Pecos Gambusia
(*Gambusia nobilis*)

5-Year Review:
Summary and Evaluation

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

5-YEAR REVIEW
Pecos Gambusia (*Gambusia nobilis*)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office:	Southwest Regional Office, Region 2 Jennifer Smith-Castro, Recovery Biologist, 281-286-8282 ext. 234
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1.2 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 information on the status of the species. Data for this status review were solicited from interested parties through a Federal Register notice announcing this review on May 31, 2018 (83 FR 25034). This review was conducted by the Austin Ecological Field Services Office using information from the Pecos Gambusia Recovery Plan (Service 1983, entire), peer-reviewed articles, agency reports, and other documents available in the Austin ESFO files and with contributions from cooperating Regional and Field Offices, and National Wildlife Refuges.

1.3 Background:

The Pecos gambusia is a small, live-bearing Cyprinodontiform fish in the family Poeciliidae. Members of the Poeciliid family are characterized by distinct sexual dimorphism, and are unusual in that the males have a highly modified anal fin, the gonopodium, which is used to deposit sperm in the genital tract of the female. Structures of the gonopodium are used to distinguish and differentiate among species of Gambusia. Fertilized eggs are carried by the female until they hatch internally; young fish emerge directly from the female.

Individuals of this species are generally light reddish-brown in color with a somewhat paler underside. Male Pecos gambusia are usually 32 millimeters (mm)[1.26 inches (in)] or less in total length, while females may exceed 60 mm (2.36 in)(Propst 1999, p. 61). The Pecos gambusia is a relatively robust *Gambusia*, with an arched back and a caudal peduncle depth that is approximately two-thirds of the head length. The margins of the scale pockets are outlined in black and spots are normally absent on the caudal fin; however, sometimes a faint medial row of spots may be present (Bednarz 1975, p. 3; Hubbs et al. 2002, p. 428). Females have a prominent black area on the abdomen that surrounds the anus and anal fin (Hubbs and Springer 1957, p. 294). There normally are eight dorsal, 12 pectoral, and six pelvic fin rays; males typically have nine anal fin rays while females have 10 (Echelle and Echelle, 1986 p. 463). The male gonopodium has a number of unique features including elongated spines on ray 3, small rounded hooks on the tips of rays 4p and 5a, and an elbow on ray 4a consisting of three or four fused segments located opposite the serrae of ray 4p (Hubbs and Springer 1957, p. 295; Bednarz 1975, p. 2; Echelle and Echelle 1986, p. 462).

Gambusia is primarily a subtropical genus (Service 1983, p. 12; Echelle and Echelle 1980, p. 45), with the closest relatives of the Pecos gambusia occurring in Mexico and south Texas (Service 1983, p. 12). The Pecos gambusia is known principally from lower elevations, with the population at Ink Pot north of Roswell, New Mexico on Bitter Lake National Wildlife Refuge (BLNWR) representing the highest elevation (1087 meters (m)[3566 feet (ft)]) and northernmost area presently known to be occupied by the species. All populations, including those at historic and current locations, occur between 822 m (2697 ft) and 1187 m (3894 ft) in elevation, a range of only 365 m (1198 ft).

The species' primary habitats include stenothermal (narrow temperature range) springs, runs, spring-influenced marshes (ciénegas), and irrigation canals carrying spring waters (Service 1983, p. 12; Hubbs 2003, p. 128). Some populations are also known from areas with little spring influence; these habitats generally have abundant overhead cover, and include sedge-covered marshes and gypsum sinkholes (Echelle and Echelle 1980, p. i). One or two other species of *Gambusia*, the western mosquitofish (*Gambusia affinis*) and the largespring gambusia (*G. geiseri*), may also be found in association with the Pecos gambusia. Where the western mosquitofish is found, the Pecos gambusia typically inhabits stenothermal (i.e., narrow temperature range) waters and the mosquitofish is most often found in eurythermal (i.e., wide temperature range) habitats. Where the largespring gambusia has been introduced, the Pecos gambusia is much more likely to be found associated with vegetation or in deeper waters, while largespring gambusia tends to be at the surface or in open water over non-vegetated substrates (Hubbs et al. 1995, p. 325).

The Pecos gambusia is adapted to a wide range range of environmental and temperature conditions (Bednarz 1979, p. 314-315). Based on measurements taken by Bednarz (1979, p. 316) at BLNWR, Pecos gambusia were found in water with pH from 8.0 to 9.3, temperature from 22.5 to 30.1 degrees Celsius (ºC)[72.5 to 86.2 degrees Fahrenheit (ºF)], salt (sodium chloride) from 1,600 to 12,000 milligrams/liter (mg/l), dissolved oxygen from 4.7 to 10.0 mg/l, and hardness from 1812 to 4651 mg/l. Gelbach et al. (1978, p. 101) reported that the upper limits of thermal tolerance for the species is 38.1 to 39.3 ºC (100.6 to 102.7 ºF). The Pecos gambusia does not occur at BLNWR nor have previous reintroduction efforts into aquatic habitats been successful where salinities exceed 3,000 mg/l or hardness values over approximately 5,000 mg/l; therefore, salinities or hardness over these values may affect the survival of the species in these habitats.

The Pecos gambusia is a carnivorous surface feeder (Bednarz 1979, p. 317). It feeds relatively non-selectively, consuming a diversity of food types including amphipods, dipterans, cladocerans, filamentous algae, arachnids and mollusks (Hubbs et al. 1978 p. 493; Winemiller and Anderson 1997, p. 300). Prime feeding time is at dusk, corresponding to increased insect activity. Based on dissection of digestive tracts, Bednarz (1979, p. 317) noted it appeared that Pecos gambusia will prey on any type of surface and mid-water insects of adequate size. In addition, *Gambusia* are also known to be cannibalistic, eating both their own young and the young of congeneric species, and predaceous, eating the young fish of other species (Hubbs 1996, p. 15).

1.3.1 FR Notice citation announcing initiation of this review:

83 FR 25034, May 31, 2018

1.3.2 Listing history

Original Listing
FR notice: 35 FR 16047-16048
Date listed: October 13, 1970
Entity listed: Pecos gambusia (*Gambusia nobilis*)
Classification: Endangered

1.3.3 Associated rulemakings:

Not applicable.

1.3.4 Review history:

Status reviews for the Pecos gambusia were conducted in 1970 for the final listing of the species (35 FR 16047-16048) and 1983 for the Pecos Gambusia Recovery Plan (Service 1983, entire). No previous 5-year review has been conducted for this species.

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

The Recovery Priority Number at the start of this 5-year review was 2, meaning a high degree of threat, the recovery potential is high, and the listed entity is a species.

1.3.6 Recovery Plan or Outline

Name of plan or outline: Pecos Gambusia Recovery Plan
Date issued: 1983

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate?

__X__ *Yes*
_____ *No*

2.1.2 Is the species under review listed as a DPS?

_____ *Yes*
__X__ *No*

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy?

______ *Yes*
__X__ *No.* The Pecos gambusia is currently listed as endangered across its entire known range and not at the population level. There is no new relevant information available in which the Service would consider listing this species as a DPS under the 1996 policy.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan? Yes.

2.2.1.1 Does the recovery plan contain objective, measurable criteria?

______ *Yes*
__X__ *No.* See section 2.2.3.

2.2.2 Adequacy of recovery criteria.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

______*Yes*
__X__ *No.* The 1983 recovery plan provides no specific delisting or downlisting criteria for the species. Additionally, new potential threats to the species have been identified that were not originally considered under the original plan, such as extensive new oil and gas development, invasive snails and their associated gill parasite, and climate change.

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

______*Yes*
__X__ *No.* Recovery plan development for this species was prior to the application of 5-factor analysis and therefore are not specifically addressed.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

The 1983 Pecos Gambusia Recovery Plan does not provide specific delisting and/or downlisting criteria; in fact, the plan provides no specific recovery criteria for this species at all. Instead, it states the primary objective of the plan and then lists a more detailed four-point "step-down outline" (Service 1983, pp. 20-21). The stated primary objective of the plan is as follows:

> "Improve the status of the Pecos gambusia to the point that survival of the populations from the four major areas of occurrence is secured."

The four primary actions listed in the recovery plan's step down outline for the Pecos gambusia are as follows:

1. Maintenance and enhancement of existing Pecos gambusia populations and habitats.
2. Reestablish Pecos gambusia within portions of its historic range.
3. Disseminate information about Pecos gambusia.
4. Hold and propagate Pecos gambusia in a hatchery.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

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

The Pecos gambusia is presumed to have a life-span of at least three years, and is capable of reproducing for two of those years (Swenton and Kodric-Brown 2012, p. 677). The Pecos gambusia produces live young, and averages from one to four broods during the April through August breeding season (Swenton and Kodric-Brown 2012, p. 670). Bednarz (1979, p. 317) reported that the number of embryos was related to female size and that the mean number of embryos was 38 in the Blue Spring population in New Mexico. Hopkins and Kodric-Brown (2015, p. 1841) from a study of the species at BLNWR, noted that Pecos gambusia reproductive strategy shifted over the breeding season from investment in many small embryos to fewer, larger offspring. They also indicated that brood size was correlated positively with female body size, and that both large and small females had very similar average egg mass. Hubbs (1996, p. 14) found that the birth weight of Pecos gambusia from Texas populations ranged between 35 and 50 mg (0.0012 and 0.0018 ounces (oz) and females had an interbrood interval averaging 52 days.

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

I. San Solomon Spring System, Texas

San Solomon Spring: Balmorhea State Park was originally acquired by the state to provide a recreational facility at or near San Solomon Spring. The area around San Solomon Spring historically supplied a large, natural wetland ciénega but this ciénega was all but destroyed when the park swimming pool was constructed by the Civilian Conservation Corps in 1936 (TPWD 1999, p. 1). In 1974, TPWD began a series of long-term activities within Balmorhea State Park to create and/or restore habitat areas that could replace some of the functions and values of the original San Solomon ciénega that was destroyed. In 1974 and 1975, TPWD constructed a refuge canal within the park that was primarily intended for the benefit of the endangered Comanche Springs pupfish, but also provided additional quality habitat for the Pecos gambusia (TPWD 1999, p. 47). This refuge canal was stocked with Pecos gambusia from the existing population at Giffin Spring, where the population flourished (Johnson and Hubbs 1989, p. 313). In 1996, TPWD restored a desert wetland habitat within the site of the original, natural ciénega that occurred on the park property. Referred to as San Solomon Ciénega, it provided additional vital habitat for terrestrial, wetland-adapted, and aquatic species, including the Pecos gambusia (TPWD 1999, p. 22). In 1999, TPWD developed a second refuge ciénega, the Clark Hubbs Ciénega, adding additional aquatic habitat within the park boundaries to support wetland dependent biota.

Little data exists on the population size and/or abundance of Pecos gambusia within San Solomon Spring prior to 1974. The 1983 Pecos Gambusia Recovery Plan (Service 1983, p. 10) indicates that more than 100,000 individuals occurred within the San Solomon Spring System in the late 1970s and early 1980s, but it did not address numbers at San Solomon Spring specifically. Echelle and Echelle (1980, p. 16) briefly discussed San Solomon Spring, and noted that although no surveys were conducted within the state park boundary, intensive observations by the members of their group suggested that no *Gambusia* occurred in the refuge canal or elsewhere within the park in the late 1970s.

Population estimates of the Pecos gambusia within the refuge canal (from 2009), the San Solomon Ciénega (from 2009 to 2013), and the Clark Hubbs Ciénega (from 2009 to 2013) were reported by Dr. Chad Hargrave (2012, p. 7-8). Dr. Hargrave estimated that 506 to 1,216 Pecos gambusia occurred in the refuge canal habitat, 325 to 2,023 individuals in the San Solomon Ciénega, and approximately 2,062 individuals occurred within the Clark Hubbs Ciénega. Although significant seasonal variation in species density and abundance within these three habitats was noted, the populations at Balmorhea State Park appear to be currently stable and reproductively viable (Hargrave 2012, p. 27).

Giffin Spring: Giffin Spring and its outflow are privately owned, and little information is available on Pecos gambusia abundance within this system. Echelle and Echelle (1980, p. 49-50) and the Service (1983, p. 10) indicated that approximately 3,000-3,400 individuals occurred within the Giffin Spring headwaters. No additional information on current population size or abundance estimates could be found in the available literature for this site.

Phantom Lake Spring: Prior to development of the Balmorhea area, flow from Phantom Lake Spring emerged from the mouth of the associated cave and formed a shallow lake and desert ciénega several acres in size. The BOR purchased Phantom Lake Spring and the surrounding land in 1945, and subsequently built a concrete-lined irrigation ditch to capture most of the spring flow and convey it to the District's main canal at San Solomon Spring for irrigation and agricultural purposes (Service 2000, p. 9). Due to the spring flow diversion and the continuous spring flow declines since the 1940s, there was only a small pool and ciénega area left at the mouth of the spring where the Pecos gambusia persisted, but in much reduced numbers.

In the early 1980s, Echelle and Echelle (1980, p. 16) noted that the Pecos gambusia was the dominant species from the head of Phantom Lake Spring where it emerges as a quiet pool at the base of the cliff. Both Echelle and Echelle (1980, p. 16) and the Service (1983, p. 10) gave estimates of the total population within the existing pools and irrigation canal system, and indicated that between 9 and 10,000 Pecos gambusia occurred there.

In 1993, a modified canal was constructed by the BOR at Phantom Lake Spring (Young et al. 1993, p. 2). The modified channel was approximately 110 m (361 ft) long with sloped earthen sides instead of the original concrete walls, and was designed to resemble a portion of a desert wetland ciénega (Garrett 2002, p. 3). The purpose of this project was to establish an off-canal facility that would transport flows through a protected, structurally diverse channel while also serving as a refugium for listed aquatic species, including the Pecos gambusia. During the construction phase of this project, approximately 135 Pecos gambusia were collected from the lower canal area and introduced into the refugium pool habitat (Young et al. 1993, p. 2).

Between November 1994 and August 1995, the constructed Phantom Spring refuge was surveyed quarterly. The abundance of Pecos gambusia within the refuge increased markedly during this period, becoming the most abundant fish species in the system (Winemiller and Anderson 1997, p. 208). The abundance of Pecos gambusia by collection date varied between a low of 415 in May 1995, to a high of 863 in August 1995. Between 1998 and 1999, Dr. Clark Hubbs conducted monthly collections at Phantom Lake Spring. Pecos gambusia made up between 35% to 80% of the total *Gambusia* population, with the introduced largespring gambusia being the other primary gambusia species in the system (Hubbs and Karges 1999, p. 340).

Flows from Phantom Lake Spring continued to decline, and by 1999 to 2000, all discharge from the spring to the surface aquatic habitat had ceased (Service 2000, entire). As a temporary measure to prevent the drying of the spring habitat, the BOR and the Service installed an emergency system in May 2001, to pump water from within the cave to the outflow spring pool. This provided freshwater to maintain a small amount of surface aquatic ciénega habitat and within a short stretch of the downstream concrete canal, about 91 m (300 ft) long. The pumped water was recirculated back into the cave/aquifer. During this timeframe, the total number of Pecos gambusia persisting at Phantom Lake Spring is estimated to have been less than 100 (N. Allan, Service, personal observation, 2003).

Between 2004 and 2007, improvements were made to the pumping system at Phantom Lake Spring with construction of a new check dam, a downstream berm, and a backup generator (Service 2004, entire). Expansion of the main pool, replacement of the pumps, and extension of the inlet pipes deeper into the cave were completed in 2011, providing additional habitat for all of the endangered species occurring there, including the Pecos gambusia. Lewis et al. (2013, p.236) conducted surveys for the Pecos gambusia within Phantom Lake Spring in 2010. April surveys conducted by visual counts yielded 75 to 100 Pecos gambusia in the system, but due to methodology used, counts may have been conservative. September 2010 surveys used an alternative methodology, which yielded counts of approximately 230 Pecos gambusia, nearly double the number documented during the April survey effort.

From March to September 2011, the Service's Texas Fish and Wildlife Conservation Office (TXFWCO) and TPWD conducted additional habitat restoration/improvement projects at Phantom Lake Spring, including the addition of alarms to the pumping system. Due to concerns regarding the status of all listed species in the system, including the Pecos gambusia, abundance surveys were conducted in 2012 and again in 2014. The fish survey methodology used in 2012 (mesh seine net hauls) proved problematic because of the amount of *Chara* (green algae) in the system. Due to the issues with the 2012 surveys, no Pecos gambusia abundance estimates were made although more than 600 individual *Gambusia* were collected during these efforts. In order to get more accurate survey results and avoid issues with the *Chara*, the methodology was changed in 2014 to use a 1 square meter (sm) (10.8 square feet (sf)) drop nets. Drop net surveys yielded approximately 48 Pecos gambusia per sm (4.4 Pecos gambusia per sf), and extrapolating these results indicated total abundance of approximately 5,543 Pecos gambusia in the Phantom Lake Spring system (Service 2012, p. 2; Service 2014, p. 2).

East Sandia Spring: In the early 1980s, Echelle and Echelle (1980, p. 49-50) and the Service (1983, p. 10) indicated that approximately 88 to 100,000 Pecos gambusia occurred within the head pool of East Sandia Spring. Little additional information could be found providing recent estimates of population size or abundance within this system. Some limited data is available from a habitat segregation study of *Gambusia* species by Dr. Clark Hubbs, who conducted trapping efforts within both surface and deep-water habitats at East Sandia Spring between January 1998 and June 1999. Dr. Hubbs reported that the Pecos gambusia made up between 73% and 90% of the total *Gambusia* population within the system. Although the study did not provide an estimate of population size or abundance, it did indicate that a large, healthy population still occurred within the system during this timeframe (Hubbs and Karges 1999, p. 340).

II. Diamond Y Spring System, Texas

The Pecos gambusia is the predominant species within the Diamond Y Spring System except for Monsanto pool, located in the lower watercourse (Echelle et al. 2002, p. 10). Estimates of total population numbers of Pecos gambusia within the Leon Creek/Diamond Y Spring System were provided in the early 1980s by Echelle and Echelle (1980, p. 49-50) and the Service (1983, p. 10). Pecos gambusia were estimated to comprise over 1 million individuals within Leon Creek, with approximately 100,000 individuals occurring within the Diamond Y Spring System.

In February 1976, the entire lower watercourse of Diamond Y was treated with rotenone and antimycin A, both ichthyocides, in an effort to eliminate the non-native sheepshead minnow (*Cyprinodon variegatus*) and all hybrid crosses with the endangered Leon Springs pupfish. Between 1976 and 1978, additional ichthyocide treatments, seining, and pupfish reintroductions to swamp out the invasive genome were conducted. The attempts to eliminate the genetic introgression of Leon Springs pupfish with sheepshead minnows also resulted in the elimination of the Pecos gambusia from the lower watercourse. Following all treatment protocols, Pecos gambusia from the upper watercourse in Diamond Y Spring and its outfall were restocked into the lower watercourse

(Echelle and Echelle 1980, p. 21). These efforts to eradicate the sheepshead genome clearly had an impact on the abundance and diversity of other fishes inhabiting Leon Creek (Hubbs et al. 1978, p. 493), including the Pecos gambusia.

In 1994, evidence of sheepshead minnow once again being present within both watercourses of the Diamond Y Spring System was detected (Echelle and Echelle 1997, p. 154). As a result, a second effort to eradicate the hybrid genome of sheepshead minnow was conducted between 1998 and 2000 (Echelle et al. 2001, p. 4). More than 1,000 Pecos gambusia were collected from the upper and lower watercourses and transported to the SNARRC in Dexter, New Mexico. Although no specific numbers were given, Echelle et al. (2001, p. 14) indicated that pre-treatment surveys of Pecos gambusia abundance within the Diamond Y Spring System indicated that the species occurred in all 20 sample sites, and represented 96% of the total fish collected. In 1999, post-treatment surveys following restocking efforts with fish being held at SNARRC indicated that the Pecos gambusia still occurred in 19 of the 20 sample sites, and represented 87% of all fish collected (Echelle et al. 2001, p. 14). Although overall abundance of Pecos gambusia was lower post-treatment, observations by Echelle et al. (2001, p. 23) indicated that the Pecos gambusia was thriving in both the headpool of Diamond Y Spring and elsewhere within the draw. One unexpected benefit of the restoration efforts was the complete eradication of largespring gambusia from the system (Echelle et al. 2001, p. 15), a species that competes and hybridizes with the Pecos gambusia.

As part of a habitat segregation study of *Gambusia* species, Dr. Clark Hubbs conducted trapping efforts within both surface and deep-water habitats within both the upper and lower watercourse of Diamond Y Spring/Draw. Fish were collected between January 1998 and September 1998 at Diamond Y Spring, and between January 1998 and June 1999 at Monsanto Well. The shorter duration of sampling efforts at Diamond Y Spring was due to the treatments being conducted to eliminate the invasive sheepshead minnow genome from this portion of the system, as discussed previously. Dr. Hubbs reported that the Pecos gambusia made up between 66% and 76% of the total *Gambusia* population at Diamond Y Spring (upper watercourse), and between 15% and 38% of the total *Gambusia* population within the Monsanto Well (lower watercourse). Although the study did not provide an estimate of population size or abundance, it did indicate that a large, healthy population still occurred within the system during this timeframe (Hubbs and Karges 1999, p. 340).

III. Bitter Lake National Wildlife Refuge, New Mexico

Bednarz (1979, p. 315) reported that populations of Pecos gambusia in the mid to late 1970s were known to occur within the following sites at BLNWR: Lost River/Dragonfly Springs, Sago Spring, and sinkholes 2, 7, 10, 20, and 27

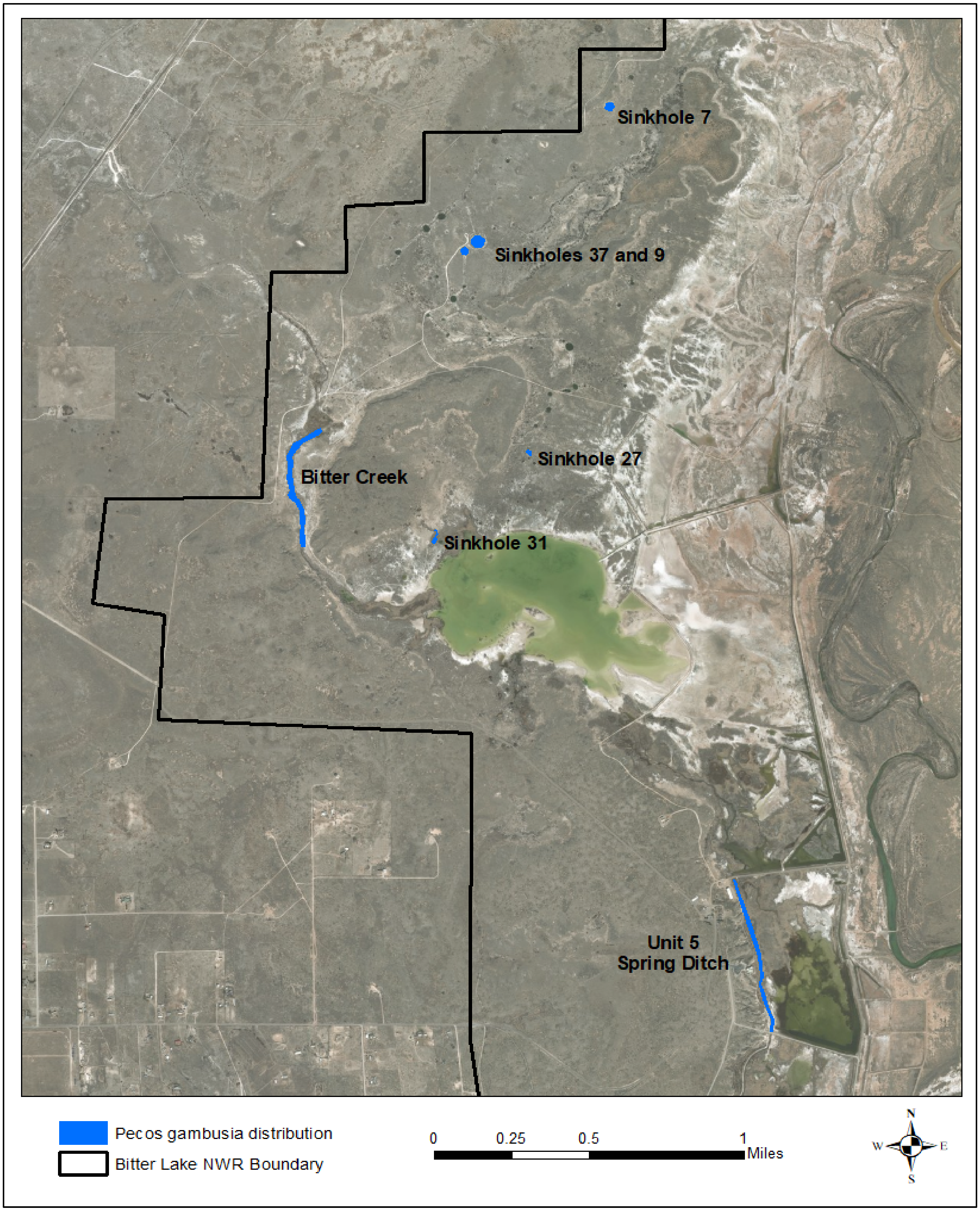
(Figure 1). The populations in sinkholes 2 and 10 resulted from a stocking effort by Lawrence Kline, a former refuge manager, in 1973. Mr. Kline introduced Pecos gambusia into 20 sinkholes on the refuge, one of which (#20) was already occupied by the species. The stocking efforts were unsuccessful in the majority of the sinkholes (Echelle and Echelle 1980, p. 4). The Service (1983, p. 4) notes that an introduced population also occurred in Ink Pot, an isolated gypsum sinkhole on the Salt Creek Wilderness Area of BLNWR that also resulted from Mr. Kline's 1973 stocking efforts. Bednarz (1975, p. 5; 1979, p. 313) made population estimates at BLNWR using two methods: (1) actual counts; and (2) rough surveys of available habitat. Bednarz estimated the total adult population of Pecos gambusia at BLNWR from all habitats occupied by the species in the mid to late 1970s to be approximately 33,500 individuals.

Echelle and Echelle's study (1980, p. 4), which was conducted before Bednarz' 1979 paper was published, found the Pecos gambusia at an additional location in the Unit 3 canal leading to Unit 5 on the refuge. However, two of the locations Bednarz' surveyed were not visited by the Echelles. The Echelles did not provide estimates of Pecos gambusia population size, but rather gave estimates of relative abundance of the species as a percentage of individual fish present in the habitat (Echelle and Echelle 1980, p. 7; Bouma 1984, p. 48).

Bouma (1984, p. 48) found the Pecos gambusia at Lost River/Dragonfly Springs, Sago Springs, and sinkholes 7, 10, 20, 27, 31, and 32. Bouma (1984, p. 46) noted that sinkhole #32 represented a new locality for the species, and that the population reported by Bednarz at sinkhole #2 had gone extinct by 1979. Bouma (1984, p. 47) provided densities of Pecos gambusia from both trap and visual observations at all known locations for fall, winter, spring, and summer surveys. Extrapolating the density data for summer surveys, he estimated the total population size for the Pecos gambusia at BLNWR to be approximately 96,000 individuals (Bouma 1984, p. 47).

Between the studies by Bednarz (1979, entire), Echelle and Echelle (1980, entire), and Bouma (1984, entire), and the present, the locations of the populations of Pecos gambusia at BLNWR have changed over time. This is due to many factors, including but not limited to localized extirpations, changes in habitat conditions, hybridization and competition with other *Gambusia*, predation by predatory fish, discovery of new populations, refuge management activities, and stocking efforts. Currently, the Pecos gambusia occurs in the following locations at BLNWR: Sinkholes 7, 9, 27, 31 (Sago Spring), 37 (Lake St. Francis), a portion of Bitter Creek (Dragonfly Spring), and the Unit 5 Spring ditch. There are no current data available regarding population estimates in the occupied habitats on the refuge, although populations appear to be stable (Jeffrey Beauchamp 2018, pers. comm.).

Figure 1. Current distribution of the Pecos gambusia at Bitter Lake National Wildlife Refuge, New Mexico.



IV. Blue Spring, New Mexico

Pecos gambusia has been documented as being abundant within the upper watercourse of Blue Spring where there is permanently flowing water from the existing springs, but have been relatively uncommon downstream and within the lower watercourse area. It is presumed that the low numbers of Pecos gambusia in the lower watercourse is due to irrigation diversion and occasional seasonal drying of that portion of the system (Echelle et al. 1989, p. 161).

Bednarz (1975, p. 6; 1979, p. 314) attempted to estimate Pecos gambusia numbers with a mark-recapture study of all *Gambusia* within a roughly 240 sm [2583 sf] area of the upper watercourse of Blue Spring, which was isolated from the remainder of spring run. The mark-recapture study was abandoned due to excessive mortality of individuals from capture, handling, and marking by clipping the caudal fin. With the limited data available from the mark-recapture and visual observations of this area, he estimated that approximately 25,000 *Gambusia* occurred there. Bednarz then estimated all available habitat area within the Blue Spring system except where he excluded a small area within the main current of the spring run. From this estimate of approximately 30,240 sm (325,501 sf) of available habitat and an approximate ratio of 2.5 western mosquitofish for every Pecos gambusia, Bednarz (1975, p. 6; 1979, p. 314) estimated population size within the Blue Spring system at 900,000 individuals.

Echelle and Echelle (1980, p. 11) noted that Bednarz (1979, p. 314) likely overestimated the amount of marshy habitat available to the Pecos gambusia within the Blue Spring system, with their rough estimates being closer to 215, 258 sf (20,000 sm). Additionally, they noted that Bednarz' reported ratio of 2.5:1 western mosquitofish to Pecos gambusia varied considerably within the system, with the Pecos gambusia being more abundant than the western mosquitofish in the upper watercourse, and the exact opposite trend noted within the lower watercourse. In spite of these differences, Echelle and Echelle (1980, p. 11) generally agreed with Bednarz' approximation of 900,000 Pecos gambusia within the Blue Spring system as an appropriate estimate.

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

The Pecos gambusia coexists well in aquatic systems with most small species of fish with the exception of other *Gambusia* species. Hybrids between Pecos gambusia and the western mosquitofish and/or largespring gambusia are occasionally found, especially in habitats where one of the species is rare (Echelle and Echelle 1980, p. 47-48; Service 1983, p. 14). Echelle and Echelle (1980, p. 48) noted that the levels of hybridization were typically higher with the more genetically similar western mosquitofish than with the largespring gambusia, and could be influenced by how recently populations had been introduced or in contact with one another. *Gambusia* males tend to court females of their own species more often that of other species. This courtship behavior coupled with differences in male and female genital structures likely act to partially isolate reproduction between species, keeping hybridization rates low (Bednarz 1979, p. 319).

Echelle et al. (1989, p. 164-165) conducted genetic analyses of the four major areas currently occupied by the Pecos gambusia. This study demonstrated a high level of genetic variability among the different populations, indicating significant genetic and morphological diversification between populations (Echelle et al. (1989, p. 166). The San Solomon Spring System in Texas and the Blue Spring population in New Mexico were the most morphologically and genetically diverse of the extant populations, with the San Solomon Spring population having the highest genetic heterogeneity (Echelle and Echelle 1986, p. 464-467; Echelle et al. 1989, p. 166-167).

2.3.1.4 Taxonomic classification or changes in nomenclature:

The Pecos gambusia was first described by Baird and Girard (1853, p. 390) as *Heterandria nobilis* from specimens collected in Leon and Comanche Springs, Pecos County, Texas (Sublette et al. 1990, p. 272). The Pecos gambusia was later synonymized with *G. senilis* from northern Mexico (Regan 1913, p. 985), but beginning with Hubbs (1926, p. 32-33), both have been recognized as distinct species. Leon Springs in Pecos County, Texas, was later designated the type locality for this species (Hubbs and Springer 1957, p. 297). No changes in the classification or nomenclature of the Pecos gambusia have occurred since being recognized as a distinct species.

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

I. Historic Distribution: Natural and Introduced Populations

Natural Populations: New Mexico and Texas

Pecos River, North Spring, Comanche Springs, and Leon Springs: The Pecos gambusia is endemic to the Pecos River Basin in southeastern New Mexico and western Texas and originally ranged from near Fort Sumner, New Mexico, to the area around Fort Stockton, Texas. Although the mainstem Pecos River probably was never important as permanent habitat, it served as a dispersal route between tributary springs and streams. Important spring and stream habitats adjacent to the Pecos River were initially impacted by extensive groundwater pumping of the aquifers in the mid-1900s. This caused cessation of flow and extirpation of the Pecos gambusia from two historically known locations in New Mexico: (1) at the Pecos River near the City of Fort Sumner; and (2), at the North Spring River near the City of Roswell. Additionally, two populations of Pecos gambusia were extirpated from Pecos County, Texas: (1) at Comanche Springs located in the City of Fort Stockton; and (2), at Leon Springs (the type locality for the species) in the Leon Creek drainage about 16 kilometers (km)[9.94 miles (mi)] upstream from Diamond Y Spring (Service 1983, p. 4; Echelle et al. 1989, p. 162). This groundwater pumping also caused reduced flow with loss of habitat in other areas, and resulted in many of the remaining Pecos gambusia populations becoming isolated in permanent springs and dependent upon spring flow for their survival.

Tunis Spring: Johnson and Hubbs (1989, p. 313) indicated that Tunis Spring located approximately 16 km (10 mi) upstream from Diamond Y Spring in Pecos County, Texas, is another historic location where Pecos gambusia were reported to be extirpated. However, the Pecos Gambusia Recovery Plan (Service 1983, p. 10) noted that Tunis Spring was incorrectly reported as a historic locality that once contained Pecos gambusia. No definitive information can be found in the available literature regarding the validity of this site as a historic location for the species.

Unnamed spring-seep pond: Bednarz (1975, p. 4) reported a population of Pecos gambusia had been noted in the existing literature to occur at a 13 m (30-ft) diameter spring-seep fed pond near Bottomless Lakes State Park in Chaves County, New Mexico. This small, round pond was surveyed by Bednarz (1975, p. 4) and over 1000 *Gambusia* were collected and examined. Because no Pecos gambusia were documented among the collected specimens and the originally collected specimens of presumed Pecos gambusia could not be located, Bednarz (1975, p. 4) questioned whether the species ever occurred in this location.

Introduced Populations – New Mexico

Geyser Spring: Echelle and Echelle (1980, p. 4) reports that Pecos gambusia were introduced into Geyser Spring, Eddy County, New Mexico, in the late 1970s but the introduction effort was not successful. No additional information could be found regarding this introduction in the available literature.

Living Desert State Park: Living Desert State Park near Carlsbad, New Mexico, was stocked with Pecos gambusia in a number of artificial pools from a source population presumed to be from Blue Spring in 1975 (Service 1983, p. 4). The introduced stock that once occurred in these artificial pools is extirpated (Service 1997, p. 25).

Southwestern Native Aquatic Resources and Recovery Center (SNARRC): The Service's SNARRC (formerly Dexter National Fish Hatchery) located in Dexter, New Mexico, established a refugium population of 30 to 40 Pecos gambusia taken from the Diamond Y Spring System in November 1974 (Bednarz 1975, p. 5). The refugia program was discontinued in 1981 due to the belief that the widely separated existing natural populations were secure (Edds and Echelle 1989, p. 442; Johnson and Hubbs 1989; p.313). Therefore, there are currently no Pecos gambusia being kept in captivity and/or for refugia purposes.

New Mexico Department of Game and Fish (NMDGF): The NMDGF and the New Mexico Environmental Improvement Agency established a population of Pecos gambusia in the late 1970s from Blue Spring at an abandoned sewer treatment facility in Carlsbad, New Mexico, to possibly serve for mosquito control reintroductions in the Pecos River drainage. The project was discontinued when the Pecos gambusia failed to survive (Echelle and Echelle 1980, p. 4; Johnson and Hubbs 1989, p. 313).

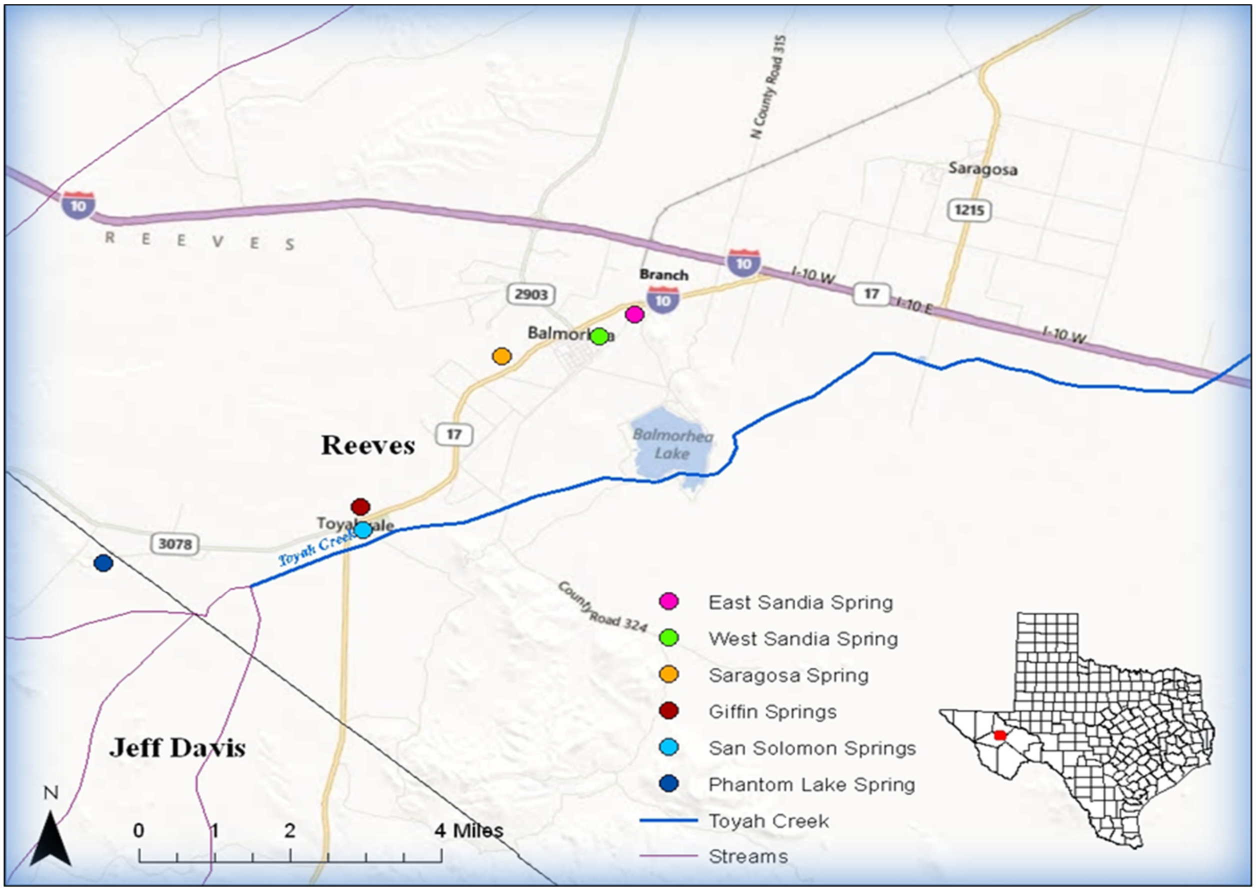
II. Current Distribution – New Mexico and Texas

No significant changes in spatial distribution or trends in spatial distribution have been documented since the listing of the Pecos gambusia in 1970. Currently, the species occurs in four widely separated localities in the Pecos River drainage of western Texas and southeastern New Mexico: (1) Diamond Y Spring system, Pecos County, Texas; (2) Localities in the Balmorhea area: Phantom Lake Spring, Jeff Davis County, Texas, San Solomon, Griffin and East Sandia springs, Reeves County, Texas; (3) BLNWR, Chaves County, New Mexico; and (4) Blue Spring, Eddy County, New Mexico (Echelle et al. 1989, p. 160; Hubbs et al. 2008, p. 39). The Pecos gambusia does not occur outside of the Pecos River drainage of New Mexico and Texas (Hubbs and Springer 1957, p. 296).

San Solomon Springs System, Texas: The San Solomon Spring System is located in the Chihuahuan Desert of western Texas at the foothills of the Davis Mountains near Balmorhea in Reeves County (Figure 2). This spring system is commonly referred to as Toyah Basin springs or Balmorhea area springs. All of these springs historically drained into Toyah Creek, an intermittent tributary of the Pecos River that is now dry except following large rainfall events. All four springs in this system are located in proximity to one another; the farthest two (East Sandia Spring and Phantom Lake Spring) are about 13 km (8 mi) apart, and all but East Sandia Spring likely originate from the same groundwater source (Service 2013, p. 41233).

San Solomon Spring: San Solomon Spring is located about 4 mi (6 km) west of the town of Balmorhea in the historic community of Toyavale. San Solomon Spring is located within the 18.62 hectares (ha)[46-acre (ac)] Balmorhea State Park, which is owned and managed by the Texas Parks and Wildlife Department (TPWD) and is by far the largest of the springs in the San Solomon system. San Solomon Spring provides all the water for the large flow-through

Figure 2. San Solomon Spring System, Texas.



swimming pool and two restored/created ciénegas (desert wetland aquatic habitats) located within the state park. Additionally, San Solomon Spring provides all of the water used for downstream agricultural irrigation by the Reeves County Water Improvement District No. 1 (District). Water provided by the District for irrigation is channeled through an extensive system of concrete-lined irrigation channels, with much of the water stored in nearby Lake Balmorhea until it is delivered through the canals for flood irrigation on farmlands (Simonds 1996, p. 2). Brune (1981, p. 385) reported San Solomon Spring flows in the range of 0.8 to 1.3 cubic meters per second (cms)[28 to 46 cubic feet per second (cfs)] between 1900 and 1978 indicating an apparent declining trend. Texas Water Development Board (TWDB)(2005, p. 84) studies reported an average flow rate of about 0.85 cms (30 cfs) from data between 1965 to 2001, with a calculated slope showing a slight decline in discharge over this timeframe.

The Pecos gambusia occurs throughout all of the aquatic habitats associated with San Solomon Spring at Balmorhea State Park, including the swimming pool area, refuge canals, and the two restored refuge ciénegas. The gambusia occurs sympatrically with another federally- listed endangered fish, the Comanche Springs pupfish (*Cyprinodon elegans*), as well as several species of endangered invertebrates, the Phantom tryonia (*Tryonia cheatumi),* Phantom springsnail (*Pyrgulopsis texana*), and diminutive amphipod (*Gammarus hyalleloides*).

Giffin Spring: Giffin Spring is located on private property less than 1.6 km (1.0 mi) west of Balmorhea State Park across State Highway 17, with spring flows typically captured in earthen irrigation channels for agricultural use. Brune (1981, p. 385) reported flow from Giffin Spring ranged from 0.07 to 0.17 cms (2.3 to 5.9 cfs) between 1919 and 1978, with a gradually declining trend. During calendar year 2011, Giffin Spring flow rates were recorded between 0.10 and 0.17 cms (3.4 and 5.9 cfs) (USGS 2012, p. 1). The Pecos gambusia occurs throughout this spring system, and occurs sympatrically with the endangered Comanche spring pupfish, the Phantom tryonia, Phantom springsnail, and diminutive amphipod.

Phantom Lake Spring: Phantom Lake Spring is located at the base of the Davis Mountains about 9.7 km (6 mi) west of Balmorhea State Park, with the 6.9 ha (17-ac) site around the spring and cave opening owned and managed by the U.S. Bureau of Reclamation (BOR). The outflow of the spring originates from a large crevice on the side of a limestone outcrop cliff. Prior to 1940, the recorded flow of this spring was regularly exceeding 0.5 cms (18 cfs). Outflows after the 1940s were immediately captured in concrete-lined irrigation canals and provided water for local crops before connecting to the District's canal system in Balmorhea State Park (Service 2013, p. 41234). Flows at Phantom Lake Spring have declined steadily over the last 70 years, and they ceased completely around 2000 (Brune 1981, pp. 258–259; Allan 2000, p. 51; Hubbs 2001, p. 306). The aquatic habitat at the spring pool has been maintained by a pumping system since that time, taking water from the deeper cave system (i.e., spring opening) and transporting it to the surface to maintain the aquatic surface habitat. Between 2002 and 2012, corresponding aquifer levels around Phantom Lake Spring are documented to have dropped 0.76 m (2.5 ft) in elevation (Service 2013, p. 41240). The Pecos gambusia occurs within all of the maintained surface aquatic habitat at Phantom Lake Spring, and occurs sympatrically with the endangered Comanche spring pupfish, the Phantom tryonia, Phantom springsnail, and diminutive amphipod.

East Sandia Spring: The smallest of the San Solomon springs, East Sandia Spring, is located near the community of Brogado approximately 3 km (2 mi) northeast of the town of Balmorhea and 7.7 km (4.8 mi) northeast of Balmorhea State Park. The spring is within a 97 ha (240 ac) preserve owned and managed by The Nature Conservancy (TNC), a private nonprofit conservation organization (Karges 2003, pp. 145–146). Historically there was an additional, smaller nearby spring outlet called West Sandia Spring. Brune (1981, pp. 385–386) reported the combined flow of East and West Sandia Springs as declining, with measurements ranging from 0.02 to 0.09 cms (0.7 to 3.2 cfs) between 1932 and 1976. In 1976, outflow from East Sandia was 0.01

cms (0.5 cfs) of the total 0.02 cms (0.7 cfs) of the two springs. In 1995 and 1996 Schuster (1997, p. 94) reported combined flow rates from both springs, which ranged from 0.01 to 0.12 cms (0.45 to 4.07 cfs), with an average of 0.05 cms (1.6 cfs). Karges (2003, p. 145) indicated West Sandia Spring has only intermittent flow, with further investigation required to ascertain if aquatic fauna still occurs there. The outflow waters from East Sandia Spring discharge to an irrigation canal within a few hundred meters from its source.

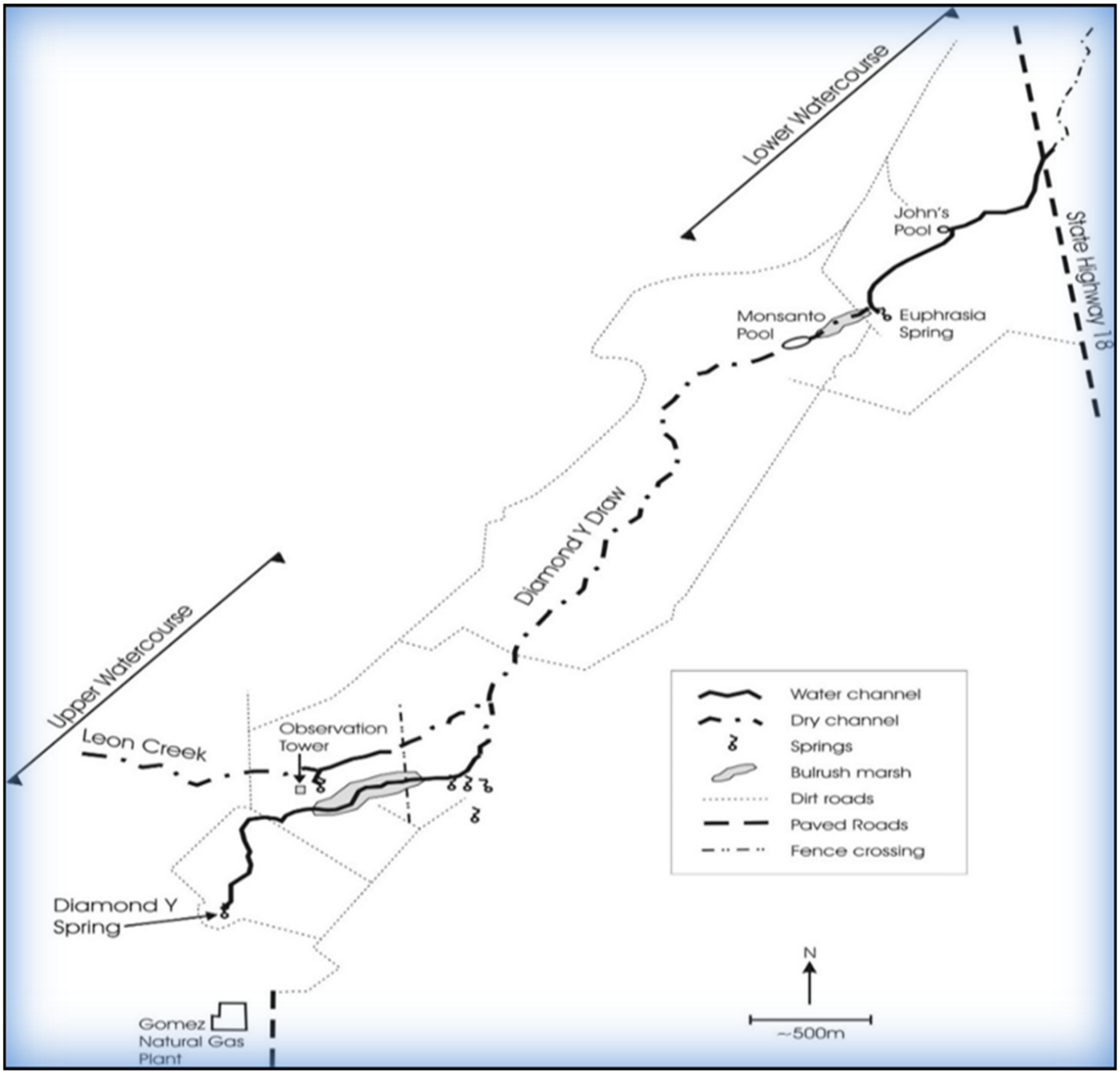
The Pecos gambusia occurs within the spring outlet, pool, and associated aquatic habitat, and occurs sympatrically with the endangered Comanche spring pupfish, the Phantom tryonia, Phantom springsnail, Pecos assiminea (*Assiminea pecos*), and diminutive amphipod. The endangered Pecos sunflower (*Helianthus paradoxus*) also occurs in wetland habitats within East Sandia Preserve adjacent to East Sandia Spring and the associated spring run.

Diamond Y Spring System, Texas: The Diamond Y Spring System is located approximately 12 km (8 mi) north of the City of Fort Stockton in Pecos County, and is within a tributary drainage of Diamond Y Draw/Leon Creek (Figure 3). Purchased in 1990, TNC owns and manages the entire surface area containing the Diamond Y Spring/Diamond Y Draw system in a 1,603 ha (3,962-ac) preserve (Karges 2003, p. 144; Hubbs et al. 2008, p. 41). The Diamond Y Spring System is composed of an upper and lower watercourse, which are only connected hydrologically by surface flows during rare large rainstorm runoff events, and they are typically separated by at least 1 km (0.6 mi) of dry stream channel. The upper watercourse is about 1.5 km (0.9 mi) long and starts at the Diamond Y Spring head pool, which drains into a small spring outflow channel (Service 2013, p. 41234).

This outflow merges with the Leon Creek drainage and flows through a marsh like meadow referred to as Diamond Y Draw. After moving through the draw, the outflow in this portion of the drainage is again referred to as Leon Creek. There are numerous springs, seeps, and wetlands within this area, which provide aquatic habitat and are spread out over a large area of the upper watercourse. The lower watercourse of Diamond Y Draw has a small headpool spring and outflow known as Euphrasia Spring. The lower watercourse is about 1 km (0.6 mi) long and contains several small, isolated pools, such as Monsanto and John's Pool, with associated seeps and wetlands within this area (Service 2013, p. 41234).

The Pecos gambusia occurs within both the upper and lower watercourses of Diamond Y Spring/Draw, and is sympatric with another federally-listed endangered fish, the Leon Springs pupfish (*Cyprinodon bovinus*), as well as several species of endangered invertebrates, the Diamond tryonia (*Tryonia adamantine),* Gonzales tryonia (*Tryonia circumstriata*), Pecos assiminea

Figure 3. Diamond Y Spring System, Texas.



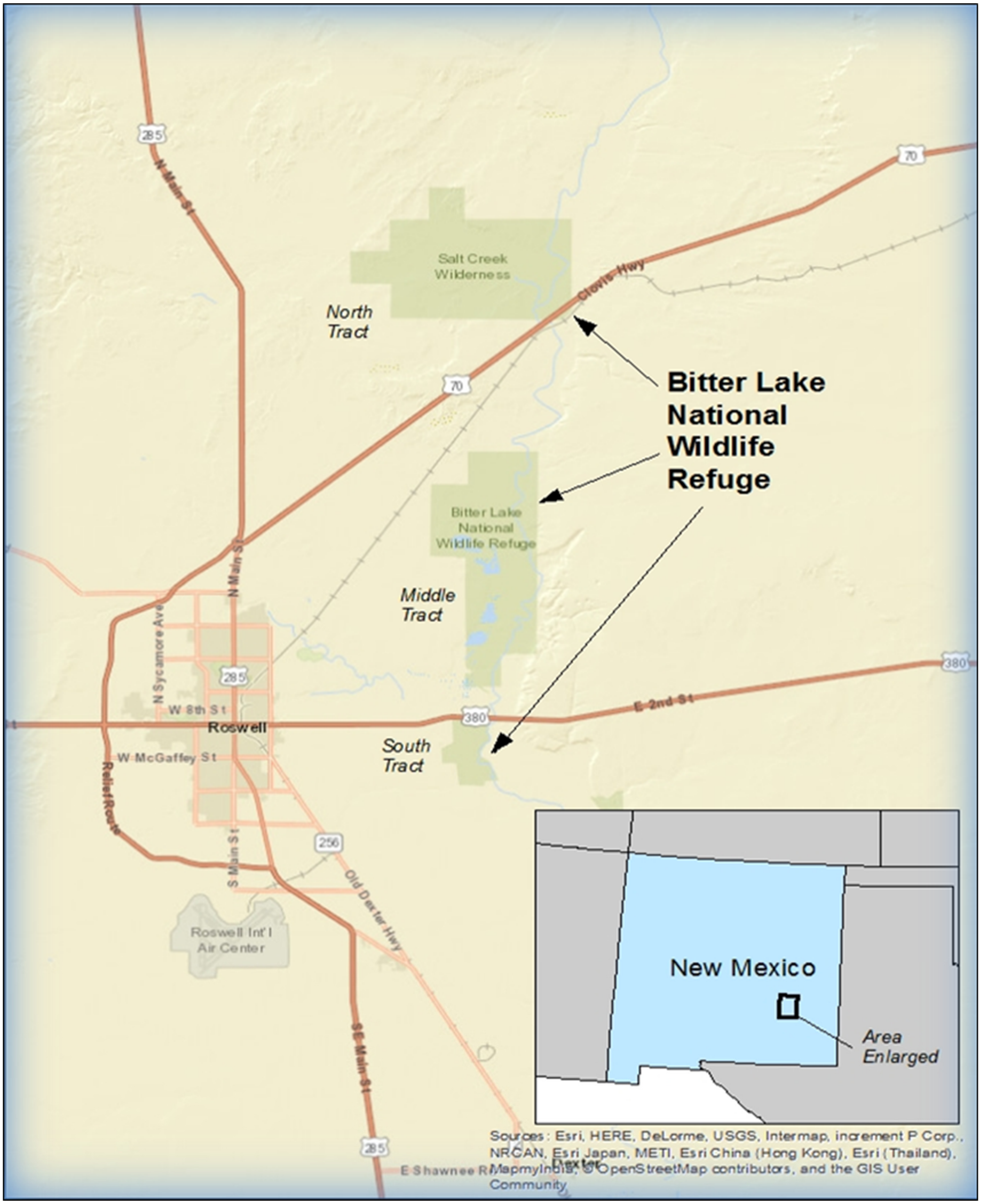
(*Assiminea pecos*), and the Pecos amphipod (*Gammarus pecos*. The endangered Pecos sunflower also occurs in wetland habitats within Diamond Y Draw adjacent to the spring and spring run habitats.

Bitter Lake National Wildlife Refuge (BLNWR), New Mexico: This refuge was established in 1937 to provide wintering habitat for migratory birds within the Pecos River watershed where the Chihuahuan Desert and Great Plains meet in New Mexico (Figure 4). The refuge is composed of three separate land units (a north, middle, and south tract), and together these tracts encompass approximately (9929 ha (24,536 ac). Scattered across the refuge are more than 70 natural sinkholes, springs, and depressions that were created by groundwater erosion of the gypsum karst topography (Service 2018).

In the early 1900s, many of these sinkholes, springs, and depressions were connected by surface flows (Echelle et al. 1989, p. 160). Historically, these systems were likely interconnected as portions of the overall Pecos River watershed. Santa Rosa and Sumner Reservoirs, built on the Pecos River, altered the pattern of runoff and eliminated flood flows that once connected isolated aquatic habitats and supplemented the shallow groundwater aquifer (Service 2004, p. 6). A declining water table by groundwater withdrawal in excess of natural recharge has eliminated surface flow since the 1970s (Echelle et al. 1989, p. 160). The waters of the various sinkholes at BLNWR vary drastically in stoichiometric conditions and many sinkholes have high salinity and hardness values that are intolerable for *Gambusia* (Bednarz 1979, p. 315-316).

The Pecos gambusia occurs in a number of the spring and sinkhole habitats that occur across the refuge, and may occur sympatrically with several endangered aquatic invertebrates, the Roswell springsnail (*Pyrgulopsis roswellensis*), Koster's springsnail (*Juturnia kosteri*), Noel's amphipod (*Gammarus desperatus*), and the Pecos assiminea snail. The endangered Pecos sunflower also occurs within BLNWR.

Figure 4. Bitter Lake National Wildlife Refuge, New Mexico.



Bitter Lake National Wildlife Refuge

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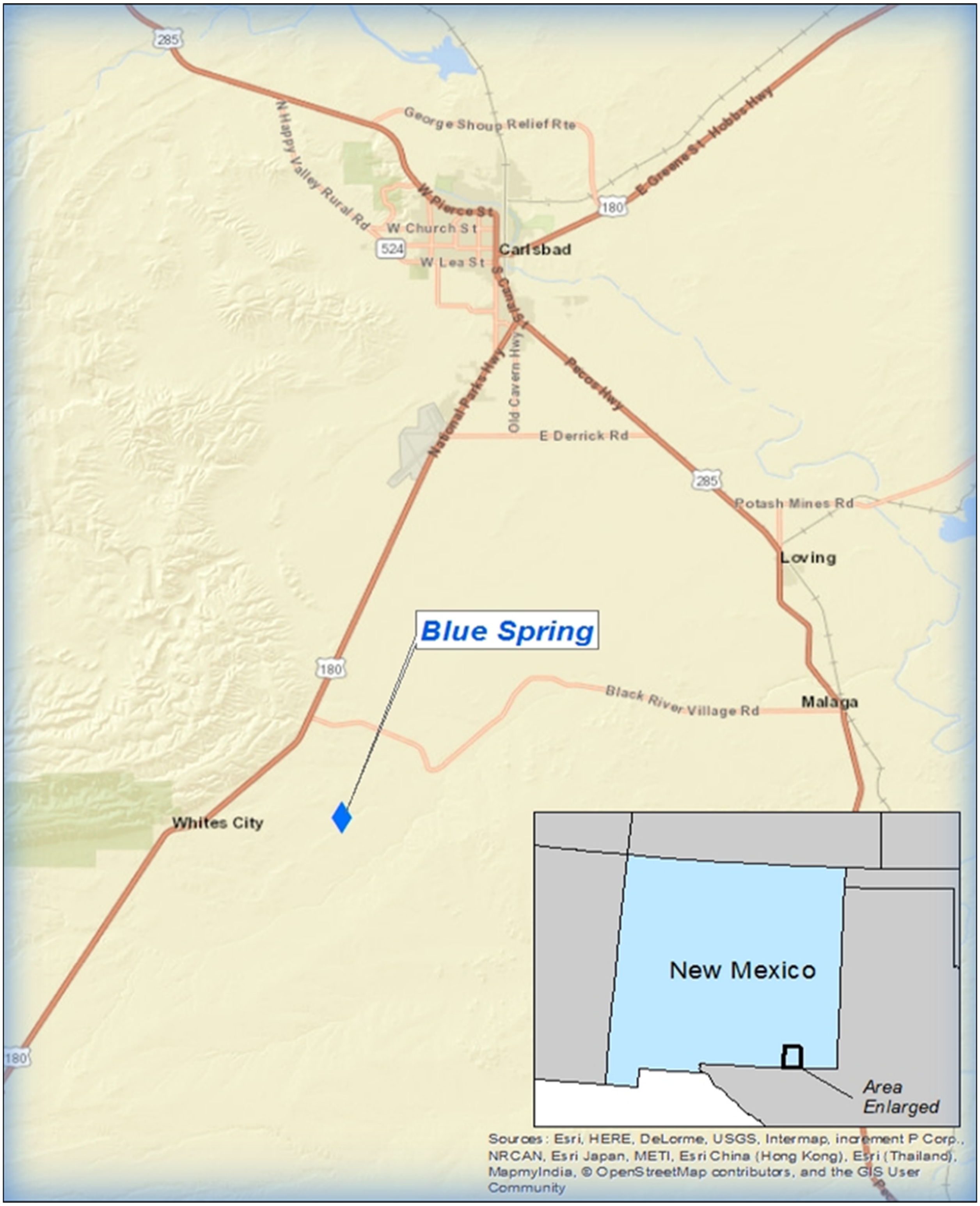
Blue Spring, New Mexico: Blue Spring is a privately owned spring composed of two separate watercourses, an upper and a lower, which differ significantly in their overall habitat characteristics (Figure 5). The upper watercourse is fed by two major spring openings in which water flows from one of the spring openings in a rock formation down to a small pool, which is fed by the second spring located at the bottom of the pool. The upper watercourse is approximately 1.5 km (0.93 mi) in length (Echelle et al. 1989, p. 161). Water from the pool flows through a narrow channel that receives additional flow from a number of seepage spring-fed marshes.

The long natural portion of the lower watercourse is approximately 2 to 2.5 km (1.25 to 1.55 mi) long, and can be diverted into a system of irrigation canals, with the main canal being over 5 km (3.1 mi) in length. The lower watercourse of Blue Spring begins at an irrigation box and eventually empties into the Black River, approximately 15 km (9.3 mi) away (Echelle and Echelle 1980, p. 9; Echelle et al. 1989, 162-163). U.S. Geological Survey (USGS) records maintained from 1952 until 1988 showed an average spring-flow discharge of 0.24 to 0.44 cms (8.6 to 15.7 cfs), and did not indicate a declining trend over this time-period (Echelle et al. 1989). The Pecos gambusia occurs throughout the available aquatic habitat at Blue Spring, but tends to be more abundant in the permanently flowing upper watercourse and relatively uncommon in the lower watercourse (Echelle et al. 1989, p. 161). No other federally-listed species occurs in Blue Spring.

Figure 5. Blue Spring, New Mexico.



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

No new information.

2.3.1.7 Other:

No new information.

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

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

Water Quantity: Spring Flow Declines

San Solomon Spring System: Within the San Solomon Spring System, habitat for the Pecos gambusia is entirely dependent on flows from springs in the Balmorhea area. In the extreme case, if the flow from a spring ceased, then all of the species' habitat downstream of that spring would be lost. Leon Springs, located about 64 km (40 mi) east of Balmorhea in Pecos County, was measured at 0.5 cms (18 cfs) in the 1930s and was also known to contain rare fish, but ceased flowing in the 1950s following significant irrigation pumping (Brune 1981, p. 359). This also occurred in Comanche Springs in Fort Stockton, the type locality of the Comanche Springs pupfish, in 1961 (Brune 1981, p. 358). Several other springs in the Toyah basin, including Alamo, Irving, Buck, Hoban, Weinacht, Santa Isabel, and Splittgarber Springs, went dry around the same period (Brune 1981, pp. 383-386; Schuster 1997, p. 61).

Springs in this area are clearly vulnerable to desiccation. Waters from Phantom Lake Spring emerge at a higher elevation than other springs in the Balmorhea system, resulting in Phantom Lake Spring being the first to impacted by declining groundwater levels (Brune 1981, p. 259). Since regular measurements began in 1948, discharge from Phantom Lake Spring declined until it reached 0 cms (0 cfs) in 1999. Today, there is no natural outflow from Phantom Lake Spring and spring flow is artificially maintained with pumps.

Although long-term data are scarce, San Solomon Spring flows have declined somewhat over the history of record, but not as much as Phantom Lake Spring (Schuster 1997, p. 82; Sharp et al. 1999, p. 4-5). San Solomon Spring discharges are usually in the 0.7 to 0.8 cms (25 to 30 cfs) range (Schuster 1997, p. 82, Sharp et al. 1999, p. 5) and are consistent with the theory that the water bypassing under Phantom Lake Spring are later discharged at the San Solomon Spring. Additionally, Brune (1981, pp. 384-385) reported declining discharges from Giffin, West Sandia, East Sandia, and Saragosa springs.

In recent decades, Giffin Spring has maintained a near constant 0.08 to 0.11 cms (3 to 4 cfs) outflow (Ashworth et al. 1997, p. 6), while West Sandia Spring has ceased flowing over long periods of time (Schuster 1997, p. 93). East Sandia had measured discharges in 1995 and 1996 ranging from 0.01 to 0.12 cms (0.45 to 4.07 cfs) (Schuster 1997, p. 94). Saragosa Spring failed in the late 1970s (Brune 1981, p. 386) and currently provides no habitat for the Pecos gambusia (Service 2004, p. 16).

The exact cause or causes for this decline in spring flow are unclear. Some of the most likely reasons are groundwater pumping of the supporting aquifer and decreased recharge of the aquifer from drought. Ashworth et al. (1997, pp. 1-13) provided a brief study to examine the cause of declining spring flows in the Toyah Basin. This study suggested that recent declines in spring flows are more likely to be the result of diminished recharge due to the extended dry period rather than from groundwater pumping (Ashworth et al. 1997, p. 5). Although certainly a factor, drought is unlikely the only reason for the declines as the drought of record in the 1950s had no effect on the overall flow trend (Allan 2000, p. 51; Sharp 2001, p. 49). Sharp et al. (1999) further proposed that the decline in flows is most likely the result of groundwater pumping in this region.

An assessment of the springs near Balmorhea by Sharp (2001, p. 49) concluded, "The effects of humans on the Toyah Basin aquifer have been significant. Irrigation pumpage increased rapidly after 1945. Many springs in the area have since ceased to flow (Brune 1981, pp. 382-383). Irrigation pumpage from the Toyah Basin lowered water-table elevations and created a cone of depression (that is a lowering of the groundwater elevation around pumping areas). Thus, pumpage totals altered the regional flow-system discharge zone from the Pecos River to irrigation wells within the Toyah Basin (Boghici 1997, pp. 100-108; Schuster 1997, pp. 16-19). Recent declines of pumpage for irrigation because of economic conditions have allowed partial recovery of water levels, but it seems doubtful that predevelopment conditions will be achieved."

The TWDB (2005, pp. 1-120) provided a thorough review of the hydrogeology and the regional flow system for the springs that support the Pecos gambusia. The complexity of the aquifer system and the limited availability of data result in a high level of uncertainty about the cause of spring flow declines. However, the report concluded that, "…if most of the base flow to the springs consists of ancient groundwater that accumulated long ago, any extraction of this water from the system anywhere along the flow path may adversely affect water levels" (TWDB 2005, p. 108). Management and conservation of these aquifers is the key for ensuring the continued survival of rare species in the spring habitats (Bowles and Arsuffi 1993, p. 327).

In 2016, the Apache Corporation announced the discovery of oil and gas deposits in the Delaware Basin in the Trans-Pecos region of western Texas, primarily within southwestern Reeves County. This oil and gas field, referred to as "Alpine High," is approximately 161,874 ha (400,000 ac) in size and anticipated to hold more than 2.12 trillion cm (75 trillion cf) of gas and over 3 billion barrels of oil. Apache Corporation has secured leases on over 141,640 ha (350,000 ac) and is anticipating 2,000 to 3,000 future drilling locations over the next 20 years (TPWD 2017, p. 5).

The four springs within the San Solomon Spring system (San Solomon, Giffin, Phantom Lake Spring, and East Sandia) which support the Pecos gambusia all have the potential to be impacted by oil and gas exploration and development within this region. A chief concern with the Alpine High oil and gas development is use of groundwater for natural gas extraction by hydraulic fracturing, or fracking. With 2,000 to 3,000 extraction wells planned and each well typically requiring 2 to 5 million gallons (7.6 to 18.93 million liters) of water, an estimated 4 to 5 billion gallons (15.14 to 18.93 billion liters) of water will be needed for future operations (TPWD 2017, p. 5).

The sources of the water to be used for the fracking operations is currently unknown. As discussed previously, numerous historically flowing springs within Reeves, Pecos, and other nearby counties that once supported habitat for the Pecos gambusia have ceased to flow, and all of the springs within the San Solomon Springs System have exhibited a declining trend in flow over time. Pumping from the source aquifers within the regional flow system could lead to further declines in flow within the San Solomon Springs system and cause some springs to cease flowing entirely. Additional concerns include direct and indirect impacts to groundwater and surface water quality resulting from drilling activities, such as groundwater or surface water contamination from leaks and spills.

Apache Corporation's Alpine High oil and gas extraction activities in western Texas are in the beginning stages of development. Therefore, many uncertainties exist regarding potential impacts to water quantity and quality within the San Solomon Spring system over the lifetime of the planned operations and beyond. However, Apache's Alpine High activities have the potential to place significant demands on water resources in the region and could have negative short and long-term impacts on water quantity and quality of the San Solomon Spring System. In response, TPWD in 2016 initiated the Trans-Pecos Oil and Gas Working Group, a cooperative group of state, federal, and non-governmental partners. The working group meets to discuss issues related to oil and gas development in west Texas, to develop partnerships, provide recommendations, and implement on-the-ground measures to conserve and protect the water quantity, quality, and rare and imperiled species of the region (TPWD 2017, entire).

Diamond Y Spring System: Diamond Y Spring is the last major spring still flowing in Pecos County, Texas. Pumping of the regional aquifer system for agricultural production of crops has resulted in the drying of most other springs in this region (Brune 1981, p. 356). Other springs that have already failed include nearby Comanche Springs and Leon Springs (Brune 1981, p. 358; Scudday 1977, p. 515). Comanche Springs was once a large surface spring in Fort Stockton, Texas, about 13 km (8 mi) from Diamond Y Draw that flowed at more than 1.18 cms (42 cfs)(Brune 1981, p. 358). Comanche Springs ceased flowing by 1956, resulting in the extirpation of many species of fish, amphibians, and other fauna (Scudday 1977, p. 516). Leon Springs, located upstream of Diamond Y in the Leon Creek watershed, was measured at 18 cfs (0.51 cms) in the 1930s and was also known to contain rare fish, but ceased flowing in the 1950s following significant irrigation pumping (Brune 1981, pp. 358-359).

The Diamond Y upper watercourse was estimated by Veni (1991, p. 86) to have a total discharge of 0.05 to 0.08 cms (2 to 3 cfs), and total discharge from the lower watercourse of 0.04 to 0.05 cms (1 to 2 cfs). The nature of the system with many diffuse and unconfined small springs and seeps makes the estimates of water quantity discharging from the spring system difficult to attain. Additionally, there have been no continuous records of spring flow discharge at Diamond Y Spring to determine any trends in spring flow. However, many authors (Veni 1991, p. 86; Echelle et al. 2001, p. 27; Karges 2003, pp. 144–145) have described the reductions in available surface waters observed compared to older descriptions of the area (Kennedy 1977, p. 93; Hubbs et al. 1978, p. 489; Taylor 1985, pp. 4, 15, 21). The amount of aquatic habitat at Diamond Y may vary to some degree based on annual and seasonal conditions, but the overall trend in the reduction in the amount of surface water over the last several decades is apparent. The precise reason for the declining spring flows remains uncertain, but it is presumed to be related to a combination of groundwater pumping, mainly for agricultural irrigation, and a lack of natural recharge to the supporting aquifers. In addition, future changes in the regional climate are expected to exacerbate declining flows.

Studies by Veni (1991, p. 77) and Boghici (1997, p. *v*) indicate that the spring flow at Diamond Y Spring comes from the local aquifers located west of the spring outlets. Initial studies of the Diamond Y Spring System suggested that the Edwards-Trinity aquifer was the primary source of flows (Veni 1991, p. 86). However, later studies seem to confirm that the Rustler aquifer is instead more likely the chief source of water (Boghici 1997, p. 107). The Rustler aquifer is one of the less-studied aquifers in Texas and encompasses most of Reeves County and parts of Culberson, Pecos, Loving, and Ward counties in the Delaware Basin of western Texas (Boghici and Van Broekhoven 2001, pp. 209–210). The Rustler strata are thought to be between about 250 and 670 ft (75 and 200 m) thick (Boghici and Van Broekhoven 2001, p. 207). Very little recharge to the aquifer likely comes from precipitation in the Rustler Hills in Culberson County, but most of it may be contributed by cross-formational flows from old water from deeper aquifer formations (Boghici and Van Broekhoven 2001, pp. 218–219). Groundwater planning for the Rustler aquifer anticipates that recharge (defined as the addition of water from precipitation or runoff by seepage or infiltration to the aquifer from the land surface, streams, or lakes directly into the formation or indirectly by way of leakage from another formation) on an annual basis is effectively zero (Middle Pecos Groundwater Conservation District 2010b, p. 18).

Historical pumping from the Rustler aquifer in Pecos County may have contributed to declining spring flows, as withdrawals of up to 9 million cubic meters (cm)[7,500 acre-feet (af)] in 1958 were recorded, with estimates from 1970 to 1997 suggesting groundwater use averaged between 430,000 cm (350 af) to 2 million cm (1,550 af) per year (Boghici and Van Broekhoven 2001, p. 218). As a result, declines in water levels in Pecos County wells in the Rustler aquifer from the mid-1960s through the late 1970s of up to 30 m (100 ft) have been recorded (Boghici and Van Broekhoven 2001, p. 213). We assume that groundwater pumping has had some impacts on spring flows in the Diamond Y Spring System in the past; however, they have not yet caused the main springs to cease flowing.

Future groundwater withdrawals may further impact spring flow rates if they occur in areas of the Rustler Aquifer that affect the spring source areas. Groundwater pumping withdrawals in Pecos County are expected to continue in the future mainly to support irrigated agriculture (Far West Texas Water Planning Group 2011, pp. 2-16–2-19), and will result in continued lowering of the groundwater levels in the Rustler aquifer. The latest plans from Groundwater Management Area 3 (the planning group covering the relevant portion of the Rustler Aquifer) allows for a groundwater withdrawal in the Rustler Aquifer not to exceed 90 m (300 ft) in the year 2060 (Middle Pecos Groundwater conservation District 2010a, p. 2). This level of draw down will accommodate 12.9 million cm (10,508 af) of annual withdrawals by pumping (Middle Pecos Groundwater Conservation District 2010b, p. 15). This level of pumping would be 30 times more than the long-term average and could result in an extensive reduction in the available groundwater in the aquifer based on the total thickness of the Rustler strata. Therefore, it is anticipated that this level of groundwater draw down may contribute to continued declines in spring flow rates in the Diamond Y Spring system.

Although TNC owns and manages the property surrounding the Diamond Y Spring System, it has no control over groundwater use that affects spring flow (Karges 2003, p. 144). The spring flow is very small (0.028 to 0.057 cms [1 to 2 cfs]) for Diamond Y Spring, the largest spring in the system), so any measurable decrease could prove substantial for the downstream ecosystem. Additionally, comparative analysis of maps and descriptions of the region show that the extent of surface waters in both the upper and lower watercourses of Diamond Y Draw have been reduced over the years (Echelle et al. 2001, p. 27).

Bitter Lake National Wildlife Refuge: BLNWR occurs within the Roswell

Artesian Basin of New Mexico. Use of the Roswell artesian aquifer began in 1880, and by 1905, there were at least 2,185 artesian wells in operation. By 1925, artesian flow was greatly reduced with most of the major springs reduced to near zero flow (NMDGF 2005, p. 17). Between 1927 and 1940, the water table of the Roswell alluvial aquifer was lowered by as much as 8.5 m (27.89 ft). In 1944, annual pumping exceeded recharge and by 1953, the aquifer had mostly lost artesian pressure (NMDGF 2005, p. 17). Historically, the shallow groundwater table sustained extensive lakes and marshes in sink depressions, but many of these were drained for cropland. In 1967, regulation of groundwater pumping was initiated in the Roswell basin by metering all wells and restricting discharge. The water table has risen since that time (NMDGF 2005, p. 17); however, many historical springs, such as North Spring, that harbored endemic species are still dry.

Prior to establishment of BLNWR, many of the sinkholes, depressions, and springs now within the refuge boundaries were once connected by surface flows (Echelle et al. 1989, p. 160). Historically, these systems were likely interconnected as portions of the overall Pecos River watershed. Santa Rosa and Sumner Reservoirs, built on the Pecos River, altered the pattern of runoff, and eliminated flood flows that once connected isolated aquatic habitats and supplemented the shallow groundwater aquifer (Service 2004, p. 6). The nature and timing of flows within the Pecos River have been significantly altered by reservoir operations. Prior to 1937, base flows of the Pecos River through BLNWR rarely dropped below 0.28 cms (80 cfs), and by 2005, they had dropped below 0.85 cms (30 cfs) approximately 50% of the time and 0.28 cfs (10 cfs) 20% of the time (Service 2001, p. 3). Surface water flow at BLNWR has diminished over time by groundwater pumping in excess of natural recharge, and declining water tables have eliminated surface flow since the 1970s (Echelle et al. 1989, p. 160). Bendarz (1979, p. 321) reported that the water level in the sinkholes containing Pecos gambusia was lowering at a rate of several inches per year, and Jones and Balleau (1996, p. 12) documented dry springs on Salt Creek and a reduction in spring flows on the refuge. Since the New Mexico Office of the State Engineer began measuring and controlling groundwater withdrawals, water levels in the Roswell Artesian Basin have mostly stabilized (NMDGF 2005, p. 18). BLNWR secured local water allocation rights to the refuge property in 1996, stabilizing water levels surrounding the refuge. However, because BLNWR is dependent upon the quality and quantity of its groundwater aquifer to support the habitat of the flora and fauna, including the Pecos gambusia, the principal threat to these species and habitats is the fall of the watertables in the Roswell Artesian Basin (Service 2001, p. 5-6).

Blue Spring: Presumably due to its location on private property, very little information can be found on historic or current spring flow and other natural habitat conditions at Blue Spring. A technical report conducted by the State of New Mexico – State Engineer Office (SNMSEO)(1955, p. 35) indicated that discharge from the spring had been measured at monthly intervals between October 1952 and June 1954, with observed flow ranging from 0.31 to 0.39 cms

(10.8 to 13.8 cfs). During this short period of measurements, the fluctuation in flow had shown no definite cyclical pattern. A later study done by the USGS (1963, p. 21) reported measured flow from Blue Spring between 1952 and 1961, with flow of 0.4 cms (14.1 cfs) in January 1952 and 0.23 cms (8.1 cfs) in June 1960. Between 2000 and 2018, the USGS recorded flows at Blue Spring that varied between a low of 0.22 cms (7.82 cfs) in 2011, to a high of 0.41 cms (14.4 cfs) in 2005. The most recent flow data for Blue Spring in mid-May 2018 was approximately 0.29 cms (10.1 cfs), within the range of historical flow data (USGS 2018). It appears that flows at Blue Spring have been historically stable, presumably in part due to the New Mexico Office of the State Engineer managing groundwater withdrawals within the state. However, flows at Blue Spring are susceptible to the same factors that have caused declining flows, loss of habitat, and drying of numerous springs that once supported the Pecos gambusia within New Mexico and Texas, specifically the withdrawal of groundwater from the aquifers in excess of recharge that support the springflows.

Summary

The primary threat to the continued existence of the Pecos gambusia is the degradation and potential future loss of aquatic habitat (i.e., flowing water from the spring outlets) due to the decline of groundwater levels in the aquifers that support spring surface flows. The habitat for the Pecos gambusia is exclusively aquatic and completely dependent on spring flows emerging to the surface from underground aquifer sources in all four of the known areas currently occupied by the species within New Mexico and Texas. Spring flows throughout the San Solomon Spring system, Diamond Y Spring system, and within the Roswell Basin have declined and continue to decline in flow rate, and as spring flow declines, available aquatic habitat is reduced and altered. The springs do not have to cease flowing completely to have an adverse effect on the Pecos gambusia. The small size of the spring outflows makes them particularly susceptible to changes in water chemistry, increased water temperatures during the summer, and freezing in the winter. Because these springs are small, any reductions in the flow rates from the springs can reduce the quantity and quality of available habitat for the species, which decreases the number of individuals available and increases the risk of extinction.

Pollution: Oil and Gas Activities and Other Contaminants

Diamond Y Spring System: The Diamond Y Spring system is within active oil and gas extraction fields (Echelle et al. 2001, p. 26; Karges 2003, p. 144). These activities threaten the Pecos gambusia because of the potential groundwater or surface water contamination from pollutants (Fullington and Goodloe 1991, p. 6; Veni 1991, p. 83). There are still many active wells located within about 100 m (328 ft) of surface waters. In addition, a natural gas refinery is located within 0.8 km (0.5 mi) upstream of Diamond Y Spring. Oil and gas pipelines traverse the habitat, and many oil extraction wells are located near the occupied habitat (Echelle et al. 2001, p. 26). A catastrophic spill event is possible at any time. Additionally, there are brine pits from previous drilling within feet of surface waters, which could contaminate the habitat if they were to leak. Oil and gas pipelines traverse under the spring outflow channels and marshes where the species occurs, creating a constant potential for contamination from pollutants from leaks or spills. These activities pose a threat to the habitat by creating the potential for pollutants to enter underground aquifers that contribute to spring flow or by spills and leaks of petroleum products directly into surface waters. Presently, there is no evidence of habitat destruction or modification due to groundwater or surface water contamination from leaks or spills; however, an event catastrophic to the Diamond Y Spring species from a contaminant spill or leak is possible at any time (Veni 1991, p. 83).

As an example of the possibility for spills, in 1992 approximately 10,600 barrels of crude oil were released from a 15 cm (6 in) pipeline that traverses Leon Creek above its confluence with Diamond Y Draw. The pipeline ruptured in close proximity to the channel of Leon Creek. The spill site itself is about 1.6 km (1 mi) overland from Diamond Y Spring. The pipeline was operated at the time of the spill by the Texas–New Mexico Pipeline Company, but ownership has since been transferred to several other companies. The Texas Railroad Commission has been responsible for overseeing clean-up of the spill site. Remediation of the site initially involved aboveground land farming of contaminated soil and rock strata to allow microbial degradation. In later years, remediation efforts focused on vacuuming oil residues from the surface of groundwater exposed by trenches dug at the spill site. No impacts on the rare fauna of Diamond Y Springs were observed, but no specific monitoring of the effects of the spill was undertaken (Industrial Economics, Inc. 2005, p. 4-12).

Another example of possible contaminants affecting the Diamond Y Spring system occurred in early June 2013, when an unknown, white-colored substance, described as a surface scum and clouding of the water, was reported in the lower watercourse area of the upper Monsanto Pool. A large number of Pecos gambusia were reported dead and collected in the pool area (Itzkowitz 2013, pers. comm.). It was presumed that the most likely cause of the contaminant was related to an oil and gas pad site that is approximately 328 ft (100 m) south of the upper Monsanto pool (Orsak 2013, pers. comm.).

Bitter Lake National Wildlife Refuge: Oil and gas drilling currently occurs throughout the Roswell Basin of New Mexico. This activity and associated actions can threaten the water quality of the aquifer. For example, oil and other contaminants from drilling activities throughout the basin could enter the aquifer supplying the springs at BLNWR when the limestone layers are pierced by drilling activities. As of 2004, there were at least 190 oil wells in the area surrounding BLNWR that are potential sources of contamination. The total number of wells that could potentially contaminate the underground water supply that is the source of water on the refuge has not been quantified. The Bureau of Land Management continually permits extensive natural gas development in the Pecos River flood plain just north of the boundary of the refuge middle tract (Service 2004, p. 9). Between May 2017 and May 2018, there were 19 "intentions to drill" in Chaves County according to Go-Tech, which is a database of oil and gas development and exploration actions in New Mexico (http://octane.nmt.edu/gotech/Well/wellactivity.aspx). Data collected by Crafton et al. (2018, p. 14) in a report to Congress on oil and gas activities within the National Wildlife Refuge System indicated there are currently a total of 15 oil or gas well locations at BLNWR.

In addition to oil and gas development activities, contamination of groundwater sources from industry and commercial operations in and around Roswell is well documented. For example, perchloroethylene (PCE) was discovered in the McGaffey and Main groundwater plume in Roswell in 1994 (Environmental Protection Agency (EPA) 2018, webpage). It is suspected that a dry cleaning facility that operated from 1956 to 1963, is the source of the PCE. The New Mexico Environment Department subsequently detected PCE in 13 of 16 groundwater wells in a 1995 investigation. A 5-year review by the EPA in 2017 indicated that the plume continues expand in the local groundwater resources, requiring new wells to be sampled for possible contamination (EPA 2018). This ground plume contamination was proposed for addition to the EPA's National Priority List on September 13, 2001 (66 FR 47612). This list assists the EPA in determining national priority sites that warrant further investigation of the nature and extent of environmental risks associated with the release of hazardous substances. It is not known whether this ground water plume will eventually affect water quality on the refuge or whether this contamination could impact the Pecos gambusia. However, portions of the shallow alluvial aquifer underlying Roswell are a source zone for many different contaminants that could eventually reach the Bitter Lakes spring complex (Service 2004, p. 9).

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

There is no evidence at this time that the Pecos gambusia is 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, TPWD (Title 31, Part 2, Chapter 69, subchapter J), NMDGF (Title 19, Chapter 35, Part 6), and special use permits on properties owned by the BOR and TNC in Texas.

2.3.2.3 Disease or predation:

An additional factor potentially affecting the Pecos gambusia is the introduced aquatic snail, the red-rim melania (*Melanoides tuberculatus)* and its associated gill parasite (*Centrocestus formosanus*). This exotic trematode from Asia is known to infect the gills of fish in large numbers, causing inflammation and gill tissue destruction (Mitchell et al. 2005, pp. 12-15). Surveys conducted in 1999 and in 2011 in Texas found red-rim melania at San Solomon Spring, Phantom Lake Spring, and within the Diamond Y Spring System, but not East Sandia Spring (McDermott 2000, pp. 14-15; McDermott et al. 2014, p. 215). Giffin Spring was not included as a survey site and it is unknown whether red-rim melania occurs at this location. All of these spring sites surveyed where red-rim melania was present, with the exception of the Diamond Y Spring system, were infected with the trematode. Almost 59% of Pecos gambusia collected from those three sites where red-rim melania were infected tested positive for the gill parasite (McDermott et al. 2014, p. 216). The range of the red-rim melania and parasitic trematode has expanded since 1999, in part due to relatively constant water conditions within many spring fed systems in Texas (McDermott et al. 2014, p. 216). Conditions for colonization of red-rim melania at BLNWR and Blue Spring in New Mexico may be suitable, however, little information could be found on the current status of this exotic snail at these locations. The effects of the gill parasite on the Pecos gambusia within these systems is currently unknown (Dr. Tom Brandt, 2000, pers. comm.), and requires further research.

Predation on Pecos gambusia could be a limiting factor in areas lacking submerged vegetation or other sources of cover that can provide protection from predators. Predation by green sunfish (*Lepomis cyanellus*) and largemouth bass (*Micropterus salmoides*) may have limited the introduced population of Pecos gambusia in Lake St. Francis on BLNWR and contributed to the failure of a population introduced into Geyser Spring, New Mexico. The near absence of Pecos gambusia from the head pool of Diamond Y Spring may be partly attributable to the presence of these two predators (Echelle and Echelle 1980, p. 44; Service 1983, p. 13). More research is needed to determine how predation may be affecting the Pecos gambusia's abundance and distribution in occupied habitats.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

Regulatory mechanisms, beyond those imposed by the Act, that are important for conservation of the Pecos gambusia include protections of the species by TPWD, NMDGF, BOR, TNC, and the Service.

State of Texas Listing

The State of Texas lists the Pecos gambusia as endangered under Title 31, Part 2 of the Texas Administrative Code. TPWD regulations prohibit the taking, possession, transportation, or sale of any animal species designated by state law as endangered or threatened without the issuance of a permit.

Some protection for the habitat of this species is provided with the land ownership of San Solomon Spring at Balmorhea State Park; however, there is no protection by state law for habitat or minimum stream or spring flows for state-listed species. State of Texas protections do not address the most significant threats to the species associated with habitat loss or protection for maintaining groundwater levels to ensure continuous spring flows.

State of New Mexico Listing

The State of New Mexico lists the Pecos gambusia as endangered under Title 19, Chapter 33 of the New Mexico Administrative Code. NMDGF regulations prohibit the taking, possession, transportation, exportation, processing, sale or offering for sale or shipment of any species of fish or wildlife listed as threatened or endangered by the State of New Mexico. The NMDGF may issue permits for authorized activities, such as wildlife for education, law enforcement, research, or scientific purposes.

There is no protection by state law for habitat or minimum stream or spring flows for state-listed species. Therefore, State of New Mexico protections do not address the most significant threats to the species associated with habitat loss or protection for maintaining groundwater levels to ensure continuous spring flows.

Bureau of Reclamation: Phantom Lake Spring

Some protection for the habitat of the Pecos gambusia is provided with the land ownership of Phantom Lake Spring by the Bureau of Reclamation (BOR). However, this land ownership provides protection to the spring outflow channels only and provides no protection for maintaining groundwater levels to ensure continuous springflows. As already indicated, Phantom Lake Spring currently has no natural flow to the wetland ciénega habitat at the mouth of the cave that is habitat for the Pecos gambusia, but instead is totally reliant on a pumping system to move water from deep in Phantom Cave to maintain the surface habitat. Without the pumps or a catastrophic failure of the system, all of the surface aquatic habitat could be eliminated and the Pecos gambusia population completely eliminated from the site.

The Nature Conservancy: Diamond Y Spring System and East Sandia Spring

Some protection for the habitat of the Pecos gambusia is provided with the land ownership of Diamond Y Spring and East Sandia Spring by TNC. However, this land ownership provides protection to the spring outflow channels only and provides no protection for maintaining groundwater levels to ensure continuous springflows. Additionally, TNC does not own the mineral rights to either of these properties; therefore, TNC does not have authority to regulate activities such as seismic exploration or additional oil and/or gas development on these properties, which may have short and/or long-term negative impacts to the habitat the Pecos gambusia depend on.

U.S. Fish and Wildlife Service - Bitter Lake National Wildlife Refuge

Some protection for the habitat of the Pecos gambusia is provided with the land ownership of BLNWR. Additionally, the Service engages in management and conservation activities for the long-term benefit of the species within the refuge. However, this land ownership and management provides protection to the sinkholes, depressions, and spring outflow channels only and provides no protection for maintaining groundwater levels to ensure continuous springflows.

Summary

The threats to the Pecos gambusia from the lack of regulatory mechanisms are considered low at this time because the species occurs primarily on properties under Federal, State, and private ownership which are managed to provide a strong level of protection for the factors under their control.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Competition

The common western mosquitofish has been regarded as being detrimental to populations of small native fishes (Bednarz 1979, p. 319). The western mosquitofish shares essentially the same feeding habits as the Pecos gambusia; therefore, competition for resources could negatively impact the Pecos gambusia where these species co-occur (Bednarz 1979, p. 317). Additionally, Bednarz (1979, pp. 317, 320) found that western mosquitofish had higher fecundity rates, as indicated by the number of embryos in gravid females, and faster maturation rates than the Pecos gambusia. These factors may explain why the western mosquitofish is typically dominant when the two species are sympatric (Bednarz 1979, p. 318). Because of their earlier maturation and higher reproductive rate, mosquitofish are able to increase their population size more effectively during the breeding period and thus out populate Pecos gambusia (Bednarz 1979, p. 321). Where these species occur sympatrically, some habitat partitioning occurs where Pecos gambusia tends to correspond strongly with stable habitats near spring flows and seepages, and the western mosquitofish tends to be found in unstable habitats such as isolated pools and downstream waters removed from spring influence (Bednarz 1979, p. 319; Service 1983, p. 13). Pecos gambusia can compete with western mosquitofish in spring-fed habitats with stable environmental conditions; however, the western mosquitofish will displace the Pecos gambusia from environments with fluctuating water conditions (Bednarz 1979, p. 319). It is unknown how long Pecos gambusia can compete with the western mosquitofish in these habitats with unstable environmental conditions, but over time can be a potentially decimating factor to Pecos gambusia populations (Bednarz 1979, p. 13).

Another *Gambusia* species, the largespring gambusia, poses perhaps an even greater competitive threat to the Pecos gambusia than the naturally occurring western mosquitofish (Echelle and Echelle 1980, p. i). Largespring gambusia occurs in west Texas as a result of introductions from springs near San Marcos, Texas. Largespring gambusia was documented in Comanche Springs as early as 1937, and from the Balmorhea area by 1956. Because both species occupy the same types of habitat (i.e., stable, stenothermal spring-fed waters), the largespring gambusia may outcompete the Pecos gambusia in those systems, negatively affecting the abundance of the species (Hubbs et al., 1995, p. 325). Studies conducted noted that the history of collections in the Balmorhea area suggested that the largespring gambusia was replacing Pecos gambusia in that system (Echelle and Echelle 1980, p. i; Lewis et al. 2013, p. 235). The largespring gambusia once occurred in all of the spring systems in western Texas where the Pecos gambusia is presently known to occur. However, the largespring gambusia was eliminated from Diamond Y Spring and Phantom Lake Spring, and recent observations suggest that the Pecos gambusia populations in those two systems are stable (Lewis et al. 2013, p. 235). More studies are needed to determine the long-term effects of the largespring gambusia on the Pecos gambusia in the habitats where they co-occur.

Hybridization

Whole populations of fish species can be quickly lost due to hybridization with an introduced, non-native, related species. For examples, see Pecos pupfish (*Cyprinodon pecosensis*) in the Pecos River (Echelle and Connor 1989, pp. 725-726) and Leon Springs pupfish in Diamond Y Spring (Echelle and Echelle 1997, pp. 159-160). The Pecos gambusia is known to hybridize with both the western mosquitofish and the largespring gambusia, with hybridization most often occurring with western mosquitofish (Service 1983, p. 14). The levels of hybridization are primarily determined by how close the genetic relationship is between the two species, how recently the species have been in contact with one another, and the relative abundance of the species (Echelle and Echelle 1980, p. 48). Hybridization rates between western mosquitofish and Pecos gambusia typically occur at low rates, presumably due to *Gambusia* males courting females of their own species more frequently than that of other species and defined structural differences in the female genitalia. These differences in behavior and genital structure probably act to isolate reproductive mechanisms (Bednarz 1979, p. 319). Rodriguez (2017, pp. 5, 38) noted that hybridization between Pecos gambusia and largespring gambusia were at least partially isolated due to habitat partitioning and differences in physical and behavioral reproductive characteristics. More research is needed to determine patterns and levels of introgression of these two species with the Pecos gambusia, and how this may be affecting the species.

Climate Change

Our analyses under the Endangered Species Act include consideration of ongoing and projected changes in climate. The terms “climate” and “climate change” are defined by the Intergovernmental Panel on Climate Change (IPCC). The term “climate” refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007a, p. 78). The term “climate change” thus refers to a change in the mean or variability of one or more measures of climate (for example, temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2007a, p. 78).

According to the IPCC (2007b, p. 1), “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.” Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1,300 years (IPCC 2007b, p. 1). It is very likely that over the past 50 years cold days, cold nights, and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent (IPCC 2007b, p. 1). It is likely that heat waves have become more frequent over most land areas, and the frequency of heavy precipitation events has increased over most areas (IPCC 2007b, p. 1).

The IPCC (2007b, p. 6) predicts that changes in the global climate system during the 21st century are very likely to be larger than those observed during the 20th century. For the next two decades a warming of about 0.2°C (0.4°F) per decade is projected (IPCC 2007b, p. 6). Afterwards, temperature projections increasingly depend on specific emission scenarios (IPCC 2007b, p. 6). Various emissions scenarios suggest that by the end of the 21st century, average global temperatures are expected to increase 0.6 to 4.0°C (1.1 to 7.2°F) with the greatest warming expected over land (IPCC 2007b, pp. 6-8).

Localized projections suggest the southwest may experience the greatest temperature increase of any area in the lower 48 States (IPCC 2007b, p. 8). The IPCC also predicts that hot extremes and heat waves will increase in frequency and that many semi-arid areas like the western United States will suffer a decrease in water resources due to climate change (IPCC 2007b, p. 8). Model projections of future climate in southwestern North America show a transition to a more arid climate that began in the late 20th and early 21st centuries (Seager et al. 2007, p. 1183). An increased risk of drought in the southwest could occur if evaporation exceeds precipitation levels in a particular region due to increased greenhouse gases in the atmosphere (CH2M HILL 2007, p. 18). A reduction of recharge to aquifers and a greater likelihood for more extreme droughts, such as the droughts of 2008 to 2009 and 2011, were identified as potential climate change related impacts to water resources (CH2M HILL 2007,

p. 23). Extreme droughts in Texas are now much more probable than they were 40 to 50 years ago (Rupp et al. 2012, pp. 1053–1054).

Expected future warming from climate change could decrease overall availability of water recharging to aquifers in western Texas and eastern New Mexico. If this were to occur, then further declines in spring flows that have already occurred within the habitats that the Pecos gambusia depends would continue. These declines would be directly due to decreases in recharge from declining precipitation, because the aquifer is dependent on rainfall precipitation for recharge (Anaya and Jones 2009, p. 47). Mace and Wade (2008, p. 659) also expected the Edwards-Trinity Aquifer to be susceptible directly to climate change because the karstic nature (porous rocks) of the aquifers provides quick recharge from precipitation events. In other words, rainfall entering the Edwards-Trinity Aquifer spends little time in storage underground, providing spring flows with very little supply buffer during extended periods of drought.

Indirectly, any declines in precipitation or increases in evaporation rates from climate change could result in increases in groundwater pumpage. Climate has a significant effect on the amount of groundwater pumpage. Within Texas, Anaya and Jones (2009, p. 48) noted declines from the Edwards-Trinity Aquifer because of increased irrigation pumpage during drought times, and Mace and Wade (2008, p. 664) also concluded that increasing pumping rates may be one of the indirect effects of climate change on aquifers.

Other direct effects of climate change on the physical and biological environment of the Pecos gambusia are possible, but difficult to predict as no formal vulnerability assessment has been completed. The Pecos gambusia may be sensitive to the effects of climate change because its habitat is closely dependent on stable flows. The spring habitats of the fish is dependent on groundwater levels that are directly influenced by precipitation patterns, which could be altered as a result of climate change.

Other indirect climate change effects to water quality, non-native species, disease susceptibility, or other factors are possible. Warmer water and poor water quality (that is, low dissolved oxygen) tend to increase breathing rates in fish, making them more vulnerable to gill parasite infection (McDermott 2000, p. 19). In addition, the red-rimmed melania is more tolerant of warmer temperatures compared to native snail species (Weir and Salice 2012, p. 390). While it appears reasonable to assume that the Pecos gambusia may be affected by climate change, we lack sufficient certainty to know specifically how climate change will affect the species.

Small Population Size and Stochastic Events

The Pecos gambusia is susceptible to threats associated with small population size and impacts from stochastic events. The risk of extinction for any species is known to be highly inversely correlated with population size (Pimm et al. 1988, pp. 774-775; O'Grady et al. 2004, pp. 516, 518). In other words, the smaller the population the greater the overall risk of extinction. True population size estimates have not been generated for this species, but the small areas of suitable habitat severely limits the number of individuals. Small population sizes can also act synergistically with other traits (e.g., habitat specialization or limited distribution) to greatly increase risk of extinction (Davies et al. 2004, p. 270). Stochastic events from either environmental factors (e.g., severe weather) or demographic factors (e.g., random birth and death rates) are also heightened threats to species with small population sizes (Melbourne and Hastings 2008, p. 100).

2.4 Synthesis

The best available information indicates that the primary threats to the Pecos gambusia are: 1) habitat loss from the potential loss of spring flow due to a decline in groundwater levels, 2) competition and hybridization with the western mosquitofish and the largespring gambusia, 3) predation of the Pecos gambusia by species such as green sunfish and largemouth bass, and 4) potential contamination of habitat from local oil and gas activities, all of which are compounded by the small size and number of populations of the Pecos gambusia currently existing in the wild.

The information reviewed indicates that impacts to spring flows from significant increase in groundwater use or declines in recharge are likely to occur in the upcoming decades. Many springs within the historic range of the Pecos gambusia in New Mexico and Texas with similar groundwater sources have failed in the past 50 years, and most of the remaining springs have shown declining trends in outflow. Since the development of the 1983 Recovery Plan, one spring habitat (i.e., Phantom Lake Spring) with a population of Pecos gambusia has gone dry, and has since been maintained artificially by a pump system. In addition, there is much uncertainty in the San Solomon Spring system over near future groundwater withdrawals and/or contamination that may result from the "Alpine High" oil and gas development and "fracking" activities in that region over the next 20 years. Therefore, the magnitude of impact on the Pecos gambusia from the loss of spring flow is extremely high.

Because the range of the species is limited to a small number of locations, habitat modification due to a decline in spring flows could result in additional local extirpations and eventual extinction in the wild. Although there have been conservation efforts at Phantom Lake Spring and San Solomon Spring that have improved Pecos gambusia habitat, these efforts would be all for naught if spring flow continued to decline. In addition, there are no currently established captive refugium stocks for possible reintroduction efforts in the event of unforeseen or catastrophic losses of populations in the wild.

Secondary threats to the species include the threats from hybridization and competition from both the western mosquitofish and the largespring gambusia, habitat modification from water quality degradation, local habitat changes, predation, and the introduction of a disease, parasite, or non-native species. None of these threats acting alone in otherwise robust populations are likely to result in substantial threats to the species, but together or in small populations, any of these could negatively impact the Pecos gambusia.

Climate change is another source of potential threats to the species. All possible impacts associated with future climate change cannot presently be reliably assessed. However, accelerating climate change could exacerbate any of the threats already considered or could result in entirely new threats that are not conceived at this time. Subtle but significant changes in the ecosystem of the Pecos gambusia resulting from climate change in the foreseeable future of 50 to 100 years could cause the species' extinction in the wild and presents a high magnitude threat.

All threats, both primary and secondary, have remained constant or increased since the listing of the Pecos gambusia and final recovery plan in 1983. Some of the threats, specifically, increased susceptibility to the gill parasite and climate change, are novel threats that have emerged since recovery plan development. Although the creation of additional habitat has increased the abundance of Pecos gambusia in some populations, the species as a whole remains vulnerable. All of the threats to the species must be considered in the context of a fish with an extremely small range, little to no opportunity for movement (i.e., relocation), a small population size, and a short life span. Therefore, the magnitude of impact of any potential threat or future stochastic event is exceptionally high. Any events negatively affecting the species or its habitat could result in local population extinctions, or with potential range-wide changes in water quantity, quality, or other changes in habitat over time due to the effects of a threat such as climate change, could cause the extinction of the species in the wild. Therefore, we recommend that the Pecos gambusia retain its endangered status.

3.0 RESULTS

3.1 Recommended Classification:

____ **Downlist to Threatened**
____ **Uplist to Endangered**
____ **Delist (*Indicate reasons for delisting per 50 CFR 424.11):***
    ____ *Extinction*
    ____ *Recovery*
    ____ *Original data for classification in error*
__X__ **No change is needed**

3.2 New Recovery Priority Number: 11

Brief Rationale: The degree of threat to the species is moderate, meaning the Pecos gambusia will not face extinction in the immediate future if recovery is not imminent. This is due to the relatively stable and protected populations at protected sites. Although some populations are vulnerable to extirpation (e.g., Phantom Lake Spring), other populations are not in immediate danger due to the relatively robust populations, habitat monitoring and protection by BLNWR, TPWD, BOR, and TNC, and large spring flows in San Solomon Spring which have only declined slightly in the past 40 years. The recovery potential is considered low due to threats, particularly declining spring flows, hybridization and competition with other *Gambusia* species, oil and gas activities, and climate change, which are pervasive on-going threats that are difficult to alleviate.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

The following recommendations are provided to direct actions in the coming years to further the recovery of the Pecos gambusia. These recommendations are based on the species recovery plan (Service 1983, entire) and potential new threats to the species not originally considered under the plan, such as extensive oil and gas development within the San Solomon Springs system, the invasive red-rim melania and associated gill parasite, and climate change. The recommended actions are to:

I. Cooperate with Federal, State, and NGO landowners to protect habitat

While Pecos gambusia populations located on private property (i.e., Blue Spring and Giffin Spring) are important to the long-term conservation and recovery of the species, most of the conservation actions for the Pecos gambusia require the participation of the Service, BOR, TPWD, and TNC. Therefore, it is vital to maintain open dialogue and regular communications between these federal, state, and NGO landowners interested in conservation and recovery of the species.

II. Monitor water quantity and quality

Long-term water quality and quantity monitoring should be undertaken for the spring outflows and downstream spring dependent habitats of the Pecos gambusia throughout its current range. Some limited spring flow and water quality monitoring is currently underway by TPWD at San Solomon Spring, and by other researchers at Diamond Y Spring and East Sandia Spring. These efforts should continue and be expanded to other Pecos gambusia locations to provide data on long-term changes in spring flow rates, aquifer levels and flow paths, temperatures, water chemistry parameters, contaminants, and other biotic and abiotic factors that may have long-term impacts to the species or habitats. This is especially important given the significant future oil and gas development activities in and around the San Solomon Spring system that are expected to occur over the next 20 years. (Recovery Plan Task 1.22 [Service 1983, p. 22])

III. Monitor fish populations and habitat

Monitoring of Pecos gambusia populations should be undertaken on a regular basis to establish baseline data on status, abundance, and trends of the species in those occupied habitats. Monitoring should also cover areas that are lacking in recent abundance estimates, especially those areas where recent habitat restoration/improvement efforts have occurred (i.e., San Solomon and Phantom Lake springs), or recent introductions of new populations into habitats have occurred, such as at BLNWR. Coincident with population monitoring, monitoring of habitat conditions should occur. Habitat conditions such as potential water quality or quantity changes (decreases in amount of available habitat, potential contaminants), changes in abundance and type of aquatic or shoreline vegetation, and any other indicators of change in habitat quality should be monitored. Special attention should be made to monitor pump system integrity and function at Phantom Lake Spring. [Recovery Plan Task 1.11 (Service 1983, p. 22)]

IV. Enhance existing habitats

The existing habitat of the species should be improved when opportunities arise, only after evaluating the impacts on other endangered species within the system. This includes monitoring restoration efforts at San Solomon Spring and Phantom Lake Spring, and focusing on improving habitat in the remainder of the areas in New Mexico and Texas known to be occupied by the species. [Recovery Plan Task 1.23 (Service 1983, p. 23)]

V. Monitor genetic status of populations

Hybridization and introgression of western mosquitofish and largespring gambusia has the potential to significantly impact existing Pecos gambusia populations. Periodic monitoring of genetic status should be conducted to establish a quantifiable baseline status of the species sufficient to document future trends in the populations. Monitoring should include relative abundance of Pecos gambusia compared to western mosquitofish and largespring gambusia, and the proportion of hybrid fish based on genetic sampling. [Recovery Task 1.5 (Service 1983, p. 23)]

VI. Monitor for effects of the gill parasite

Pecos gambusia should be routinely inspected for presence of gill parasites in all populations. The host snail and parasites should be counted to determine trends in parasite load and host snail abundances through time. Any observations of adverse effects of the gill parasites on individual Pecos gambusia should be recorded.

VII. Evaluate the need to establish a captive refugia stock

Because of the small number of existing populations currently known in New Mexico and Texas, the establishment of a captive refugia stock of the species to protect against losses of populations in the wild, maintain genetic diversity, and have fish available for reintroduction into historical habitats or after a catastrophic loss of a population, or to supplement existing populations. (Recovery Plan Task 4.0 [Service 1983, p. 26])

VIII. Conduct climate change vulnerability analysis

Studies should be initiated to evaluate the vulnerability of Pecos gambusia to the future impacts associated with climate change. For example, direct studies should be undertaken to determine thermal preferences, tolerances and effects of temperature on life history parameters that influence Pecos gambusia population dynamics. Studies should consider the effects of accelerating climate change on future groundwater levels and water temperatures at spring outlets.

IX. Update the recovery plan

The recovery plan should be updated to include objective and measurable criteria that take into consideration all of the threats to the species, including climate change. This is currently considered the lowest priority action because other conservation actions described in this 5-year review should be conducted first to accomplish tangible benefits for conservation of the species.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the Pecos Gambusia (*Gambusia nobilis*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Review Conducted By: Clayton Napier, Austin Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve ______________________ Date July 6, 2018

Appendix I: Site Photos

SAN SOLOMON SPRING, REEVES COUNTY, TEXAS

Clark Hubbs Ciénega, Balmorhea State Park

San Solomon Ciénega, Balmorhea State Park

Refuge canal, Balmorhea State Park

Comanche Springs pupfish and Gambusia spp., Clark Hubbs Ciénega

PHANTOM LAKE SPRING, JEFF DAVIS COUNTY, TEXAS

Phantom Lake Spring wetland ciénega habitat

Phantom Lake Spring cave gate opening

Phantom Lake Spring wetland ciénega

Phantom Lake Spring main spring opening

EAST SANDIA SPRING, REEVES COUNTY, TEXAS

East Sandia Spring habitat

East Sandia Spring habitat

East Sandia Spring outflow ciénega habitat

DIAMOND Y SPRING, PECOS COUNTY, TEXAS

Diamond Y Spring

Diamond Y Spring Draw, oilfield pumpjack in the background

BITTER LAKE NATIONAL WILDLIFE REFUGE, CHAVES COUNTY, NEW MEXICO

Lake St. Francis (Sinkhole #37) at BLNWR

Sinkhole #27 at BLNWR