities and spills completed above here for the Blue Springs area. We used data from S&P Global's Enerdeq Browser to identify wells and pipelines within 1.0, 3.0, and 5.0 km (0.6, 1.8, and 3.1 mi) of Blue Springs (S&P Global 2025b; 2025g). We summarize the results of all wells, regardless of status, in Table 19. Table 20 shows these values for the wells, classified into active, inactive, and unknown status, within the 5.0 km (3.1 mi) buffer. A total of 24 new wells have been drilled within 5.0 km (3.1 mi) of the habitat since the last five-year status review was prepared in 2018 (S&P Global 2025e). Table 21 shows the total calculated length of all natural gas and crude oil pipelines within these buffer distances.

Table 19. Wells associated with oil and gas production in the vicinity of Blue Springs by type of well. The cumulative number of wells within 1 km, 3 km, and 5 km of those areas is shown. For example, the ten gas wells within 1 km are also included in the count of gas wells within 3 km and 5 km. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2025g).

Well Classification	**1 km**	**3 km**	**5 km**
gas well	10	43	89
oil well	2	17	36
unclassified, co2, etc.	0	1	1
injection	0	2	3
plugged gas well	91	52	94
plugged oil well	8	7	27
plugged oil and gas well	9	1	1
dry hole	20	12	27
abandoned	22	35	109
dry w/gas shows	12	3	9
dry w/oil shows	26	5	13
dry w/oil and gas shows	14	14	15
Total	**4**	**18**	**44**

Table 20. Wells associated with oil and gas production within 5 km of Blue Springs by well status. Wells with an attribute of “<Null>” in the geospatial layer are labeled “Undefined” in this table. Data obtained from S&P Global’s Enerdeq Browser (S&P Global 2025g).

Well Classification	Undefined	Active	Inactive
gas well	11	74	4
oil well	8	28	0
unclassified, co2, etc.	0	0	1
Injection	0	3	0
plugged gas well	32	4	58
plugged oil well	6	1	20
plugged oil and gas well	0	0	1
dry hole	26	0	1
abandoned	109	0	0
dry w/gas shows	5	0	4
dry w/oil shows	11	0	2
dry w/oil and gas shows	14	0	1
Total	**232**	**110**	**92**

Table 21. Total length of pipelines, in kilometers in the vicinity of Blue Springs, calculated using the GCS North American 1983 coordinate system. The cumulative length of pipelines within 1 km, 3 km, and 5 km of those two springs is shown. Data obtained from S&P Global’s Enerdeq Browser (S&P Global 2025b).

Well Classification	1 km	3 km	5 km
Natural Gas	2	9	19
Crude Oil	0	0	1

We used New Mexico Oil Conservation Division spills data to evaluate spills from oil and gas production operation in Eddy County for the period 2013–2024 (New Mexico Oil Conservation Division 2025). Spatial coordinates were available for the spills, so we queried the dataset for the spills that occurred within 5.0 km (3.1 mi) of Blue Springs. Spills are reported to the Oil Conservation Division continuously; since 2003, this value has ranged from 1 to 18 spill events per year (Figure 21). Spills have been higher in the last five years, and most spills are of produced water.

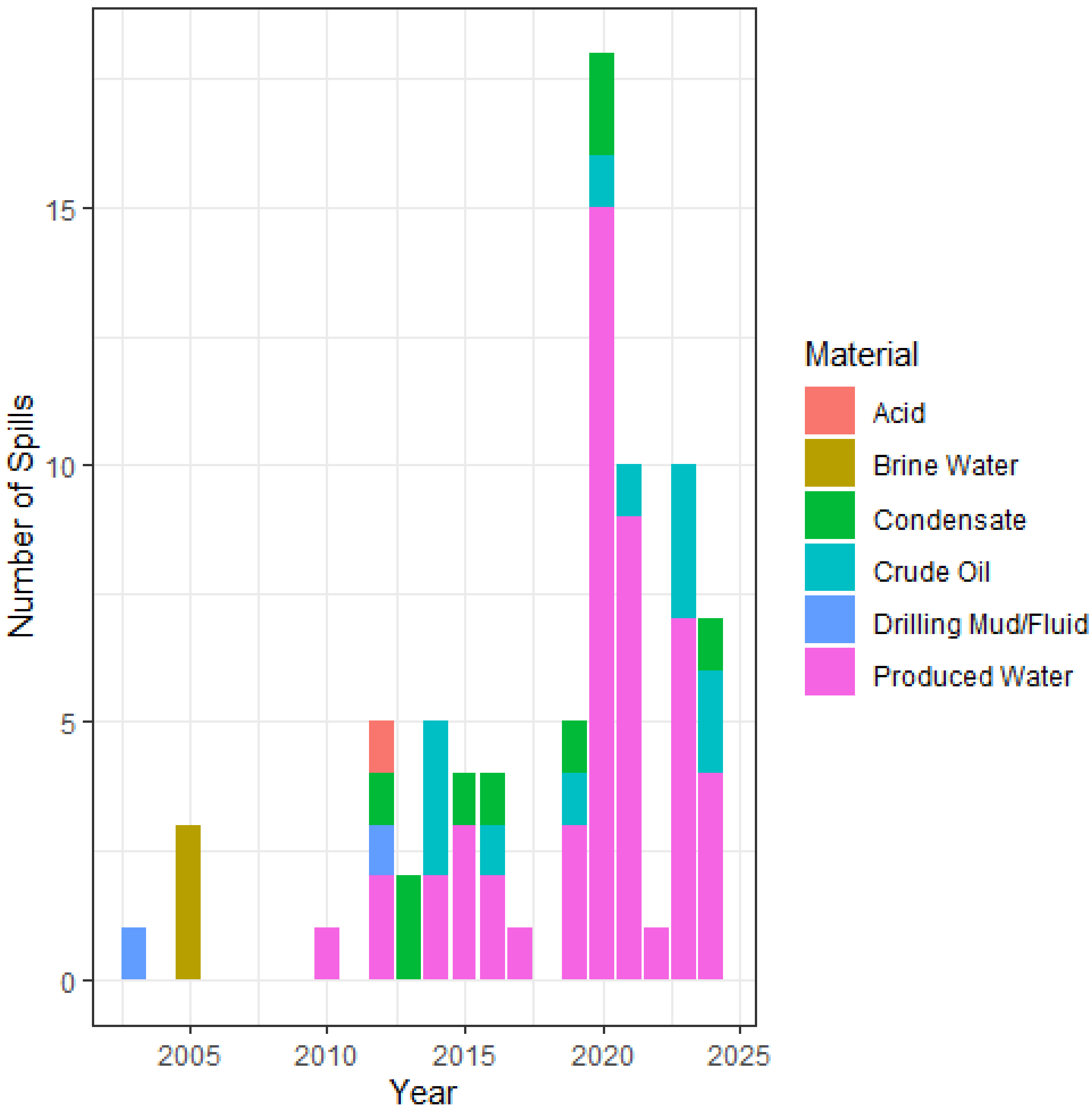

Figure 21. Number of spills per year from 2003–2024 within 5 km of Blue Springs, based on information reported to and made available by the New Mexico Oil Conservation Division (New Mexico Oil Conservation Division 2025). Colors denote type of liquid spilled; most spills are from produced water (pink).

Bitter Lake National Wildlife Refuge

Habitat Availability

As experienced by the other populations of Pecos gambusia, the populated areas at Bitter Lake NWR have also been impacted by declining groundwater flows, including changes to habitat availability over the long term and in the time since the previous five-year status review. Although water levels in the sinkholes, Bitter Creek, and Bitter Lake fluctuate within and across years, this has not resulted in the extirpation of Pecos gambusia from any of their longstanding occupied localities. That said, within the last five years, portions of Bitter Creek have been drying seasonally, necessitating emergency salvage procedures and prompting discussions about how to maintain the habitat in Bitter Creek over the long term.

A flume was installed on Bitter Creek in April 1995 to measure discharge through the creek, which serves as a proxy for the spring inflows (such as from Dragonfly Spring and Lost River) above the flume (Butler and Tashjian 2016, p. 2). Data for Bitter Creek, analyzed by Service hydrologists and reproduced in Figure 22, show a clear decline in discharge over time. Median monthly discharge ranged from 0.085–0.530 cfs (Butler and Tashjian 2016, p. 5). Discharge rates are lower during drought and during the growing season (Butler and Tashjian 2016, p. 5).

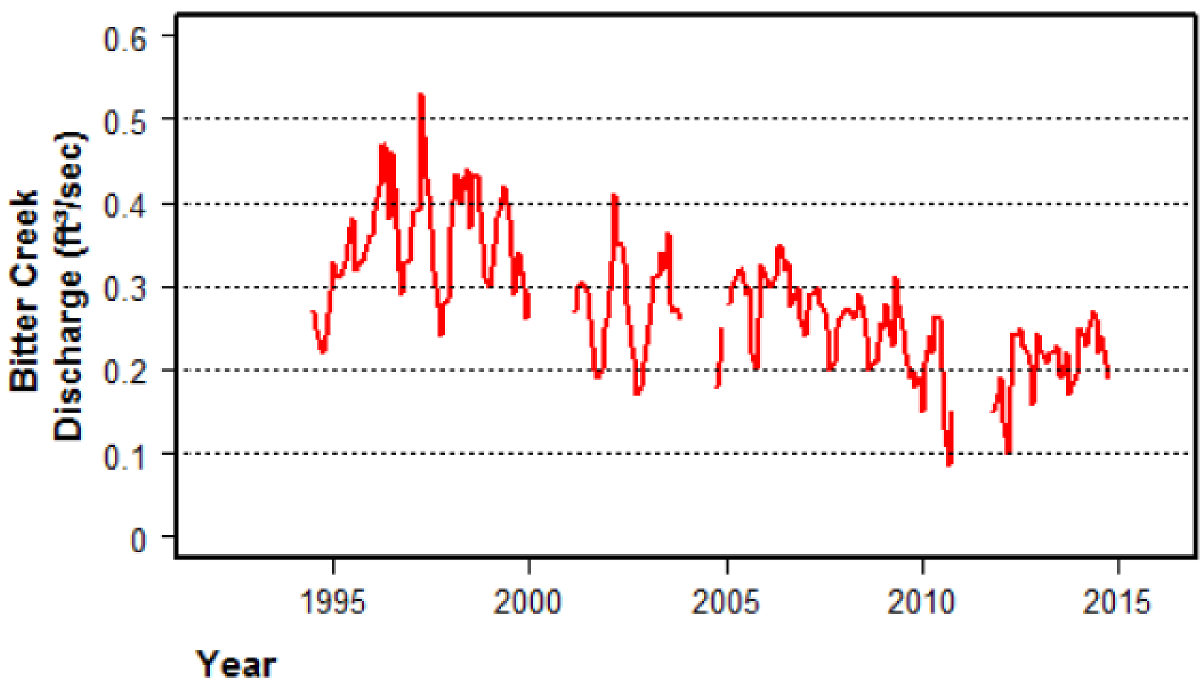

Figure 22. Time-series of discharge data for Bitter Creek on the Middle Tract of Bitter Lake National Wildlife Refuge from 1995–2015. Reproduced with slight modification from Butler and Tashijan (2016, p. 4).

The analysis of the data assumed that a minimum flow of 0.25 cfs during the growing season and 0.30 cfs during the dormant season would be adequate to meet recovery goals for four federally-listed spring invertebrates (Butler and

Tashjian 2016, p. 1,8). Pecos gambusia needs more water than the invertebrates to persist. Discharge levels have been below these thresholds virtually year-round since 2010 (Figure 22). The analysis by Butler and Tashijan (2016, pp. 7–11) predicted that discharge from 2016–2021 would almost never meet the minimum thresholds under dry conditions, and would only meet it sometimes given wet conditions. These predictions have come to pass, as the water levels in Bitter Creek are very low all the time. Since 2020, drying events have been recurring, increasing in severity each year. Figure 23 shows the dry areas mapped in 2020, 2023, and 2024 by Refuge staff. In 2024, drying was sufficiently extensive that Refuge staff performed an emergency salvage operation in August (Bean et al. 2024, p. 1). Nearly 1,000 fish were removed from drying portions of Bitter Creek and taking them to the Southwestern Native Aquatic Resources and Recovery Center (SNARRC) in Dexter, New Mexico, which is about 48 km (30 mi) from the Refuge (Bean et al. 2024, p. 1). They were held at SNARRC until early October (Bean et al. 2024, p. 1). We expect the need to perform emergency salvage operations to recur in the future. Given that the sinkholes and ditches are also fed by groundwater, the viability of these habitats is also at a higher risk now than at the time of the last status review.

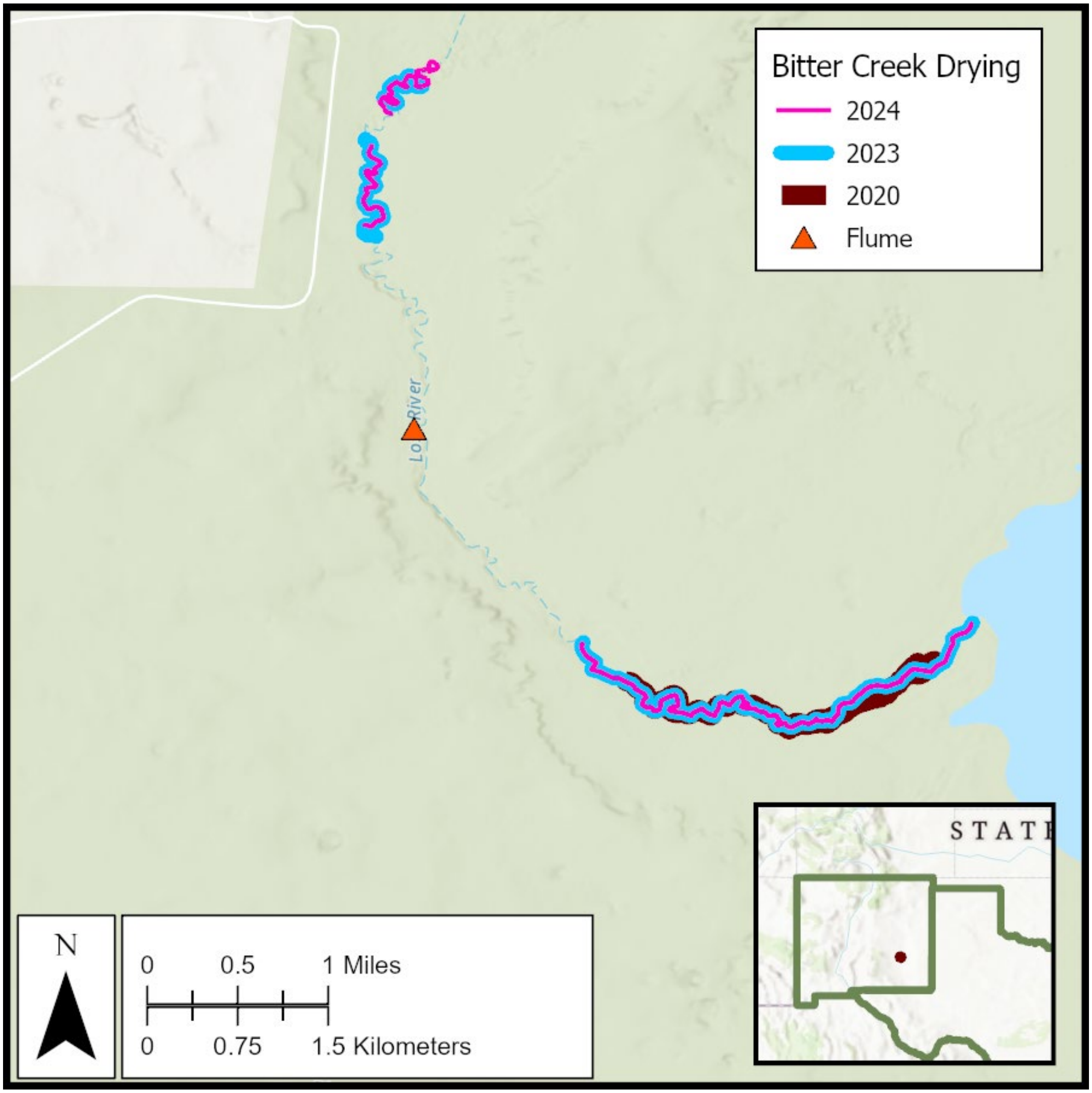

Figure 23. Drying on Bitter Creek in 2020, 2023, and 2024. Map lines were created by Refuge staff walking dry areas to document these events. Due to overlap, 2020 is given the widest width and is the bottom layer in brown, 2023 is narrower and appears in light blue, and 2024 is the thinnest and is the top layer in pink. The drying in 2020 only impacted the lower portion of Bitter Creek where it drains into Bitter Lake. In 2023 and 2024, drying expanded to a region upstream of the flume that measures discharge along the creek.

The drying of Bitter Creek above the flume used for the study discussed here was observed for the first time in 2023 and is a major concern because this was previously thought to be a stable and robust population. The flume itself has never gone dry, but its function is compromised because sometimes flow in the stream is so low that there is no flow at all across the flume (i.e., the water is still), or even flows upstream because of wind (Jacobsen 2025b, p. 1). The Refuge has been working with Service hydrologists to replace and recalibrate the flume, but it had not been implemented as of this review (Jacobsen 2025b, p. 1). Although the Refuge has senior water rights to spring flows, these rights cannot be easily exercised without first documenting whether or not they are receiving their allotted amount using a standardized measuring device like the flume (Jacobsen 2025b, p. 1). We identify the need to repair the Refuge's ability to evaluate flows on Bitter Creek in Section 4.0 below on recommendations for future actions.

Habitat Quality

An important limiting factor for Pecos gambusia in the wild with respect to water quality are concentrations of dissolved solids, hardness, and salinity or conductivity. Being a spring-adapted species, there are many habitats on the Refuge that are too high in concentrations of these parameters to support Pecos gambusia. This was learned through attempts to introduce Pecos gambusia into various locations on the Refuge in the past (e.g., Bednarz 1975, pp. 6–8).

Since then, various authors have attempted to predict suitable introduction sites for Pecos gambusia based on water quality characteristics. Bouma (1984, pp. 64–69) suggested that Sinkholes 2, 28, 37, and 42 were suitable candidates, with sinkholes 3 and 17 likely marginal. Attempts were made to stock Pecos gambusia into these (and other) sinkholes on the Refuge in 1981, but only the stocking of Sinkholes 2 and 37 appeared to be successful two years later (Bouma 1984, pp. 69–71). The lack of success at the other sites was attributed to salinity, and increasing salinities in sinkholes across the Refuge cited as an important restriction on future translocation efforts (Bouma 1984, pp. 71–77). Based on water quality (primarily salinity) data collected in 2006 and 2007 Swaim (2008, pp. 50, 60–63) suggested introducing Pecos gambusia into sinkholes 4, 40, 42N, 42S, and 59. Johnson and Tobler (2024, pp. 10–12) assessed water quality across numerous sinkholes and determined that Sinkholes 1, 10, 42N, and 42S could be options, with Sinkholes 25 and 41 characterized as marginally suitable, though they cautioned that these suggestions are preliminary.

We repeat the analysis of oil and gas facilities and spills completed above here for the Bitter Lake NWR. We used data from S&P Global's Enerdeq Browser to identify wells and pipelines within 1.0, 3.0, and 5.0 km (0.6, 1.8, and 3.1 mi) of the occupied habitat on the Refuge (S&P Global 2025c; 2025h). Figures 4–6 show these occupied habitats. We summarize the results of all wells, regardless of status, in Table 22. Table 23 shows these values for the wells, classified into active, inactive, and unknown status, within the 5.0 km (3.1 mi) buffer. No new wells have been drilled within 5.0 km (3.1 mi) of the habitat since the last five-year status review was prepared in 2018 (S&P Global 2025e). Table 24 shows the total calculated length of all natural gas and crude oil pipelines within these buffer distances.

Table 22. Wells associated with oil and gas production in the vicinity of occupied habitat on Bitter Lake NWR by type of well. The cumulative number of wells within 1 km, 3 km, and 5 km of those areas is shown. For example, a gas well within 1 km is also included in the count of gas wells within 3 km and 5 km. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2025h).

Well Classification	**1 km**	**3 km**	**5 km**
gas well	1	28	94
oil well	2	30	30
injection	0	10	10
plugged gas well	21	56	189
plugged oil well	0	80	152
dry hole	20	170	400
abandoned	0	77	429
dry w/gas shows	0	12	24
dry w/oil shows	13	130	273
dry w/oil and gas shows	0	14	28
Total	**57**	**607**	**1629**

Table 23. Wells associated with oil and gas production within 5 km of occupied habitat on Bitter Lake NWR by well status. Wells with an attribute of "<Null>" in the geospatial layer are labeled "Undefined" in this table. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2025h).

Well Classification	**Undefined**	**Active**	**Inactive**
gas well	2	92	0
oil well	0	24	6
Injection	5	0	5
plugged gas well	56	0	133
plugged oil well	40	0	112
dry hole	390	0	10
abandoned	429	0	0
dry w/gas shows	12	0	12
dry w/oil shows	221	0	52
dry w/oil and gas shows	28	0	0
Total	1183	116	330

Table 24. Total length of pipelines, in kilometers, in the vicinity of occupied habitat on Bitter Lake NWR, calculated using the GCS North American 1983 coordinate system. The cumulative length of pipelines within 1 km, 3 km, and 5 km of those two springs is shown. Data obtained from S&P Global's Enerdeq Browser (S&P Global 2025c).

Well Classification	1 km	3 km	5 km
Natural Gas	<1	7	13
Crude Oil	0	0	1

We used New Mexico Oil Conservation Division spills data to evaluate spills from oil and gas production operation in Eddy County for the period 2013–2024 (New Mexico Oil Conservation Division 2025). Spatial coordinates were available for the spills, so we queried the dataset for the spills that occurred within 5.0 km (3.1 mi) of occupied habitat on Bitter Lake NWR. Spills are reported to the Oil Conservation Division continuously and records of spill events go back to 1985 in Chaves County. In that time, one crude oil spill was recorded in 2019.

Summary

The previous five-year review reported that there was no new information about habitat or ecosystem conditions. We find that the habitat and ecosystem conditions upon which Pecos gambusia rely are changing, usually in ways that degrade those conditions and impair the likelihood of recovery for the species. Habitat availability is declining for the populations associated with the Diamond Y Preserve, the San Solomon Springs System, and Bitter Lake NWR. The status of habitat availability at Blue Springs is not well understood due to lack of access and reporting, but based on discharge data may have experience less change than the other sites. Habitat quality has declined as a result of declines in total quantities of surface water. Contamination events remain possible, but are generally uncommon, and no specific instances of contamination were reported for any of the populations. Overall, habitat and ecosystem conditions are declining.

2.2.1.7 Other:

Climate Projections

New climate projections have been developed since the previous five-year review was conducted in 2018. Downscaled climate projections for the four counties containing Pecos gambusia populations were obtained from the U.S. Climate Resilience Toolkit and are presented in Tables 25–32 in the subsections below (U.S. Federal Government 2023). We present projections for RCP 4.5 and 8.5 because these are the best available projections for future climate and temperature for the years 2050 and 2099. No projections for other RCP pathways were available from The Climate Explorer (U.S. Federal Government 2025d) Detailed information about the models and projects are available from the Climate Explorer website (National Oceanic and Atmospheric Administration 2020).

These tables also include the relevant data from the weather station closest to a given Pecos gambusia population. We used the most recent year for which both temperature and precipitation data were available for each day within the year; as a result, the comparison year varies across populations. Across both RCP 4.5 and RCP 8.5 scenarios, temperatures are projected to increase in all locations. In general, total annual precipitation is not projected to change significantly, but the number of days where no precipitation occurs is projected to increase under RCP 8.5.

Increased variability in precipitation patterns and the concentration of precipitation events into fewer days is likely to lead to more and longer drought events in the future (Nielsen-Gammon et al. 2021, p. 15). Higher temperatures and increased aridity are likely to result in increased evaporation of lentic habitats (Nielsen-Gammon et al. 2021, p. 17), potentially compromising water quality and/or water quantity within Pecos gambusia surface water habitats, especially if the inflows from springs decline simultaneously. Although groundwater is generally considered less directly pressured by climate change than surface water, groundwater pumping is related to water demand (Nielsen-Gammon et al. 2020, p. 9). Hotter and drier weather could lead to increased groundwater use due to increased water needs by users or due to a shift in water sourcing from surface water to groundwater as surface water supplies become unavailable or unreliable (Nielsen-Gammon et al. 2020, p. 9).

Diamond Y Preserve

Projections for this population come from those calculated for Pecos County, Texas (U.S. Federal Government 2025c). The weather station used for the 2024 data has an ID of USW00023091 and is named “Fort Stockton Pecos County AP” (U.S. Federal Government 2025g). Data from 2024 were selected for display because 2024 is the most recent year for which temperature and precipitation spanning the full year were available from that weather station. In 2024, the number of dry days was much higher, and the total precipitation much lower, than any of the future projections at either timestep. The average minimum temperature for 2024 was hotter than the RCP 4.5 projection for 2099. The average maximum temperature was similar to the RCP 8.5 projection for 2050.

Table 25. Future climate projections from the U.S. Climate Toolkit (U.S. Federal Government 2023). Baseline data for the projections is from 2005. Data from 2024 are actual recorded values from the closest weather station. Future projections are based on RCP 4.5 and RCP 8.5. The table enumerates the average number of days projected to have high temperatures above 105°F (40.6°C), low temperatures above 80° F (26.7°C), or no precipitation. Fractional days are shown because they are computed averages.

Year	**2005**	**2024**	**2050**		**2099**	
Data Source	Baseline	Actual	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Days with a high temperature > 105°F	3.6	8	9.9	15.5	19.8	63.4
Days with a low temperature > 80°F	0.1	0	1.7	3.4	4.6	31.7
Days without precipitation	279.3	332	281.9	279.5	278.4	289.3

Table 26. Future climate projections from the U.S. Climate Toolkit (U.S. Federal Government 2023). Baseline data for the projections is from 2005. Data from 2024 are actual recorded values from the closest weather station. Future projections are based on RCP 4.5 and RCP 8.5. The table enumerates the average daily minimum temperature, the average daily maximum temperature, and the average total annual precipitation.

Year	**2005**	**2024**	**2050**		**2099**	
Data Source	Baseline	Actual	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Average minimum temperature (°F)	50.5	57.1	53.1	54.5	54.9	59.8
Minimum temperature (°C)	10.3	14.0	11.7	12.5	12.7	15.4
Average maximum temperature (°F)	80.3	83.7	82.9	83.9	84.4	89.7
Maximum temperature (°C)	26.8	28.7	28.3	28.8	29.1	32.1
Annual precipitation (in)	12.63	5.96	12.99	13.62	13.18	12.29
Annual precipitation (mm)	320.8	151.4	329.9	345.9	334.8	312.2

San Solomon Springs System

Projections for this population come from those calculated for Reeves County, Texas (U.S. Federal Government 2025c). The weather station used for the 2020 data has an ID of USC00410498 and is named “Balmorhea” (U.S. Federal Government 2025e). Data from 2020 were selected for display because 2024 is the most recent year for which temperature and precipitation spanning the full year were available from that weather station. In 2020, the number of dry days was much higher, and the total precipitation much lower, than any of the future projections at either timestep. The average minimum and maximum temperatures for 2020 were similar to that recorded in 2005, and well below all of the future projections.

Table 27. Future climate projections from the U.S. Climate Toolkit (U.S. Federal Government 2023). Baseline data for the projections is from 2005. Data from 2020 are actual recorded values from the closest weather station. Future projections are based on RCP 4.5 and RCP 8.5. The table enumerates the average number of days projected to have high temperatures above 105°F (40.6°C), low temperatures above 80° F (26.7°C), or no precipitation. Fractional days are shown because they are computed averages.

Year	**2005**	**2020**	**2050**		**2099**	
Data Source	Baseline	Actual	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Days with a high temperature > 105°F	7	8	18.6	25.8	31.3	84.4
Days with a low temperature > 80°F	0.1	1	1.2	2.9	3.6	33
Days without precipitation	275.5	358	279.4	274.8	276.6	287.2

Table 28. Future climate projections from the U.S. Climate Toolkit (U.S. Federal Government 2023). Baseline data for the projections is from 2005. Data from 2020 are actual recorded values from the closest weather station. Future projections are based on RCP 4.5 and RCP 8.5. The table enumerates the average daily minimum temperature, the average daily maximum temperature, and the average total annual precipitation.

Year	**2005**	**2020**	**2050**		**2099**	
Data Source	Baseline	Actual	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Average minimum temperature (°F)	50.1	50.0	52.4	54.2	54.4	59.4
Average minimum temperature (°C)	10.1	10.0	11.3	12.3	12.4	15.2
Average maximum temperature (°F)	81.9	80.9	84.5	85.5	86.0	91.5
Average maximum temperature (°C)	27.7	27.2	29.2	29.7	30.0	33.1
Annual precipitation (in)	11.0	4.7	11.2	11.7	11.2	10.1
Annual precipitation (mm)	278.9	119.6	284.5	295.9	285.2	256.3

Blue Springs

Projections for this population come from those calculated for Eddy County, New Mexico (U.S. Federal Government 2025b). The weather station used for the 2019 data has an ID of USC00291480 and is named "Carlsbad Caverns" (U.S. Federal Government 2025f). Data from 2019 were selected for display because 2019 is the most recent year for which temperature and precipitation spanning the full year were available from that weather station. In 2019, the number of dry days was much higher, and the total precipitation much lower, than any of the future projections at either timestep. Minimum temperatures are rising at this station faster than maximum temperatures. The average minimum temperature in 2019 was in line with the RCP 4.5 projection for 2099, and there were two days where the low temperature was over 80° F (26.7°C). The average maximum temperature, conversely, was lower than that projected under either scenario for either timestep.

Table 29. Future climate projections from the U.S. Climate Toolkit (U.S. Federal Government 2023). Baseline data for the projections is from 2005. Data from 2019 are actual recorded values from the closest weather station. Future projections are based on RCP 4.5 and RCP 8.5. The table enumerates the average number of days projected to have high temperatures above 105°F (40.6°C), low temperatures above 80° F (26.7°C), or no precipitation. Fractional days are shown because they are computed averages.

Year	**2005**	**2019**	**2050**		**2099**	
Data Source	Baseline	Actual	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Days with a high temperature > 105°F	3.5	0	9.9	15.6	20.2	62.2
Days with a low temperature > 80°F	0.1	2	0.1	0.1	3.6	33
Days without precipitation	283.3	315	286.7	283.5	284.4	293.5

Table 30. Future climate projections from the U.S. Climate Toolkit (U.S. Federal Government 2023). Baseline data for the projections is from 2005. Data from 2019 are actual recorded values from the closest weather station. Future projections are based on RCP 4.5 and RCP 8.5. The table enumerates the average daily minimum temperature, the average daily maximum, and the average total annual precipitation.

Year	**2005**	**2019**	**2050**		**2099**	
Data Source	Baseline	Actual	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Average minimum temperature (°F)	47.5	52.0	50.1	51.6	52.0	57.1
Average minimum temperature (°C)	10.1	10.0	11.3	12.3	12.4	15.2
Average maximum temperature (°F)	77.9	74.6	80.6	81.8	82.5	87.9
Average maximum temperature (°C)	27.7	27.7	29.2	29.7	30.0	33.1
Annual precipitation (in)	13.02	8.92	12.49	12.72	12.96	11.44
Annual precipitation (mm)	278.9	119.6	284.5	295.9	285.2	256.3

Bitter Lake National Wildlife Refuge

Projections for this population come from those calculated for Chaves County, New Mexico (U.S. Federal Government 2025a). The weather station used for the 2015 data has an ID of USC00290992 and is named "Bitter Lakes WL Refuge" (U.S. Federal Government 2025h). Data from 2015 were selected for display because 2015 is the most recent year for which temperature and precipitation spanning the full year were available from that weather station. In 2015, the number of dry days was higher than all scenarios except RCP 8.5 in 2099. However, the total precipitation was significantly higher than under all future scenarios and timesteps. In 2015 there were fewer extreme high and low temperatures than the projections, with the average minimum and maximum temperature below all future scenarios and timesteps, as well as below 2005 levels.

Table 31. Future climate projections from the U.S. Climate Toolkit (U.S. Federal Government 2023). Baseline data for the projections is from 2005. Data from 2015 are actual recorded values from the closest weather station. Future projections are based on RCP 4.5 and RCP 8.5. The table enumerates the average number of days projected to have high temperatures above 105°F (40.6°C), low temperatures above 80° F (26.7°C), or no precipitation. Fractional days are shown because they are computed averages.

Year	2005	2015	2050		2099	
Data Source	Baseline	Actual	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Days with a high temperature > 105°F	1.9	1	6.1	10.2	14.1	51
Days with a low temperature > 80°F	0	0	0	0.1	0.3	6.8
Days without precipitation	278.2	285	281	277.5	280.6	288.3

Table 32. Future climate projections from the U.S. Climate Toolkit (U.S. Federal Government 2023). Baseline data for the projections is from 2005. Data from 2015 are actual recorded values from the closest weather station. Future projections are based on RCP 4.5 and RCP 8.5. The table enumerates the average daily minimum temperature in degrees Fahrenheit (see Table 27 for Celsius conversions), the average daily maximum temperature in degrees Fahrenheit, and the average total annual precipitation in inches (see Table 27 for metric conversions).

Year	2005	2015	2050		2099	
Data Source	Baseline	Actual	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Average minimum temperature (°F)	43.4	42.5	46.1	47.5	47.9	52.7
Average minimum temperature (°C)	6.3	5.9	7.8	8.6	8.8	11.5
Average maximum temperature (°F)	76.3	75.7	78.9	80.1	80.8	86.1
Average maximum temperature (°C)	24.6	24.3	26.1	26.7	27.1	30.1
Annual precipitation (in)	13.0	19.5	12.7	13.2	12.6	12.3
Annual precipitation (mm)	330.7	494.5	322.1	336.3	319.5	312.4

Hydrogeology

Diamond Y Preserve

TNC contracted with professional geologists to study the faulting of the geology in the immediate vicinity (8 km (5 mi) radius) of the Diamond Y Spring Preserve and construct a 3D geological model of the area (Standen and Sutherland 2021, p. 1). The authors used 137 well control points to build the model and map the faults (Standen and Sutherland 2021, pp. 6–9). A total of nine faults were mapped, generally oriented either west-east or northwest-southeast (Standen and Sutherland 2021, p. 9). A large fault crossing the Leon Creek drainage provides support for previous work from Veni (1991, entire) and Boghici (1997, entire) in the 1990s that described an upper and lower watercourse with distinct water sources (Standen and Sutherland 2021, p. 10). Other springs and seeps within the Diamond Y Preserve are also located along or very near faults, and this faulting structure appears to provide a path for pressurized Rustler Aquifer water to reach the surface (Standen and Sutherland 2021, p. 10). The 3D model revealed patterns suggesting that a shallow groundwater flow system associated with Cretaceous outcrops may exist, which could explain changes in flow and water chemistry after precipitation events (Standen and Sutherland 2021, p. 15).

San Solomon Springs System

A report by the University of Texas at Austin's Bureau of Economic Geology (Nicot et al. 2021, entire) reviewed, synthesized, and updated information on the hydrogeology of all springs in the Balmorhea area. An abbreviated and condensed writeup of these efforts was also published as a peer-reviewed journal article (Nicot et al. 2022, entire). Using a variety of measurement techniques and data sources, the report concludes that the waters that eventually emerge as springs in the Balmorhea area, including San Solomon Springs, originate from the Salt Basin portion of the West Texas Bolsons (Nicot et al. 2021, p. i). The underground flow path follows a fault zone and receives contributions from the Capitan, Rustler, and Edwards Aquifers (Nicot et al. 2021, p. i). The actual Balmorhea-area springs emerge from fractures in the Cretaceous limestones of the Edwards Aquifer (Nicot et al. 2021, p. i). The report includes a map illustrating this important flowpath, reproduced here (Figure 24) as the specific details on cross-formational flow and impacts of groundwater pumping remain unresolved, and the authors recommend additional modeling focusing on the Balmorhea-area complex of springs (Nicot et al. 2021, pp. 70–71).

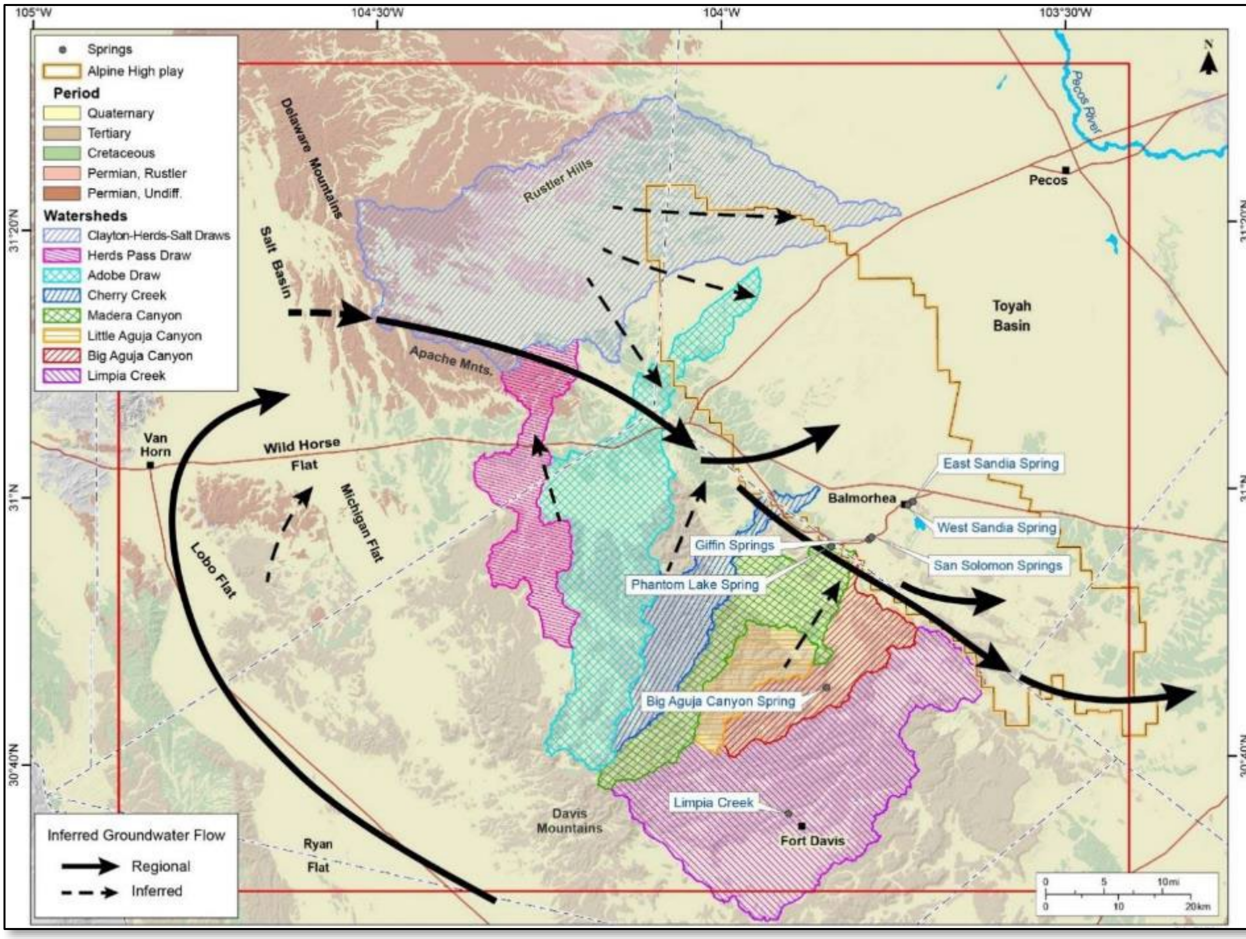

Figure 24. Map of watersheds, geology, and historical, generally agreed-upon groundwater flow systems. Image reproduced, with permission from the author, from Nicot et al. (Nicot et al. 2021, p. 92). Copyright J.P. Nicot.

Blue Springs

There have not been any new hydrogeological studies of the Blue Springs region since the last five-year review was published in 2018.

Bitter Lake National Wildlife Refuge

USGS studies on the Roswell Artesian Basin offer some insights into the water supplying Pecos gambusia habitat on the Refuge. Before European settlement of the region, groundwater flowed east and south from a broad area east of the Sacramento mountains, then moved through an alluvial aquifer associated with the Pecos River, up into springs and sinkholes and ultimately the Pecos River (Land and Newton 2007, pp. 7–8). The general direction of flow, based on the hydraulic head of the artesian aquifer, remains east and southeast (Land and Newton 2007, p. 12). With European settlement came increasingly intense groundwater development for irrigation, leading to a drawdown in the artesian aquifer, changes to the hydraulic head, and a cone of depression in the basin (Robson and Banta 1995, p. C24). Water rights adjudications and oversight by the State of New Mexico occurred mid-century, with restrictions on water use and reduction in irrigated farmland extent (Land and Newton 2007, p. 11). As a result, the declining water levels in the artesian aquifer was reversed and begin to rise (Land and Newton 2007, p. 26). However, seasonal declines in the artesian aquifer remain very high, and the cones of depression caused by pumping are spatially quite broad (Land and Newton 2007, p. 19). In addition, there is a positive relationship between groundwater pumping and drought, as periods of little rainfall result in higher demand for groundwater (Land and Newton 2007, p. 8). Finally, due to the changes in hydraulic pressure that occur during aquifer drawdowns, the water emerging on the Refuge is more saline (and thus less optimal for Pecos gambusia, which is best adapted to low-salinity environments) at the same time that flows are lower (Land and Newton 2007, p. 8).

Understanding the residence time of groundwater in the artesian aquifer that supplies the springs and sinkholes on the Refuge is relevant to Refuge management because the longer the residence time, the lower the likelihood that the water contains contaminants that would be harmful to Refuge resources (Land and Huff 2010, pp. 455–456). An analysis of water samples collected from several locations on the Refuge and City of Roswell irrigation wells determined that the artesian aquifer's groundwater is almost entirely comprised of old, pre-modern groundwater—possibly as much as 95% (Land and Huff 2010, pp. 468–470). The remaining component consists of runoff from winter snows and summer rains that enters the aquifer between the Sacramento Mountains and the Pecos River (Land and Huff 2010, pp. 468–470).

Groundwater Conservation Districts and Regional Water Planning

The five-year review published in 2018 provided an overview of Texas Groundwater Conservation Districts (GCDs) and regional water planning efforts applicable to Pecos gambusia populations in the state. In this review we provide an update on the relevant GCD plans and expand the regional water plan discussion to the New Mexico populations.

Diamond Y Preserve

There is one GCD whose surface boundaries overlap the Diamond Y Preserve: the Middle Pecos Groundwater Conservation District. According to the Middle Pecos GCD's 2020 management plan, the Diamond Y Preserve area is not a focal management zone (Middle Pecos Groundwater Water Conservation District 2020, p. 5). The plan does not mention the Pecos gambusia or any of the other federally threatened or endangered species that are present at the Diamond Y Preserve (Middle Pecos Groundwater Water Conservation District 2020, entire). Although the Middle Pecos GCD is supportive of efforts to better understand the geohydrology of the area, ensuring the persistence of springs in the Diamond Y Spring Complex is not a defined goal or strategy on the part of the GCD.

Texas Administrative Code (Title 31, Part 10, Chapter 36) defines desired future conditions as "the desired, quantified condition of groundwater resources (such as water levels, spring flows, or volumes) within a management area at one or more specified future times as defined by participating groundwater conservation districts within a groundwater management area as part of the joint planning process." Under Texas Water Code Chapter 36, groundwater conservation districts can consider a set of nine factors when developing desired future conditions, including aquifer uses, water supply needs, hydrological conditions (e.g., average annual recharge), environmental impacts (e.g., spring flow), and impacts on private property rights. As a result, developed conditions can be a complicated amalgam of economic, scientific, and political considerations.

A joint planning process occurred in 2021 under the umbrella of Groundwater Management Areas, which cover the spatial extent of multiple GCDs. Changes in groundwater flows in Groundwater Management Area 7 may impact Pecos gambusia pupfish habitat. Through the joint planning process, the GCDs agreed to desired future conditions resulting in drawdowns for aquifers that contribute to springs within the Pecos gambusia pupfish range (Groundwater Management Area 7 2021, pp. 1–5; see Table 33).

Table 33. Middle Pecos Groundwater Conservation District desired future conditions for managed aquifers as a result of the 2021 joint planning process. The drawdown shown in the table is the total maximum net drawdown for 2070 as compared to 2010 aquifer levels (Groundwater Management Area 7 2021, pp. 1–5)

Aquifer	Drawdown in meters	Drawdown in feet
Capitan Reef Complex	17	56
Dockum	16	52
Edwards-Trinity (Plateau), Pecos Valley, and Trinity	4	14
Rustler	29	94

Planning for future water needs in Texas is guided by projections developed by 16 regional water planning groups (Freese and Nichols, Inc. 2020a, p. 1-1). The Texas Water Development Board generated water demand projections for the water planning groups covering the period 2020 to 2070, which were used to develop the 2020 Regional Water Plans (Freese and Nichols, Inc. 2020a, p. 2-1) The primary water planning region in the regional flow path that contributes groundwater to the San Solomon Spring System is Region F (Freese and Nichols, Inc. 2020a, p. 1-2; Nunu et al. 2024, p. 51).

Groundwater is the dominant water source for west Texas (Freese and Nichols, Inc. 2020a, p. 3-1). The primary groundwater use is irrigation; 91% of groundwater supplies in Pecos County are used for irrigation (Freese and Nichols, Inc. 2020b, pp. 355–356). Pecos County is anticipated to account for 30% of the total demand for irrigation in the entire water planning region by 1970 (Freese and Nichols, Inc. 2020a, p. 2-15). Water demand in Pecos County is projected to increase substantially compared to 2010 levels (Freese and Nichols, Inc. 2020a, p. 2-8). This is due to increases in demand for water across multiple categories, including municipal use, irrigation, and "mining" (i.e. hydraulic fracturing) (Freese and Nichols, Inc. 2020a, p. 2-7; 2020b, p. 335). Given the paucity of surface water supplies available in the area, groundwater development to address these shortages is likely to occur (Freese and Nichols, Inc. 2020b, p. 5E-59).

Drought is recognized as a persistent challenge to meeting future water needs, but the specifics of drought planning are left to step-down plans (Freese and Nichols, Inc. 2020a, pp. 7-1–7-20). The Region F Water Plan does not discuss or analyze the effects of climate change on groundwater supplies or demand (Freese and Nichols, Inc. 2020a, entire). Increased use of groundwater into the future would have the potential of reducing groundwater flow to the springs on the Diamond Y Preserve.

San Solomon Springs System

Five GCDs are associated with the aquifers or flowpaths that influence the San Solomon Springs System: the Culberson County Groundwater Conservation District, the Jeff Davis County Underground Water Conservation District (UWCD), the Middle Pecos GCD, the Presidio County UWCD, and the Reeves County GCD. The Presidio County UWCD borders the regional flowpath leading to the San Solomon Springs complex but does not have a substantial influence (Nicot et al. 2021, p. 92), so we do not examine it further in this review.

The most recent management plan for the Culberson County GCD assert that after a review of listed species in the county, the District determined that no endangered species will be affected by the plans or their execution (Culberson County Groundwater Conservation District 2021, p. 12). The 2024 plan for the Jeff Davis UWCD, the 2020 plan for the Middle Pecos GCD, and the 2023 plan for the Reeves County GCD do not contain any discussion of fish or wildlife that may be dependent on the aquifer (Middle Pecos Groundwater Water Conservation District 2020, entire; Reeves County Groundwater Conservation District 2023, entire; Jeff Davis County Underground Water Conservation District 2024, entire). While these Districts do manage groundwater, they are not explicitly doing so in order to promote the recovery of Pecos gambusia or ensure the persistence of springs in the San Solomon Spring System. However, groundwater managed by these Districts does influence the spring flow at Pecos gambusia habitat (Nicot et al. 2021, pp. i, 92).

The joint planning process for Groundwater Management Areas in 2021 affecting this population of Pecos gambusia is relevant to two Groundwater Management Areas (3 and 4). Through the joint planning process, the Districts agreed to desired future conditions resulting in drawdowns for aquifers that contribute to springs within the Pecos gambusia range (Groundwater Management Area 3 2021, pp. 1–2; Groundwater Management Area 4 2021, p. 1; see Table 34).

Table 34. Groundwater Conservation District desired future conditions for managed aquifers as a result of the 2021 joint planning process. The drawdown shown in the table is the total maximum net drawdown for 2070 as compared to 2010 aquifer levels (Groundwater Management Area 3 2021, pp. 1–2; Groundwater Management Area 4 2021, p. 1).

District Name	Aquifer	Drawdown (meters)	Drawdown (feet)
Culberson County GCD	Capitan Reef Complex	15	50
	Salt Basin portion of the West Texas Bolsons	24	78
	Igneous	20	66
Jeff Davis County UWCD	Igneous	6	20
	Salt Basin portion of the West Texas Bolsons	22	72
Reeves County GCD	Dockum	6	20
	Edwards-Trinity (Plateau) and Pecos Valley	2	8
	Rustler	12	40

Two water planning regions span the regional flow path that contributes groundwater to the San Solomon Spring System (Nicot et al. 2021, p. 92): Region E (Far West Texas) and Region F (Freese and Nichols, Inc. 2020a, p. 1-2; Far West Texas Water Planning Group 2021, p. 1-1).

In the area containing the aquifers and flowpaths leading to the San Solomon Springs System, the primary groundwater use is irrigation: 87% of groundwater supplies in Culberson County, 49% in Jeff Davis County, and 90% in Reeves County are used for irrigation (Freese and Nichols, Inc. 2020b, p. 356; Far West Texas Water Planning Group 2021, pp. 3-4–3-6). Total demand for groundwater for irrigation, as well as all other uses, is projected to remain relatively stable in Culberson and Jeff Davis Counties through the planning horizon of 2070 (Far West Texas Water Planning Group 2021, pp. 2-7–2-8). However, water demand in Reeves County is projected to increase through 2040 and the decrease through 2070, compared to 2010 levels (Freese and Nichols, Inc. 2020a, p. 2-8; 2020b, p. 335). This is due to future increases in municipal demand and increases followed by decreases in mining (i.e. hydraulic fracturing) demand (Freese and Nichols, Inc. 2020b, p. 335). Water demand for oil and gas production in the shale oil plays in Reeves County is projected to increase through 2040 and then decline (Freese and Nichols, Inc. 2020a, p. 2-19). Also in

Reeves County, the planning process identified a deficit between existing water supplies and projected demand for the town of Balmorhea and the mining industry throughout the planning horizon (Freese and Nichols, Inc. 2020b, p. 5E-54). Given the paucity of surface water supplies available in the area, groundwater development to address these shortages is likely to occur (Freese and Nichols, Inc. 2020b, p. 5E-59).

As noted above, these plans recognize drought as a persistent challenge to meeting future water needs but leave the specifics of drought planning to step-down plans (Freese and Nichols, Inc. 2020a, pp. 7-1–7-20; Far West Texas Water Planning Group 2021, pp. 7-1–7-38). However, Region E and F Water Planning Groups do not discuss or analyze the effects of climate change on groundwater supplies or demand. To address future water demand, Culberson County may develop groundwater from the West Texas Bolsons Aquifer, (Far West Texas Water Planning Group 2021, p. 5A-6), Jeff Davis County may develop groundwater from the Igneous Aquifer (Far West Texas Water Planning Group 2021, p. 5A-43), and Reeves County may develop groundwater from the Pecos Valley Aquifer (Freese and Nichols, Inc. 2020b, p. 411). Increased use of groundwater into the future would have the potential of reducing groundwater flow to the Solomon Spring System.

Blue Springs

New Mexico also completes regional water plans across 16 regional groups (New Mexico Office of the State Engineer (NMOSE) 2025). Water demand projections were generated using a consistent method across the regions that took into account existing water withdrawals, physical supply, legal restrictions, supply availability during historical droughts, and demographic and economic trends (NMOSE 2016, p. ES-3).

Groundwater is the dominant water source for the region, accounting for 70% of water use (NMOSE 2016, p. 93). The primary groundwater use is irrigation; 79% of groundwater supplies in Eddy County are used for irrigation (NMOSE 2016, p. 174). The New Mexico water plans feature both a high and low water demand projections on a decadal scale going out to 2060 (NMOSE 2016, p. 167). In Eddy County, an overall increase in water demand is projected under the high demand scenario, but a decrease is projected under the low demand scenario (NMOSE 2016, p. 174). In both scenarios, increases occur across municipal categories, but the low demand scenario forecasts declines in water demand by irrigated agriculture and mining, which accounts for the difference between the two scenarios (NMOSE 2016, p. 174). Both drought and climate change impacts are explicitly incorporated into the water plan and its analysis, including a specific assessment of the water supplies likely available during a severe drought (NMOSE 2016, pp. 51–53, 65–69, 135–136). For Eddy County, the projected drought supply is about 66% of the actual 2015 usage (NMOSE 2016, pp. 136–139).

Bitter Lake National Wildlife Refuge

Much of what was written above for Blue Springs applies to the Bitter Lake NWR as well, as both are in the Lower Pecos Valley Water Planning Region. As in Eddy County, the primary groundwater use is irrigation; 89% of groundwater supplies in Chaves County are used for irrigation (NMOSE 2016, p. 173). In Chaves County, an overall increase in water demand is projected under the high demand scenario, but a decrease is projected under the low demand scenario (NMOSE 2016, p. 173). In both scenarios, increases occur across municipal categories, but the low demand scenario forecasts declines in water demand by irrigated agriculture, which accounts for the difference between the two scenarios (NMOSE 2016, p. 173). For Chaves County, which uses less surface water for irrigated agriculture than Eddy County, the projected drought supply is about 95% of the actual 2010 usage (NMOSE 2016, pp. 136–139). We also note that the Pecos Valley Artesian Conservancy District and the New Mexico Interstate Stream Commission have ongoing programs of purchasing and retiring irrigated agricultural lands in the basin (Land and Huff 2010, p. 11)

2.2.1.8 Conservation Measures:

Balmorhea State Park

The most important and largest remaining extant habitat for Pecos gambusia occurs within Balmorhea State Park, consisting of the pool, outflow canal, San Solomon Ciénega, and Clark Hubbs Ciénega. Management of all of these habitats, given the presence of listed species, is regulated by a Habitat Conservation Plan (HCP) for Balmorhea State Park and its associated Incidental Take Permit (ITP) (Texas Parks and Wildlife Department 2009, entire; U.S. Fish and Wildlife Service 2009, entire; Texas Parks and Wildlife Department 2020, entire; U.S. Fish and Wildlife Service 2020b, entire).

At the time of the previous five-year review, an HCP and ITP were in place and presumed to be functioning well, in the absence of any information that suggests otherwise. The ITP issued in 2009 was valid for a period of 10 years (U.S. Fish and Wildlife Service 2009, entire). TPWD requested a renewal of the permit after the regulatory deadline for renewals had passed; as a result, the initial permit expired in 2019 (U.S. Fish and Wildlife Service 2020a, p. 1). TPWD updated the HCP and a new ITP was issued in 2020 and will be valid for 10 years (U.S. Fish and Wildlife Service 2020b, p. 1). TPWD is in compliance with the current ITP conditions, including submission of annual reports. A range of activities are completed at the Park, including repairs and maintenance to the pool and to the recreational facilities, with no adverse effects to Pecos gambusia observed (Texas Parks and Wildlife Department 2021b, entire; 2022, entire; 2023, entire; 2024a, entire; 2025, entire).

Phantom Lake Spring Refugium

A habitat restoration effort was planned by the Service's Texas Fish and Wildlife Conservation Office for 2021 with the intent of improving aquatic habitat relied on by the Pecos gambusia and other listed species (U.S. Fish and Wildlife Service 2021, entire). A goal of the restoration was to reduce the site's reliance on a pump system to maintain adequate water levels within the refugium (U.S. Fish and Wildlife Service 2021, p. 3). The habitat restoration project would have deepened the entrance to the cave at Phantom Lake Spring to better connect spring outflow with adjacent aquatic habitat and created a more natural and secure state (U.S. Fish and Wildlife Service 2021, p. 3). However, the restoration did not prove feasible because excavation work encountered bedrock, which meant that the ciénega and cave pool could not be connected as intended (U.S. Fish and Wildlife Service 2022, p. 2). The site was restored to pre-construction conditions, which meant that the surface aquatic habitat of the refugium continued to be dependent on mechanically pumped water (U.S. Fish and Wildlife Service 2022, p. 2). As discussed above, the pumps were reported off in May 2022 and are apparently no longer maintained by the private landowner (Montagne 2022a, p. 1; 2023, pp. 1–2). A visit in February 2023 confirmed that surface aquatic habitat has been dewatered (Montagne 2023, pp. 1–2; Figure 18). As a result, habitat for Pecos gambusia at Phantom Lake Spring has been eliminated.

The Nature Conservancy

TNC has owned and managed the Diamond Y Preserve since 1990 (Garrett et al. 2002, p. 442). During this time, they have developed relationships with the Middle Pecos GCD and local oil and gas developers, and, as a result, various conservation efforts have occurred over the years (Karges 2003, p. 144). The organization has also taken a leading role in coordinating on-site research into water quality, spring flow, and monitoring of not only Leon Springs pupfish, but also the other endangered and threatened species present within the Preserve (Smith 2024b, p. 2). Since the last five-year review, The Nature Conservancy has worked with the Middle Pecos GCD to fund updates to the Pecos County groundwater availability model and the purchase of equipment enabling the expansion of the well monitoring network in the county (Smith 2024b, p. 2). They have also secured external funding to conduct invasive feral hog control, remove salt cedar (*Tamarix* spp.), install long-term hydrology monitoring equipment at four sites on the Preserve, update the existing vegetation map for the Preserve, and implement a long-term monitoring protocol for the fishes present on the Preserve (The Nature Conservancy 2023, pp. 1–4). East and West Sandia Springs are still owned and managed by The Nature Conservancy, which provides protection to spring outflow channels and the surrounding surface habitat. That said, ownership does not provide groundwater protections needed to ensure adequate and ongoing spring flow quantity and quality.

Middle Pecos Groundwater Conservation District

The Middle Pecos GCD has funded research to better understand the hydrogeology of the Diamond Y Spring System and the aquifers that supply it; recent finished studies are described in this report, but the effort is generally ongoing (Middle Pecos Groundwater Conservation District 2022, p. 3). In addition, the Middle Pecos GCD is developing a Rustler Aquifer well monitoring network that complements the existing well monitoring network, which may yield aquifer management recommendations in the future (Middle Pecos Groundwater Conservation District 2022, p. 5). The Middle Pecos GCD also requires registration of all wells in the area under its jurisdiction, notice of intent for any new wells filed in advance of drilling, and annual production reports for most wells (Middle Pecos Groundwater Water Conservation District 2020, pp. 21, 31–32).

National Fish and Wildlife Foundation

In 2017, the National Fish and Wildlife Foundation (NFWF) created the Pecos Watershed Conservation Initiative, which funds conservation projects to benefit fish, wildlife, and habitat in the Pecos River watershed (National Fish and Wildlife Foundation 2020, p. 1). Pecos gambusia is a focal species for the initiative. Funding and grant selection occurs through the contributions of oil and gas industry partners and other corporate and nonprofit sponsors, the U.S. Department of Agriculture, the U.S. Department of the Interior, TPWD, and NMDGF (National Fish and Wildlife Foundation 2018, p. 1; 2019, p. 1; 2020, p. 1; 2021, p. 1; 2022, p. 1; 2024, p. 1). Projects to directly benefit Pecos gambusia were funded in the grant slates from 2020–2024 (National Fish and Wildlife Foundation 2020, p. 2; 2021, p. 2; 2022, p. 2; 2024, p. 3). These included monitoring and habitat restoration at the Diamond Y Preserve and restoration of the Phantom Lake Spring refugium (National Fish and Wildlife Foundation 2020, p. 2), removal of invasive plants in and around Blue Springs (National Fish and Wildlife Foundation 2021, p. 2; 2022, p. 2), and removal of invasive plants around Pecos gambusia habitats on Bitter Lake NWR (National Fish and Wildlife Foundation 2024, p. 3).

2.2.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms):

2.2.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Habitat loss, due to declining spring flow and reduced surface water habitat, was identified as a major threat to Pecos gambusia in the 1983 Recovery Plan (U.S. Fish and Wildlife Service 1983, p. 11). The five-year status review completed in 2018 also discusses how groundwater pumping that, exceeds aquifer recharge, can lead to diminished spring flows and loss of Leon Springs pupfish habitat (U.S. Fish and Wildlife Service 2018, pp. 25–31). Reductions in spring flow and aquatic habitat have only accelerated since then, with greater declines and/or cessations in flow in the 2020s to present. The confirmed loss of the Phantom Lake Spring, contractions in the range at Diamond Y Spring, and intermittency in formerly perennial waters across the range are all associated with declining spring flows that have resulted in the drying of the surface water habitat necessary for Pecos gambusia to persist.

Pecos gambusia remain extant within the four populations identified in the Recovery Plan (U.S. Fish and Wildlife Service 1983, pp. 4–10). However, habitat destruction, modification, and curtailment has been documented at the Diamond Y Preserve, the San Solomon Spring System, and Bitter Lake National Wildlife Refuge (Section 2.2.1.6; new information on Blue Springs was unavailable for analysis). The flow of the springs supporting habitat is declining at the three sites for which we have information. We have no indication that this decline will slow or stop, much less reverse and produce an increase in spring flow (Section 2.2.1.6).

Increasing temperatures and aridity will continue due to climate change and will likely lead to increased demand for groundwater in the region that influences spring flow in the Pecos gambusia range (Section 2.2.1.7). If declines in spring flows are not abated before the aquifer is so drawn down that the springs sustaining the four populations cease to flow, the surface habitat the remaining populations depend on will cease to exist. Of the four main population centers, the Diamond Y Preserve is the most vulnerable to extirpation, given the magnitude of habitat loss and curtailment in that area. However, localities within each population area are vulnerable to extirpation due to habitat loss.

Separately from the stressor of habitat loss, potential contamination of the species' aquatic habitat is also important. Given the location of the species' range within the Permian Basin, a major oil and gas-producing region, the risk of contamination is ever-present. Both surface and subsurface leaks or spills are plausible future events that could occur due to a broken pipeline, leaking well, illegal dumping, or a failure to confine injected wastewater. Subsurface contamination events are of greater concern because the contamination of the aquifers or conduits that supply the springs upon which the species relies would be far more challenging to detect and mitigate. A separate threat is damage to surface water habitat by feral hog trampling, rooting, and wallowing. At the Diamond Y Preserve specifically, feral hog activity has caused major damage to Pecos gambusia habitat in both the upper and lower watercourses and could become a primary driver of local extirpations if not addressed (Section 2.2.1.6).

Consequently, the risk of extinction for this species has increased since the last five-year status review. The risk is less from a potential catastrophic event that damages habitat, and more from the relatively slow but monotonic decline in spring flow. The destruction, modification, and curtailment of habitat resulting in the loss of wild populations is the most significant threat to the species.

2.2.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

There is no evidence at this time that Pecos gambusia are threatened by overutilization. The only collections of the fish occur rarely for scientific purposes and are regulated by the Service pursuant to section 10(a)(1)(A) of the Act, by TPWD (Texas Administrative Code Title 31, Part 2, Chapter 69, subchapter J), and by NMDGF (New Mexico Administrative Code Title 19, Chapter 21, Part 2).

2.2.2.3 Disease or predation:

The previous five-year status review, completed in 2018, cited the introduced Red-rimmed melania (*Melanoides tuberculatus*) snail and its associated gill parasite (Ce*ntrocestus formosanus*) as potential threats to the species (U.S. Fish and Wildlife Service 2018, pp. 33–34), but no new information has been published on these species or their impacts to Pecos gambusia. Pecos gambusia continue to occur in the San Solomon Spring System and Diamond Y Preserve where these introduced species were previously found, but the relative impact on Pecos gambusia populations is unknown. Limited information about predation is available, as Pecos gambusia are typically found in systems without significant predation pressure. Overall, disease and predation are not currently significant threats to the species.

2.2.2.4 Inadequacy of existing regulatory mechanisms:

The inadequacy of existing regulatory mechanisms to ensure continued spring flows for the springs that are the source of Pecos gambusia surface water habitat represents an ongoing threat to the species in the wild. Groundwater management in Texas is regulated via Groundwater Conservation Districts (sometimes called Underground Water Conservation Districts), but the Districts that regulate the groundwater in the aquifers that are the source for the springs that Pecos gambusia depend on do not appear to have thus far prioritized maintenance of spring flows as a goal or desired future condition for those groundwater resources (Section 2.2.1.7). They do not currently serve as a regulatory mechanism that protects Pecos gambusia or their habitat.

The Railroad Commission of Texas and the Oil Conservation Division of the New Mexico Energy, Minerals, and Natural Resources Department regulate many activities of the oil and natural gas industry (Texas Administrative Code, Title 16, Part 1 and New Mexico Administrative Code Title 19, Chapter 15, Part 2). While these regulations may potentially reduce the risk of contaminant releases, they cannot remove the threat of a catastrophic event that could lead to the extinction of Pecos gambusia in the wild. Given the inherent risks associated with oil and natural gas activities in proximity to Pecos gambusia habitat, regulations cannot currently remove or completely alleviate threats associated with water contamination from a petroleum, produced water, and/or wastewater leak, spill, or release.

The refugium at Phantom Lake Spring was dewatered after the land parcel that includes the spring and refugium was transferred from the Bureau of Reclamation to a private landowner (Section 2.2.1.6). An informal consultation determined that the transfer was not likely to adversely affect listed species or critical habitat, despite the fact that there was no plan, agreement, or funding in place to ensure the continued maintenance of the refugium after the transfer was complete (U.S. Fish and Wildlife Service 2022, p. 1). Therefore, the protections of the Endangered Species Act were not adequate to ensure the habitat supporting the Phantom Lake Spring population persisted. There is no regulatory mechanism that exists that could compel the restoration of this habitat and the reintroduction of any of the listed species that previously existed there, further illustrating the inadequacy of existing regulatory mechanisms.

In summary, the inadequacy of existing regulatory mechanisms resulted in additional impacts to the species (through habitat loss) since the previous five-year review was completed, but there have not been any substantive changes in the regulatory environment itself that could shift the current outlook for the species in terms of its risk of extinction.

2.2.2.5 Other natural or manmade factors affecting its continued existence:

Competition and hybridization with the introduced gambusia species, western mosquitofish and largespring gambusia, was identified as a threat to Pecos gambusia in the previous five-year review and in the species' recovery plan (U.S. Fish and Wildlife Service 1981, pp. 4–6; 2013a, pp. 24–25).

Western mosquitofish are found in sympatry with Pecos gambusia at the Diamond Y Preserve, Blue Springs, and Bitter Lake NWR. Largespring gambusia are found in sympatry with Pecos gambusia in the San Solomon Springs System, with the exception of Toyah Creek, where western mosquitofish are found, and Sandia Springs, which contains Pecos gambusia, western mosquitofish, and largespring gambusia (Echelle and Echelle 1980, pp. 19–20). Although hybridization occurs, and genomic introgression by congeners has been observed, Pecos gambusia, western mosquitofish, and largespring gambusia remain distinct species at each population center, and the hybrids that are observed are typically few in number and represent a small proportion of the total gambusia present at a given location (Section 2.2.1.3). While hybridization remains a concern, it is not a near-term driver of extirpation or extinction for the species.

Given this, we believe that competition with these congeners is a more important threat to the persistence of Pecos gambusia in the wild. The diet study at Balmorhea State Park indicated that there is significant niche overlap between Pecos gambusia and largespring gambusia, and we suggest that the same is likely true for Pecos gambusia and western mosquitofish (Section 2.2.1.1). Similarly, the flow study that indicated under low flow conditions, largespring gambusia has a competitive advantage over Pecos gambusia is also translatable to areas where Pecos gambusia and western mosquitofish co-occur, since western mosquitofish dominates, sometimes to the point of exclusion, Pecos gambusia in areas with little spring influence, such as the waterfowl management units on Bitter Lake NWR (Section 2.2.1.1; Section 2.2.1.5; Echelle and Echelle 1980, pp. 4–11) (Section 2.2.1.1, Section 2.2.1.5). Because largespring gambusia is also spring-adapted, its threat to Pecos gambusia is more significant than that of western mosquitofish, which is adapted to eurythermal environments. *Gambusia* species abundance and densities fluctuate over time, and there is not currently a clear trend indicating extirpation of Pecos gambusia in the near term as a result of competition with largespring gambusia.

Overall, the scope and severity of the threat to Pecos gambusia from competition and hybridization is essentially the same as when the previous five-year review was completed in 2018.

2.3 Synthesis

The best available scientific information indicates that the primary threats to Pecos gambusia are: 1) habitat loss and degradation associated with declining spring flows, 2) hybridization or competition with western mosquitofish and/or largespring gambusia, 3) potential contamination of aquatic habitat as a result of local oil and gas development, and 4) for the Diamond Y Preserve, the destruction and degradation of habitat as a result of feral hog activity. The threat of habitat loss and degradation is the most immediate and pressing of the threats.

The resiliency (i.e., ability to withstand environmental and demographic stochasticity) of the four Pecos gambusia populations can be considered in terms of demographics and habitat. With respect to demographics, the species appears to continue to maintain adequate numbers and densities across the localities within each population to maintain itself. Phantom Lake Spring refugium, part of the San Solomon Spring System, had poor demographic markers and a dire effective population size estimate; that population is now extirpated. In terms of habitat, the resiliency of the species across its range has declined since the last five-year review as a result of declining spring flows, which have turned perennial habitats into intermittent or ephemeral habitats and led to decreased water quality as a result of decreased water quantity. The habitat degradation caused by feral hogs at both the upper and lower watercourses of the Diamond Y Preserve is a significant, newer threat. We note that we lack information about the demography or habitat conditions at Blue Spring needed to provide a full assessment of that population here.

In terms of redundancy (i.e., ability to withstand catastrophic events), Pecos gambusia continues to persist in all four of its population areas. While little information about Blue Spring is available, there is no information that suggests that Pecos gambusia has been extirpated from the area. Declines in redundancy within the Diamond Y Preserve and within the San Solomon Springs System have occurred. At the Diamond Y Preserve, portions of both the upper and lower watercourse are now usually dry and often disconnected from wetted habitat. The loss of the Phantom Lake Spring refugium also decreased redundancy within that population.

With respect to representation (i.e., the ability to adapt to near-term and long-term changes in the physical and biological environment), the species' status is mostly unchanged from 2018. It is possible that some unique genetic attributes or adaptive capacity was present in the Phantom Lake Spring refugium that has now been lost. However, the species itself is highly adaptive as shown by its ability to occupy different types of habitats (e.g., spring pools, streams, marshy wetlands) and persist in the presence of competitors. The biggest threat to representation going forward is the poor state of the habitat at the Diamond Y Preserve; an extirpation of Pecos gambusia from either the lower or upper watercourse would be a significant harm to representation—but has not yet occurred.

The status of the species with respect to resiliency, redundancy, and representation has declined since the previous five-year status review was completed in 2018. We note that the previous review also stated that all threats to the species had remained constant or increased since the listing of the species and development of the recovery plan.

Important conservation work has been conducted to advance recovery of Pecos gambusia. The Service's Texas and New Mexico Fish and Wildlife Conservation Offices, Bitter Lake National Wildlife Refuge, Texas Parks and Wildlife Department's Balmorhea State Park, New Mexico Department of Game and Fish, researchers from Texas A&M-College Station and Texas A&M-Corpus Christi, University of St. Louis, and Eckerd College, and The Nature Conservancy have engaged in major efforts to protect, restore and enhance Pecos gambusia habitat, and study and monitor the species itself. However, the threats to the species discussed above continue to exert pressure on Pecos gambusia in its remaining wild populations, despite ongoing recovery efforts. Overall, the viability of Pecos gambusia has declined since the previous five-year review, and its primary threats have increased. Consequently, the species continues to be in danger of extinction, and we recommend that it remain classified as Endangered.

3.0 RESULTS

3.1 Recommended Classification:

No change is needed

3.2 New Recovery Priority Number (indicate if no change; see 48 FR 43098):

11C

Brief Rationale:

We revise the recovery priority number from 11 to 11C to reflect the fact that there is conflict between the need for groundwater to support spring flows and the need for groundwater to supply irrigated agriculture and, to a lesser extent, hydraulic fracturing operations. Recognizing this conflict is essential to the species' recovery because it highlights the other water users with whom the Service and other partners must collaborate in order to achieve recovery.

3.3 Listing and Reclassification Priority Number, if reclassification is recommended (see 48 FR 43098):

Not applicable

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The Pecos gambusia recovery plan was last updated in 1983. We recommend developing a Recovery Implementation Strategy, if possible given workload constraints, and developing or enhancing relationships with appropriate partners, including governmental agencies and stakeholders, in order to carry out actions that will prevent the extinction of the species and promote its recovery. This will be a multi-year process. In the meantime, we recommend individual actions to be taken in coordination with the U.S. Fish and Wildlife Service Fisheries and Aquatic Conservation and National Wildlife Refuge System, the Texas Parks and Wildlife Department Inland Fisheries Program and Balmorhea State Park, the New Mexico Department of Game and Fish, The Nature Conservancy, the Middle Pecos Groundwater Conservation District, and other partners.

We recommend that currently occurring actions should continue. For example, the Nature Conservancy should continue their important role in managing the Diamond Y and Sandia Springs Preserves and promoting conservation of those landscapes and of Pecos gambusia. Similarly, Balmorhea State Park's ongoing management of the Balmorhea Pool, San Solomon Ciénega, and Clark Hubbs Ciénega, as well as the canals connecting them, as delineated within the Park's Habitat Conservation Plan should continue. These recommendation aligns with actions 1.0, 2.0, and their sub-actions from the 1983 recovery plan.

In addition to the ongoing actions, we also recommend revitalizing or initiating other actions to support Pecos gambusia and strive to recover the species to the point where it could be downlisted to *Threatened*, including but not limited to those listed below.

1) Work with The Nature Conservancy and other partners to address the threat from feral hogs, which are currently causing severe damage to the surface water habitat within the Diamond Y Preserve. We recommend urgently implementing a multi-pronged approach including aerial shooting, trapping, and installing hog-proof fencing around all occupied habitats on the Preserve. This aligns with action 1.2 and its subactions from the 1983 recovery plan
2) Work with partners to continue to implement long-term monitoring for Pecos gambusia and associated fish communities. Determine the frequency and type of monitoring of the species and its habitat needed to identify the presence of an imminent extinction risk. Identify entities who can reliably conduct monitoring over the long-term. Expand current protocols into formal plans that will guide monitoring into the future. These recommendations align with actions 1.1 and 1.2, including sub-actions, from the 1983 recovery plan.
3) Restore and enhance Pecos gambusia habitat. Evaluate options for habitat restoration or enhancement within each of the four populations.
    a. Conduct research to understand the full range of microhabitat needs for Pecos gambusia to increase in abundance and outcompete western mosquitofish and/or largespring gambusia.

   b. Evaluate whether more significant interventions, such as removing sediment, lowering channels, deepening pools, or mimicking beaver activity would improve habitat conditions.
   c. Investigate options for adding water to the system in order to offset seasonal drying, including through rain catchment systems, on- or off-site wells and pumps, pipelines, and water storage tanks.
   d. These recommendations align with actions 1.1, 1.2, and 1.7, including sub-actions, from the 1983 recovery plan.
4) Partner with the appropriate authorities and institutions (e.g., the Texas Railroad Commission or the New Mexico Energy, Minerals, and Natural Resources Department) to plug abandoned or inactive wells located near extant Pecos gambusia populations.
5) Evaluate the utility of interventions such as using aerators in pools where fish concentrate during low flows to address low dissolved oxygen levels or installing shade structures to limit water loss due to evaporation and water temperatures.
6) Install new flume on Bitter Creek that will provide scientifically and legally defensible data on actual flows at that location, including under very low or no flow conditions. Regularly collect and analyze data and share it with Bitter Lake NWR and Ecological Services staff, as well as State of New Mexico authorities when appropriate.
7) At Balmorhea State Park, add clean fill to the ciénegas and reinforce the stability and security of the perimeters of the ciénegas by shoring up the earthen berms that form this perimeter.
8) At Balmorhea State Park, add an electric irrigation irrigation-style pump that can be used to maintain water levels of San Solomon Ciénega during pool cleaning. Upgrade the electrical system to allow for a switch to be turned on when needed, reducing the specialized knowledge required for Park staff to turn on the pump. To supply redundancy and serve as a backup, install a gasoline-powered trash pump that can be used during emergencies (such as if the first pump fails or if there is no electricity to run the other pump) and pump water as needed.
9) Determine if and when translocation of wild Pecos gambusia within the four populations (i.e., within the Diamond Y Preserve, within the San Solomon Spring System, within Bitter Lake NWR) is warranted. If implemented, monitor affected populations. These recommendations align with action 1.1 from the 1983 recovery plan.
10) Work with interested zoos to initiate captive stock management for one or more of the populations. Develop management plans that include target population abundance, clearly identify the purpose of the captive populations, and include specific genetic management recommendations, such as the type of analyses to conduct and at what interval. These plans should also identify conditions for supplementation of wild or captive stocks. These recommendations align with action 4.0 from the 1983 recovery plan.
11) Develop catastrophic response plans for the populations, in collaboration with partners and landowners that addresses both contamination and drying events. This recommendation aligns with action 1.2, including sub-actions, from the 1983 recovery plan.

a. Formalize protocol for emergency salvage of Pecos gambusia from Bitter Creek so that it is robust to future turnover in personnel at Bitter Lake NWR, SNARRC, or Ecological Services.

12) Develop a genetic management plan for the species as a whole, inclusive of both wild and captive populations. The plan should include a consideration of biobanking options. This recommendation is related to actions 1.6 and 2.0 from the 1985 recovery plan.
13) Conduct experiments and monitoring to understand what management actions would maximize Pecos gambusia abundance, in both the wild and in captivity. This recommendation aligns with actions 1.1, 1.2, and 1.5, including sub-actions, from the 1983 recovery plan.
14) Complete hydrogeological studies to better understand groundwater/surface water interactions. For example, improve understanding of where groundwater development within the flowpath supplying the Diamond Y Preserve, San Solomon Spring System, and Bitter Lake springs and sinkholes would be likely to deplete flows at those springs and where such development would be unlikely to affect spring flow. This recommendation aligns with actions 1.2 and 1.5, including sub-actions, from the 1983 recovery plan.
15) Continue research into the habitat needs of co-occurring pupfishes (e.g., Comanche Springs pupfish, Leon Springs pupfish, Pecos pupfish) and develop habitat management strategies that promote both species, to ensure that actions taken for the benefit of Pecos gambusia do not harm pupfishes. This recommendation aligns with actions 1.5 and 2.6 from the 1983 recovery plan.
16) Continue monitoring spring flows and basic water quality parameters at as many localities with Pecos gambusia as possible, across the four populations. This recommendation aligns with actions 1.2 and 1.5, including sub-actions, from the 1983 recovery plan.

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U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW OF PECOS GAMBUSIA (*GAMBUSIA NOBILIS*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: Not applicable

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service, Austin Ecological Services Field Office, Austin, Texas

Approve KAREN MYERS Digitally signed by KAREN MYERS Date: 2025.07.24 07:10:39 -05'00' ____________________