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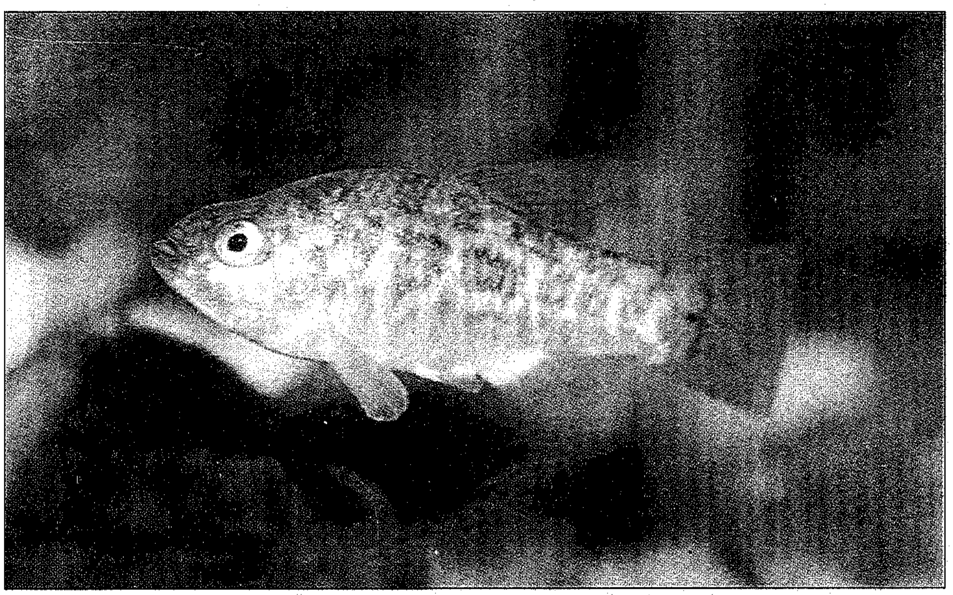
TECHNICAL REPORT 2



PECOS PUPFISH

DISTRIBUTION, STATUS, AND CONSERVATION OF THE PECOS PUPFISH, *CYPRINODON PECOSENSIS*

Distribution, Status, and Conservation of the Pecos Pupfish, *Cyprinodon Pecosensis*

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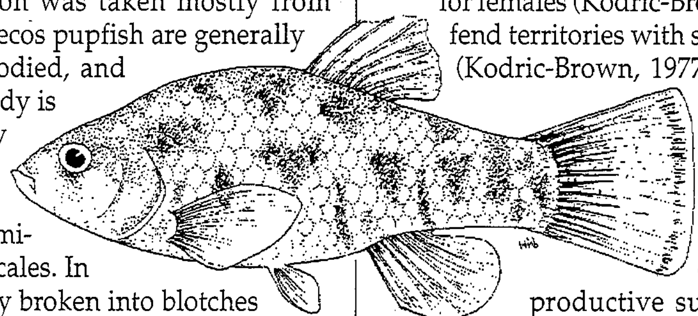
INTRODUCTION

The Pecos pupfish (*Cyprinodon pecosensis*) likely originated during the middle-late Pleistocene (Echelle and Echelle, 1978). It may have evolved from an ancestral form similar to sheepshead minnow (*C. variegatus*) after isolation of the Pecos River from the Gulf of Mexico (Echelle and Echelle, 1992). Subsequently, pupfish from the Pecos River were isolated in Diamond Y Draw, TX and diverged into Leon Springs pupfish (*C. bovinus*; Echelle and Echelle, 1992). Other species closely related to sheepshead minnow and Pecos pupfish are Red River pupfish (*C. rubrofluviatilis*) and White Sands pupfish (*C. tularosa*; Echelle and Echelle, 1992).

The following description was taken mostly from Echelle and Echelle (1978). Pecos pupfish are generally small (<75 mm SL), deep bodied, and have flattened heads. The body is silver-white with brown-gray vertical bars. They have upturned mouths, a single dorsal fin, no lateral line, abdominal pelvic fins, and cycloid scales. In females, the bars are typically broken into blotches ventrolaterally. Male Pecos pupfish have a highly arched back and often have black on the margin of the dorsal and anal fins. The abdomen of the Pecos pupfish is naked except for a few scales anterior to the pelvic fins or behind the opercular isthmus. Pecos pupfish typically have 3 to 4 pre-orbital pores on each side of the head and 20 to 21 gill rakers.



In the arid regions of northern Mexico and southwestern US, pupfishes occupy rivers, streams, marshes, small lakes, and isolated springs. Tolerance of pupfish for high temperatures, high salinity, and low dissolved oxygen is well documented (Barlow, 1958; Lowe et al., 1967; Martin, 1968; 1972; Miller, 1981; Bennet and Beitinger, 1997). Pupfish species may select habitat with poor water quality to avoid competition within a diverse fish community (Echelle et al., 1972; Martin, 1972; Miller, 1981). Salinity >20 ppt reduces the fitness of many fish species but is suitable for pupfish. Kodric-Brown and Mazzolini (1992) found that Pecos pupfish breeding was more often disrupted by plains killifish (Fundulus zebrinus) at 19.5 ppt than 29.6 ppt.

Reproductive traits and behavior of Pecos pupfish are variable, due in part to density. Pecos pupfish females in dense populations tend to have relatively small ovaries and less eggs per clutch (Garret, 1982). In one instance, Echelle et al. (1990) noted that polygonal (often hexagonal) territories were established over uniform substrates in a dense Pecos pupfish population at the peak of the reproductive season.

Due to the stress of reproductive competition, the male Pecos pupfish mortality rate is eight times greater than for females (Kodric-Brown, 1987). Males typically defend territories with structures ideal for oviposition (Kodric-Brown, 1977), but populations in limited space may set up a dominance hierarchy (Kodric-Brown, 1987). Breeding territory substrate type and intensity of breeding coloration account for variation in male reproductive success (Kodric-Brown, 1983). Males too small to defend territories are sometimes able to breed as satellites or sneakers (Kodric-Brown, 1977; 1986).

Davis (1981) described Pecos pupfish as omnivorous bottom feeders. Their diet consisted mainly of diatoms, animal material, filamentous algae, and macrophytes. Diet varied with sex, gut length, and habitat use.

Pecos pupfish has been proposed for listing as an endangered species (Federal Register, 50 CFR Part 17). The proposal emphasizes the need for an understanding of issues facing Pecos pupfish. Here we describe the distribution, conservation, and status of Pecos pupfish. Considerable time is spent describing the geology of the Pecos River and resource development in the Pecos River valley. This information is used in concert with historical Pecos pupfish collections to postulate the historical distribution of Pecos pupfish. Management recommendations to preserve and enhance Pecos pupfish status are presented.

ILLUSTRATION BY W. HOWARD BRANDENBURG

MATERIALS AND METHODS

STUDY AREA

♦ Upper Pecos

The Pecos River headwaters extend from the crest of the Sangre De Cristo Mountains to the confluence of Gallinas River in San Miguel County, NM. The headwater reach was typical of a high elevation stream, inhabited by upland, cool water, fish species. Downstream of the Gallinas River confluence, the Pecos River changed in character, becoming a high plains stream with a low gradient and a predominantly sand substrate (U.S. National Resources Planning Board, 1942; Kelley, 1971). Surface drainage in the high plains was restricted by percolation of runoff into a highly permeable outcrop of San Andres limestone. The outcrop extended from the western edge of the basin to within 15 miles of the Pecos River (Fig. 1.; Kelley, 1971). Tributaries within this segment were poorly developed since they carried only precipitation not captured by limestone. Historically, large springs discharged into the Pecos River from San Andres limestone near Santa Rosa.

The river valley in the high plains was confined by low bluffs of sandstone, limestone, and gypsum. The river channel was wide and erosive, meandering between the bluffs. Cottonwood forests were present near the town of Fort Sumner and in an area approximately 50 km south of Fort Sumner (Dearen, 1997). Small springs and seeps were present in the river channel and tributary arroyos.

♦ Roswell Basin

The Pecos River entered the Roswell Basin near the confluence of Salt Creek, in Chaves County, NM (Fig. 2). The Roswell Basin was formed by land subsidence, via dissolution making the river valley much wider than upstream (U.S. National Resources Planning Board, 1942; Thomas, 1972; Hill, 1996). Sink depressions were a common feature of the basin. Lakes, springs, and wetlands were abundant in the river valley between Roswell and Carlsbad.

The San Andres limestone aquifer was the primary source of inflow into the Pecos River in the Roswell Basin (Fiedler and Nye, 1933; U.S. National Resources Planning Board, 1942). Artesian conditions were present throughout the Roswell basin in 1900. Large springs discharged near Roswell while playa lakes and marshes were maintained with artesian seepage. Many Roswell Basin springs, including those of Bitter Lake National Wildlife Refuge (BLNWR) and Bottomless Lakes State Park (BLSP), had elevated salinity. Groundwater was also present in the alluvium of the basin and the watertable was shallow. The Pecos River was entrenched within the alluvium but commonly flooded adjacent wetlands.

♦ Carlsbad

North of Carlsbad, the Pecos River encountered the Capitan (Reef) limestone outcrop, an extension of the Guadalupe Mountain uplift (Fig. 1; Fiedler and Nye, 1933; U.S. National Resources Planning Board, 1942). The river valley narrowed as it cut through the outcrop. Capitan limestone contained the Carlsbad Aquifer which discharged into the river via Rocky Arroyo and Carlsbad Springs (Thomas, 1959; Kelley, 1971; Hill, 1996). Water from Capitan limestone was fresh compared to that of San Andres limestone.

♦ Delaware Basin

Pecos River entered the Delaware Basin downstream of Carlsbad (Fig. 2). The Delaware Basin was formed by land subsidence, via dissolution (Anderson et al., 1978; Bodenlos, 1978; Mercer and Hiss, 1978; LaFave, 1987; Hill, 1996). Alluvial aquifers were present in the Carlsbad Valley and the Toyah Basin (Fig. 2). The Toyah Aquifer was the largest source of groundwater in the Delaware basin (LaFave, 1987). Historically, it maintained extensive wetlands in the Pecos River valley and discharged into the Pecos River.

The Rustler formation underlay much of the Delaware Basin and contained water under artesian pressure (U.S. National Resources Planning Board, 1942; LaFave, 1987; Ashworth, 1990; Hill, 1996). Discharge from Rustler limestone was typically saline. Springs discharged from Rustler limestone in the Rustler Hills of Texas and Rustler Breaks of New Mexico (Fig. 1; Brune, 1981; LaFave, 1987). Historically, a brine aquifer, maintained by Rustler water circulating over salty strata, discharged into the Pecos River from Nash Draw. Historically, the river channel had high banks, was highly sinuous, virtually treeless, and was lined with extensive wetlands (Dearen, 1996; 1997)

♦ Lower Pecos

Downstream of the Delaware Basin, the Pecos River entered the Central Basin Platform (Fig. 2; LaFave, 1987; Ashworth, 1990; Hill, 1996). Surface drainage was not extensive but groundwater discharged from many strata, including Cretaceous limestone and sandstone, Rustler limestone, and alluvial sands (U.S. National Resources Planning Board, 1942; Grozier et al., 1966; Scudday, 1974; Brune, 1981; Hill, 1996; Dearen, 1988). Historically, alkalai lakes were common in the valley and the Pecos River was swift and dangerous with steep, erosive banks (Campbell, 1958; Dearen, 1996; 1997).

Near Iraan, in Pecos County, TX, the Pecos River encountered the Edwards-Stockton plateau (Fig. 1; Thomas, 1972). Springs downstream discharged from Edwards-

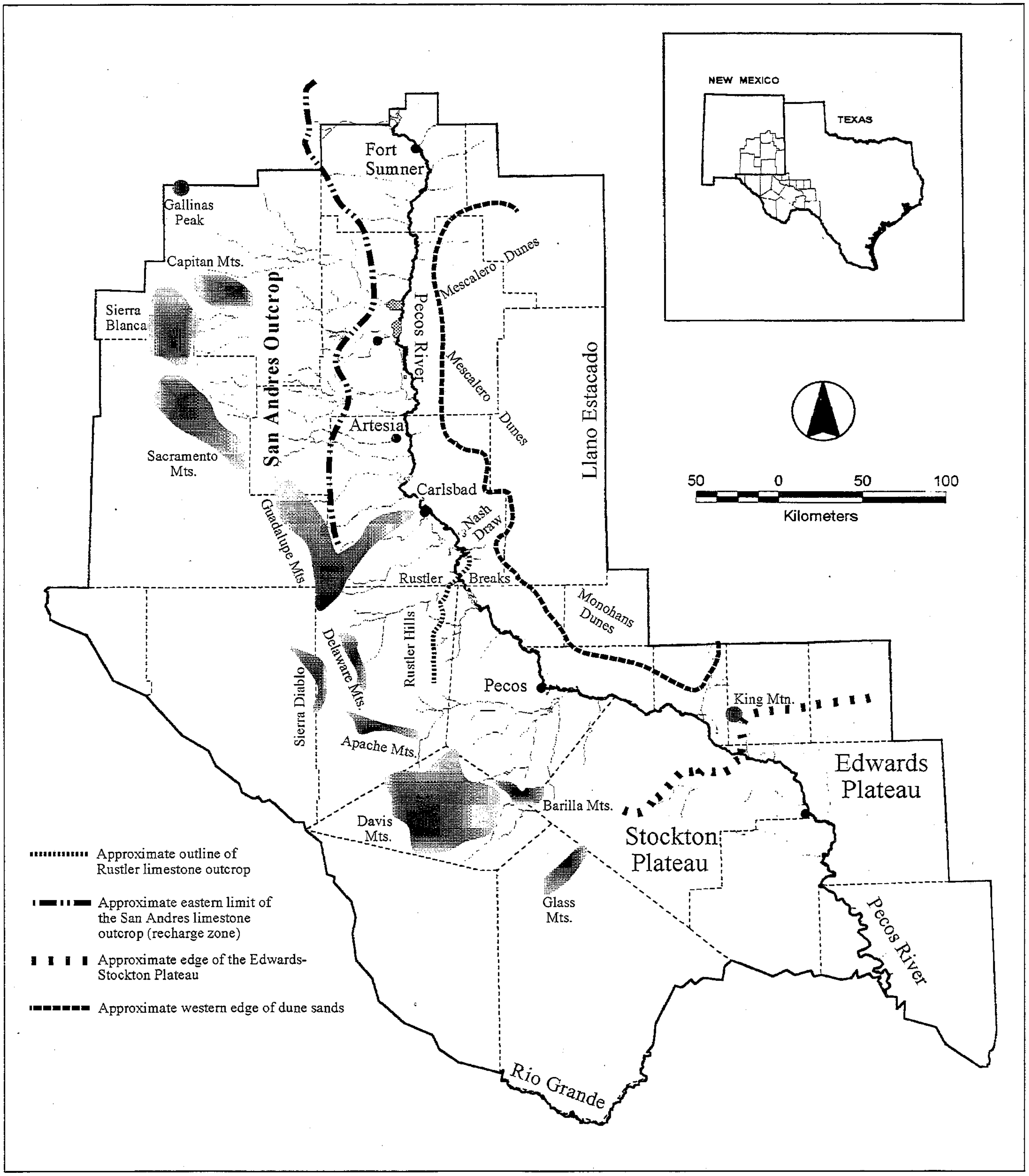


FIGURE 1. Map of the middle and lower Pecos River Basin delineating major surface features.

Trinity limestone (Brune, 1981). Fresh inflows reduced salinity in the Pecos River. The river was confined by bluffs and canyon walls on both sides, making wetlands uncommon.

METHODS

To describe the distribution and status of the Pecos pupfish, all known populations of Pecos pupfish were sampled between 1987 and 1998, using a combination of seining, minnow trapping, and dip netting. Most localities were sampled at least twice and many were sampled more frequently (Appendix I). The mainstem Pecos River between Sumner Dam and Brantley Reservoir was sampled semi-monthly for Pecos bluntnose shiner (*Notropis simus pecosensis*) studies.

Minnow traps were the most commonly used fish capture method. They were useful in inaccessible or diminutive areas and in habitats with a soft silt substrate. Minnow traps were particularly advantageous in environmentally sensitive habitats such as springs. Two to four traps were baited with dry dog food and placed at a sample site. In deep habitat, traps were often set on the substrate at varying depth. In Lake Saint Francis, additional traps were used, some were set on the substrate while others were suspended from floats at mid-lake. Traps generally were left overnight so that collection occurred over both crepuscular periods.

Seining was often performed in shallow habitats with a solid substrata. Seining was most effective in collecting pupfish in the Pecos River mainstem, the BLM overflow wetland, and the BLNWR waterfowl lakes. Collecting pupfish in soft substrata with a seine was difficult because pupfish often escape by burrowing.

Dipnets were not as effective as seines or minnow traps. They were used in place of minnow traps when there was insufficient time to run a 12- to 24-hour trap set. Dipnet data were most useful in presence/absence analyses since replication was difficult and catch rates were low compared to other sampling techniques.

Collection records were used to document the historic and current status of Pecos pupfish. The primary sources were the Museum of Southwestern Biology, Albuquerque, NM; the Texas Natural History Collection, Austin, TX; and the Oklahoma State University Collection of Vertebrates, Stillwater, OK. Collections from recent studies in Texas provided information on hybrid pupfish distribution (Hoagstrom, 1994; Larson, 1994; Linam and Kleinsasser, 1996).

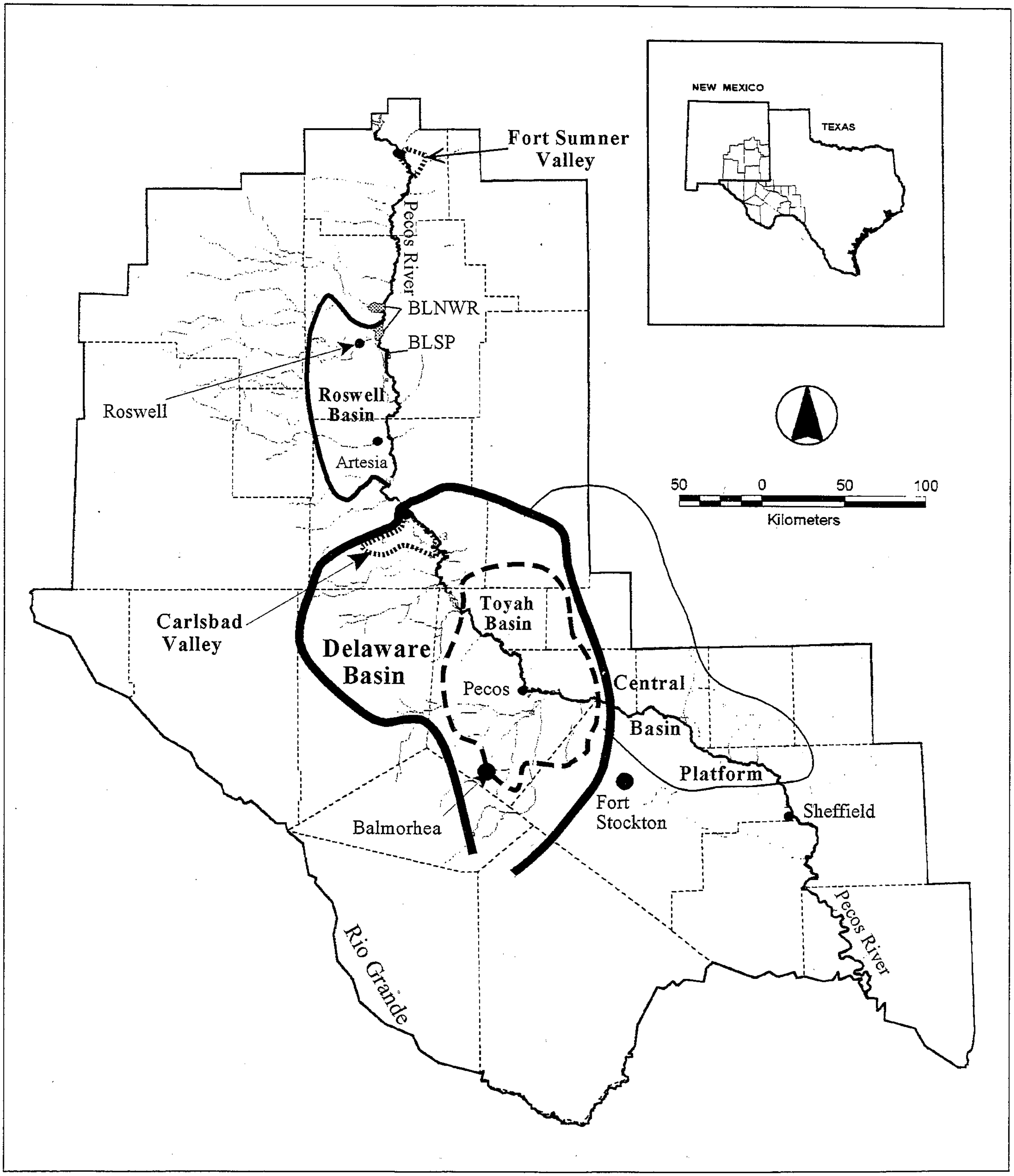


FIGURE 2. Map of the middle and lower Pecos River Basin delineating groundwater basins.

RESULTS

Little is known about the distribution and abundance of Pecos pupfish prior to extensive development of Pecos River water and the Pecos River floodplain. Very few fish surveys were conducted until the 1950's. Campbell (1958) surveyed the Pecos River in Texas but did not separate pupfish and other "killifishes". He found "alkaline marshes [were] often adjacent to the stream..." Pecos pupfish certainly would have occupied such habitat.

It is important to understand the current status of the Pecos pupfish in relation to historic conditions and historic distribution. Survey data, combined with an understanding of Pecos River valley hydrology and geology, facilitates a hypothetical reconstruction of historical Pecos pupfish distribution. Records of floodplain and water development provide insight into subsequent changes. The following is a summary of development in the valley which will be used in a discussion regarding the historic range of Pecos pupfish.

DEVELOPMENT WITHIN THE PECOS VALLEY

Before extensive groundwater depletion and flow regulation, base flows were maintained by shallow groundwater and spring discharge making the Pecos River a perennial stream (U.S. National Resources Planning Board, 1942; Thomas, 1959; Grozier et al., 1966; Sheridan, 1975; Brune, 1981; Dearen, 1996; 1997). By the time the Pecos River entered Texas, the main channel was deep and swift. In Texas, the river was treacherous and could only be safely forded in a few locations. Nineteenth century accounts suggest that intermittency in stream-flow rarely if ever occurred. In 1964, one West Texas native remarked, "[if] a man seen that river fifty years ago, and see it now, you couldn't make him believe it was the Pecos River" (Dearen, 1996).

The salinity of the soil and water in the Roswell and Delaware Basins made cottonwood (*Populus spp.*) and willow (*Salix spp.*) uncommon. The absence of trees was noted by early pioneers (Dearen, 1996). The introduction of saltcedar (*Tamarix spp.*; ca. 1912) and its rapid colonization (Robinson, 1965), changed the character of the river (Dearen, 1996). Saltcedar invasion may lead to increased channel incision and increased soil and water salinity (Robinson, 1965; Sisneros, 1994). Saltcedar may also lower the water table through high evapo-transpiration (Robinson, 1965).

New Mexico

♦ Upper Basin

Native Americans utilized Pecos River water for agriculture in the Pecos headwaters prior to 1600 (U.S. National Resources Planning Board, 1942). By 1898, a community of small farms, was irrigated by minor diversions from the headwaters of the Pecos and tributaries (U.S. National Resources Planning Board, 1942). Modern development resulted in 12 small diversion dams on the Pecos headwaters (Hanson, 1997) and three on the Gallinas. After 1921, runoff of the Gallinas headwaters was diverted into Storrie Lake near Las Vegas (U.S. National Resources Planning Board, 1942).

♦ High Plains

Development in the Fort Sumner vicinity began with establishment of the fort in 1862. In 1906 a diversion dam and a 20-mile canal were constructed. The Fort Sumner Irrigation District (FSID) was formed in 1918 and has since administered irrigated lands within the Fort Sumner Valley (Fig. 2). Sumner Dam was constructed in 1937 to increase reservoir storage. Prior to Sumner Dam construction, flow was perennial in the Pecos River at Fort Sumner (USGS gage data). Upstream of Sumner Dam, a large diversion watered farms around Puerto De Luna. In 1980, Santa Rosa Dam was constructed upstream of Santa Rosa to control floods and store water for irrigation.

Grazing of cattle and sheep predominated in the Pecos River Valley downstream of Fort Sumner. There were a small number of minor diversions for irrigation in this reach (U.S. National Resources Planning Board, 1942). Springs on the uplands were typically developed for domestic and livestock use and pumps were placed on areas with perched groundwater. The condition of the river and tributaries in this reach prior to settlement is poorly documented.

♦ Roswell Basin

Agriculture in the Roswell Basin relied on groundwater. At the onset of development, wells over 663 square miles were sustained by artesian flow from San Andres limestone (Fiedler and Nye, 1933). Direct use of the artesian aquifer initiated in 1880 and by 1925 artesian flow was much reduced (Fiedler and Nye, 1933; Report of Artesian Well Supervisor, 1934; U.S. National Resources Planning Board, 1942). Between 1927 and 1940, the watertable of the Roswell alluvial aquifer was lowered by as much as 8.5 m (U.S. National Resources Planning Board, 1942). In 1944, annual pumping from the Roswell artesian aquifer exceeded recharge and by 1953 the aquifer had mostly lost artesian pressure (Thomas, 1959). Historically, the shallow watertable sustained extensive lakes and marshes in sink depressions, but many of these were drained for cropland. Exhaustion of the Artesian aquifer depleted flow in the Pecos River. Prior to 1934, there was a 50% greater outflow than inflow from the Roswell Basin. Between 1946 and 1955, outflow from the Roswell Basin was 23% lower than inflow (Thomas, 1959). However, inflow, (mean daily flow at the Sumner Dam gage) remained relatively stable after 1906 (Fig. 3; Thomas, 1959).

Agricultural development diverted the headwaters of the Rio Hondo and Rio Peñasco (U.S. National Resources Planning Board, 1942). Off-channel reservoirs were built to store Rio Hondo water in 1904 (U.S. National Resources Planning Board, 1942) and Rio Peñasco water in 1908 (Houghton, 1993) but were unsuccessful, mostly due to leakage. Recent development resulted in six dams on the upper Rio Hondo. These dams provided flood control and recreation. The Two Rivers Reservoir, constructed in 1963, provided flood control on the lower Rio Hondo.

Diversions from tributaries depleted floodplain wetlands and Pecos River flows. The lower Rio Hondo, North Spring River, Berrendo Creek, and the South Spring River were diverted into the Northern (Hagerman) Canal (Fiedler and Nye, 1933). A series of smaller ditches watered farmland south of Roswell (Fiedler and Nye, 1933). Waters of the Rio Peñasco were diverted near Hope where a ditch association was formed in 1895 (U.S. National Resources Planning Board, 1942; Renick, 1926). Groundwater pumping in the Roswell Basin caused the water supply near Hope to fail by 1960 (Renick, 1926; U.S. National Resources Planning Board, 1942; Houghton, 1993). Depletion of spring flows made Hagerman Canal and smaller ditches obsolete as well.

Development reduced the frequency and magnitude of Pecos River floods. Although mean daily inflows into the Roswell Basin were similar throughout this century, the operation of Santa Rosa and Sumner Dams altered the hydrology of the Roswell Basin by controlling the release of water. Historical Pecos River and tributary floods supplemented the shallow aquifer and provided frequent connection between various aquatic habitats.

In 1966, regulation of groundwater pumping was initiated in the Roswell Basin by metering all wells and restricting discharge. The watertable has risen since that time. In 1974, flows in the Rio Peñasco, upstream of Hope, partially recovered (Houghton, 1993). Continued groundwater recovery within the Roswell Basin may further increase spring flow and restore aquatic habitat.

♦ Carlsbad Limestone

The Capitan limestone, intersected by the Pecos River north of Carlsbad, contained the Carlsbad Aquifer, which discharged at Rocky Arroyo and Carlsbad Springs (Theis, 1938; Thomas, 1959; Hill, 1996). This aquifer supplied a large portion of the domestic water supply for the City of Carlsbad (Hill, 1996). Spring discharge has declined since the initiation of pumping (Thomas, 1959). Discharge from Carlsbad springs was impounded in the City of Carlsbad. The lake shore was developed as a residential area and the lake was used for recreation.

♦ Delaware Basin

Carlsbad Valley

Most irrigation in Carlsbad Valley was by surface diversion of the Pecos and Black Rivers. The Carlsbad project, begun in 1888, constructed Avalon and McMillan Reservoirs on the mainstem Pecos River prior to 1900 (U.S. National Resources Planning Board, 1942). Water from Avalon Reservoir was diverted into the Southern Canal by 1893. McMillan Dam was raised a number of times to offset siltation. Reservoirs constructed near Fort Sumner (1937) and Santa Rosa (1980) greatly increased the storage capacity of the Carlsbad Project. Brantley Reservoir was constructed in 1989 to replace McMillan Reservoir and also increased storage capacity.

Mainstream flow was additionally diverted onto Harroun Ranch, Dickson Farm, and Livingston Farm (U.S. National Resources Planning Board, 1942). Springs on the upper Black River were diverted as well (U.S. National Resources Planning Board, 1942). Alluvial groundwater in Carlsbad Valley was mined in 1945, creating an 18.3-m cone of depression by 1954. Shallow groundwater east of the Pecos River was also depleted which diminished discharge from Nash Draw (U.S. National Resources Planning Board, 1942).

Pecos River inflow into the Carlsbad Valley was depleted by upstream use (Fig. 3). Dams diminished floods which connected aquatic habitats and recharged the alluvial aquifer. Degradation of the Pecos River channel lowered the watertable. Flow was confined within steeply incised banks. The establishment of saltcedar along the river and in the floodplain depleted shallow groundwater.

Toyah Aquifer

In the Toyah Basin, diversion of water from the mainstem Pecos River began in 1877, increasing through 1950 (Fig. 3). By that time, flows in the Pecos River between Carlsbad, NM and Girvin, TX were greatly reduced (Fig. 3; Brune, 1981; LaFave, 1987). In March 1964, Grozier et al. (1966) documented a 57% loss of released water between Orla and Girvin, TX. They also studied the river at low flow on 10-12 May 1965 and found it dry throughout much of this reach, flowing below 0.06 cms for 153 out of 306 river km.

Depletion of flow in New Mexico, depletion of the Toyah alluvial aquifer, and continued cropland development prompted seven irrigation projects to collaborate in an attempt to increase the water supply through construction of Red Bluff Reservoir in 1936 (U.S. National Resources Planning Board, 1942). Downstream, the Imperial and Zimmerman projects constructed off-channel reservoirs. Pecos River diversion in Texas peaked in the 1940's (Fig. 3).

Groundwater pumping became widespread in the Toyah Basin after 1940 (LaFave, 1987). Heavy use created a cone of depression in the Toyah aquifer. The aquifer was most heavily depleted near Pecos, TX where the watertable was depressed more than 61 m. (LaFave, 1987; Ashworth, 1990). Lakes and springs throughout the Toyah basin dried (Brune, 1981; LaFave, 1987). Flow in the aquifer changed direction, moving away from the Pecos River and into the cone of depression (Grozier et al., 1966; LaFave, 1987). Major drought hit west Texas in the 1950's. Over-exploitation of water resources combined with the severity of the 50's drought curtailed water-dependent agriculture.

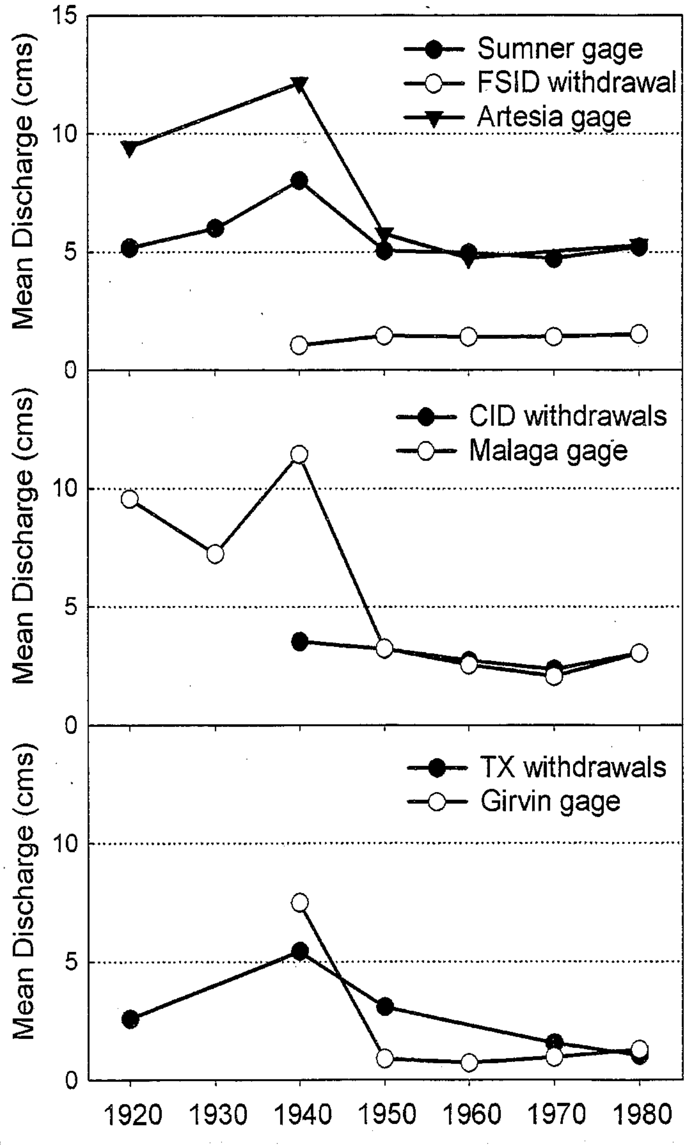


FIGURE 3. Historic flow and withdrawal in the Pecos River.

♦ LOWER BASIN

Groundwater in the Central Basin platform was also depleted (Scudday, 1974; Brune, 1981). A number of large springs (most notably Comanche Springs near Fort Stockton) became dry through excessive pumping of the Cretaceous limestone aquifer. Other local aquifers were depleted as well. Few springs in this region continued to maintain flow (Brune, 1981). The Pecos River in the Central Basin Platform was often dry between 1950 and 1970 (Campbell, 1958; Grozier et al., 1966).

HABITAT LOSS AND PECOS PUPFISH

In the Roswell Basin, Pecos pupfish may have been most rapidly depleted between Dexter and Brantley Dam. Marshes and playas south of the large springs near Roswell were heavily dependent on the alluvial aquifer which was depleted by shallow wells, loss of artesian pressure in San Andres limestone, saltcedar invasion, and loss of Pecos River floods. By 1980, Pecos pupfish in the Roswell Basin were largely restricted to the BLNWR area. These populations were able to persist where discharge from San Andres limestone was sustained.

Initial depletion of Pecos River flow in the Delaware Basin increased salinity which extirpated many fish species from the Toyah Basin and Central Basin Platform but was advantageous for Pecos pupfish. Intermittent pools in the river channel provided refuge for Pecos pupfish because of high temperature and salinity. In his survey of the fishes of the Pecos River in Texas, Campbell (1958) noted that "in all areas where the stream was intermittent or where salinity was unusually high, these fishes [pupfish, killifish, mosquitofish] were quick to gain dominance." Since 1970, increased flow in the Pecos River below Red Bluff Dam reduced salinity and eliminated isolated pool habitat. This made suitable Pecos pupfish habitat uncommon in the mainstem. After 1960, Pecos pupfish declined in collections from the Pecos River, TX (Appendix IV).

Pecos pupfish formerly occupied springs in Nash Draw and the adjacent Malaga Bend. Pupfish (Surprise) Spring discharged into the northern edge of Laguna Grande De la Sal as late as 1979 and maintained a low salinity compared to that of the lagoon (U.S. National Resources Planning Board, 1942; Albeit, 1982; Hill, 1996). Granddaddy Spring maintained wetland in the Malaga Bend. Depletion of groundwater eliminated discharge from these springs.

Toxic conditions have caused periodic, extensive fish kills in the Pecos River, particularly in Texas. Oil field pollution may have contributed to the decline of Pecos pupfish and other native fish species. Campbell (1958) reported that "A man near Iraan, Texas, makes his living from skimming the oil off the surface of the stream that has leaked or has been lost from wells in that area." Spills from wells and improper waste disposal were extensive in the middle 20th century (Campbell, 1958; Scudday, 1974; Brune, 1981; Ashworth, 1990). In recent times, blooms of toxic algae have decimated fish populations in the Pecos River, TX (James and De La Cruz, 1989; Rhodes and Hubbs; 1992).

HYBRIDIZATION

Sheepshead minnow became established in the Pecos River, TX between 1980 and 1984 (Echelle and Connor, 1989). Pecos pupfish and sheepshead minnow formed a panmictic hybrid swarm between Red Bluff Reservoir and Independence Creek by 1985. The genome of pupfish collected from 15 localities in 1984 was between 18 and 84% sheepshead minnow, depending on locality. Analysis of pupfish collected in 1991 and 1992 suggested that the hybrid swarm had reached a genetic equilibrium (Childs et al., 1996).

Hybrid pupfish were not collected upstream of Red Bluff Reservoir until July 1994 (Echelle et al., 1997). The first collection was made at Loving Crossing. Since 1994, all pupfish collected from the Pecos River downstream of Brantley Dam were hybrids. These fish were genetically contaminated by other hybrids, presumably from the Pecos River, TX (Echelle et al., 1997).

The hybrid pupfish population upstream of Red Bluff Reservoir appeared restricted primarily to the confluence of Pierce Canyon and the Pecos River. Although collections of pupfish hybrids were made at Loving Crossing in 1994 and 1995, there did not appear to be a persistent population at this locality. Morphologically, pupfish hybrids at Pierce Canyon appeared intermediate between sheepshead minnow and Pecos pupfish. The pupfish hybrids collected at Loving Crossing appeared more similar to sheepshead minnow and may have been individuals recently transported from Red Bluff Reservoir by fishermen. Saline seepage at Pierce Canyon confluence maintained salty backwaters and isolated pools that were ideal for pupfish hybrids (Appendix III). No such habitat was present at Loving Crossing.

Childs et al. (1996) suggested that the rapid introgression of the Texas Pecos pupfish population was facilitated by low population density. It is likely that fish kills, caused by toxic blooms of an exotic golden algae (*Prymnesium parvum*), reduced fish density at the time sheepshead minnows were introduced (James and De La Cruz, 1989, Rhodes and Hubbs, 1992). Salt Creek, TX was apparently unaffected by algal blooms which allowed Pecos pupfish densities to remain high. Sheepshead minnow introduced into the Pecos River may have proliferated prior to contact with Pecos pupfish and outnumbered Pecos pupfish by the time encounters occurred. In contrast, hybrids which invaded Salt Creek were likely outnumbered by Pecos pupfish. Also, genetically pure Pecos pupfish occurring upstream in Salt Creek could have continually supplemented populations where genetic contamination was present. Pecos pupfish in Salt Creek have remained genetically pure while those in the mainstem are highly introgressed.

We suggest that Pecos pupfish populations in the Pecos River, TX were also depleted by habitat loss. The largest collections of Pecos pupfish from the mainstem were in the 1950's (Appendix IV). Flows in the Pecos River were lowest between 1950 and 1970 and flow intermittency was common (Fig. 3; Grozier et al., 1966). Pecos pupfish proliferated in hot, salty, ephemeral pools present in the river bed (Campbell, 1958). Base flow in the mainstem recovered in the 1970's and flow intermittency became less common. By 1980, mainstem habitat was primarily deep pool and riffle, neither of which were ideal for Pecos pupfish. Slackwater habitat was rare and diminutive in the narrow river channel. As a result, Pecos pupfish density was reduced and micro-populations were sparsely distributed. This scenario is present in the Pecos River mainstem, NM. In Chaves County, Pecos pupfish are exclusively found in saline springs and ephemeral pools in the river bed. Hybrid pupfish between Brantley Dam and Red Bluff Reservoir are confined to saline pools within the mud flat at the confluence of Pierce Canyon.

Pupfish hybrids in Texas have exhibited the ability to expand their occurrence to locations and habitats not inhabited by Pecos pupfish. Hybrid pupfish were common in the Pecos River downstream of Sheffield (Rhodes and Hubbs, 1992; Wilde and Echelle, 1992). Hybrids were commonly collected from riffles (Hoagstrom, 1994). The ecological expansion of hybrid pupfish apparently allowed them to colonize the mainstem which was unsuitable for pure Pecos pupfish.

RECENT PECOS PUPFISH EXTIRPATIONS

The original population of Pecos pupfish in Laguna Grande De la Sal occurred in "Pupfish Spring" or "Surprise Spring" (Albeit, 1974; Sublette, 1975). This spring flowed from the northern bank of the lagoon (U.S. National Resources Planning Board, 1942; Albeit, 1974; Sublette, 1975; Hill, 1996). Discharge from Pupfish Spring was depleted by groundwater mining and ceased between 1985 and 1990. In 1990, an additional population of Pecos pupfish was discovered in two artificial holes excavated in the east bank of the lagoon (Appendix I). Groundwater seepage maintained salinities between 43.0 and 60.0 ppt. Pecos pupfish exploited the adjacent flat when seepage rates were high. After 1990, salinity increased and seepage appeared reduced. The highest salinity occupied by Pecos pupfish during this study was in the eastern pool (89.1 ppt) on 18 July 1995. Fish were extremely rare at that time and appeared emaciated. Pecos pupfish were not observed or collected on 5 June 1997 (salinity was 92.8 ppt) or 22 October 1998 (salinity 95.7 ppt). This population was presumed extirpated.

In the late 1980's genetically pure Pecos pupfish inhabited the Phipps gravel pits near Grandfalls, TX (Echelle and Connor, 1989; Appendix IV). By spring 1998, pupfish in these pits were genetically contaminated by sheepshead minnow (Echelle and Echelle pers. comm.).

HISTORIC DISTRIBUTION

Pecos pupfish were most likely restricted to the regions of the Pecos Basin where land subsidence and shallow groundwater formed extensive sink and marsh habitat (Fig. 4). The upstream extent of suitable, historic Pecos pupfish habitat was apparently the Roswell Basin. Floodplain wetlands were uncommon upstream. The downstream extent of Pecos pupfish habitat was the Edwards-Stockton Plateau, where the Pecos River valley narrowed and flow was increasingly fresh.

Pecos pupfish may have historically been segmented into meso-populations. These populations were separated from each other by areas devoid of floodplain wetlands and lentic riverine habitat. The population centers proposed below roughly corresponded with phenotypic differences observed by Echelle and Echelle (1978).

1. The Bitter Lake—Bottomless Lakes Complex: Wetlands maintained by discharge from San Andres limestone were widespread and diverse. Sinks were prevalent and included Bitter Lake, Chain Lakes, and Lazy Lagoon. Narrowing of the Pecos River valley north of Carlsbad isolated this meso-population from the Delaware Basin.
2. The Nash Draw—Salt Creek complex: Wetlands sustained with discharge from Rustler limestone were abundant in Nash Draw, Malaga Bend, and Rustler Breaks, NM and Salt Creek, TX. Sinks were common and included Laguna Grande De la Sal, Harroun Lake, and Queen Lake. This meso-population may have inhabited part or all of the Delaware River drainage. A paucity of wetland habitat between Salt Creek confluence and Arno, TX may have isolated this meso-population from the Toyah Basin.
3. The Pecos River valley from Arno to Girvin, TX: Playas and marshes were prevalent in this reach. Large springs flowed from Toyah Basin alluvium between Balmorhea and Pecos and from Cretaceous limestone and sandstone near Fort Stockton. These springs fed wetlands adjacent to the Pecos River such as Sand Lake, Toyah Lake, Mosquito Lake, Soda Lake, and Monument Springs. Springs discharged from dune sands north of the Pecos River at Antelope Spring and also fed sinks such as Juan Cordoña Lake and Lake Soda.

Wetlands around Artesia may also have provided abundant habitat and supported large Pecos pupfish populations. Sinks were prevalent in this area and included Lake Tolliver, Lake Arthur, Spring Lake, Pritchard Lakes, Manda Lake, and Brainard Lake. Pecos pupfish populations near Artesia may have been contiguous with others in the Roswell Basin.

The occurrence of Leon Springs and Comanche Springs (*Cyprinodon elegans*) pupfish in the Toyah Basin and on the Central Basin Platform suggests that Pecos pupfish were restricted to the Pecos River valley. Pupfish species do not typically co-exist, partly due to their high genetic compatibility.

There is meager documentation of Pecos pupfish away from the Pecos River floodplain. The oldest collections are from the upper Rio Hondo drainage (near Hondo, NM), April 1916 (University of Michigan Museum of Zoology #66173; University of Colorado Museum #984). If these collections represent the natural distribution (as opposed to artificial introductions), the historic range of the Pecos pupfish was quite extensive. The occurrence of Pecos pupfish in the headwaters of Salt Creek, TX and their collection from Comanche Spring, northeast of BLSP (Tulane University, #TU97033) further suggests that their distribution included many habitats outside the Pecos River floodplain.

PRESENT CONDITIONS

New Mexico

♦ Pecos River

Pecos River is closely regulated by reservoir operation. Springs discharge into the Pecos River between Colonias and Puerto De Luna but flow is captured by Santa Rosa and Sumner Dams. Spring input is minimal between Sumner Dam and Salt Creek, NM. Downstream from Salt Creek, discharge from San Andres limestone supplements Pecos River flow. Tributary and spring flow in the Roswell Basin is much reduced from historic levels. Rio Hondo and Rio Felix hold water in their lower reaches but discharge very little. A number of springs occur in uplands along the Pecos River but are generally small and impacted by livestock, agriculture, and non-native fish species. Flow downstream of Sumner Dam is captured by Brantley Dam. Flow below Brantley Dam is entirely subject to reservoir release and is collected by Avalon Dam, 14 km downstream. The Pecos River is dry between Avalon Dam and Carlsbad Springs (6.5 km). Inflows into Avalon Reservoir are diverted into the Carlsbad Irrigation District (CID). Return seepage from CID and wastewater returned via Black River sustain Pecos River flow through the Carlsbad Valley. Delaware River discharges into the mainstem upstream of Red Bluff Reservoir which captures all flows exiting New Mexico. Throughout New Mexico, the mainstem Pecos River is incised. Flood control and saltcedar forests eliminate the dynamism of the river channel. Flows rarely escape the banks to inundate the historic floodplain.

♦ Floodplain Wetlands

Water discharging from San Andres limestone creates aquatic habitat on BLNWR, BLSP, and the BLM overflow wetland (BLMOW). Habitat includes springs, playa lakes, isolated oxbows, marshland, and sinkhole lakes (Figs. 1-3). These habitats support large growths of Chara (*Chara spp.*) along with varying amounts of widgeon grass (*Ruppia maritima*), a marine, green algae (*Batophora oerstedii*), pondweed (*Potamogeton pectinatus*), cattails (*Typha latifolia*), bulrush (*Scirpus spp.*), and prairie cordgrass (*Spartina pectinata*).

Very few floodplain wetlands remain downstream of Chaves County, NM. Playa lakes such as Manda Lake, Brainard Lake, Spring Lake, Lake Tolliver and Lake Arthur

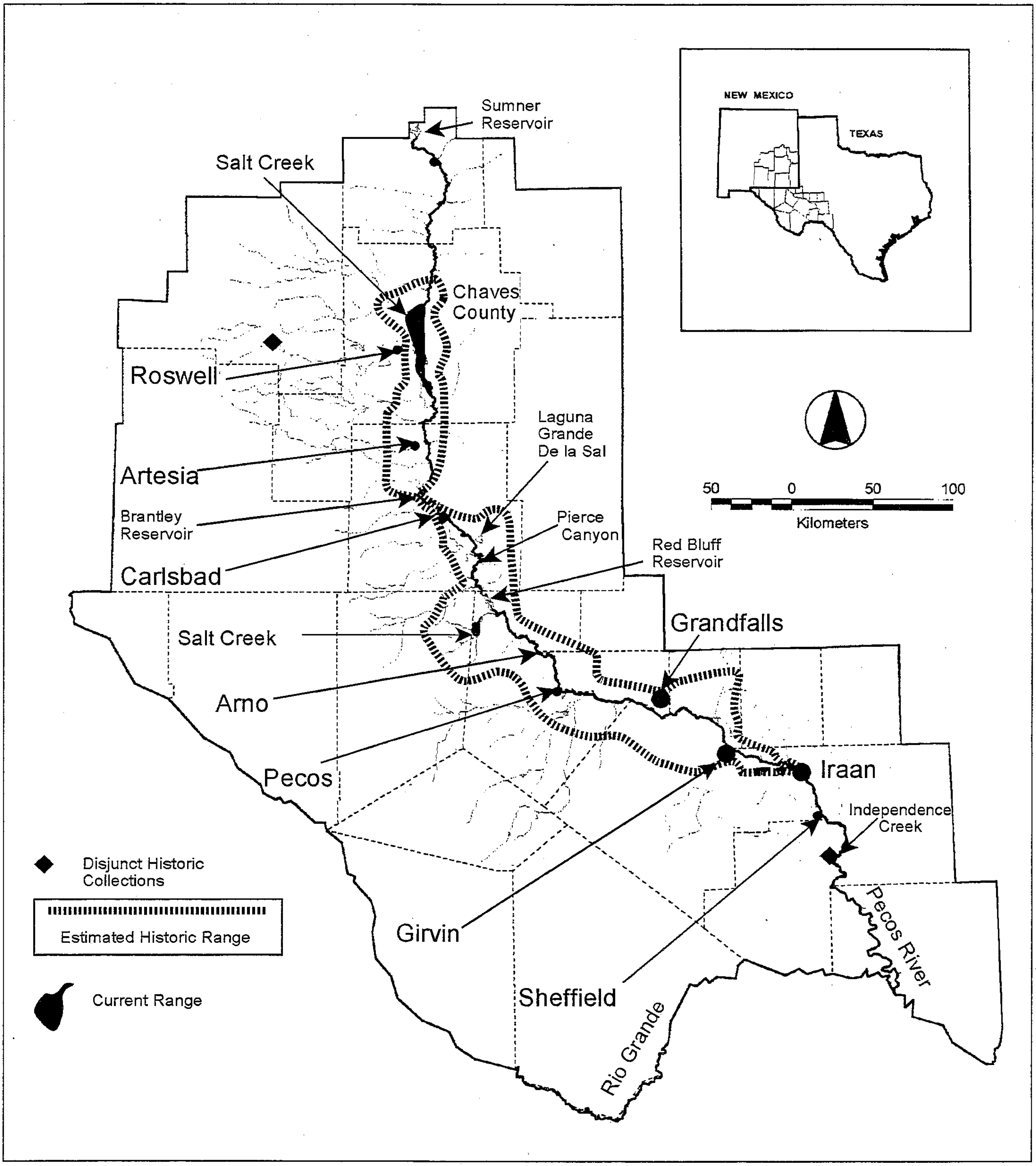


FIGURE 4. Map of the current and estimated historic range of Pecos pupfish.

are dry. The most extensive remnant sink/playa complex downstream of Chaves County is the Nash Draw, east and south of Carlsbad, NM (Fig. 1; U.S. National Resources Planning Board, 1942). However, springflow has been depleted and Laguna Grande De la Sal is too saline for Pecos pupfish (~200 ppt) while the mainstem is too swift and deep.

Texas

The Pecos River is highly diminished in Texas. Diversion canals feed Imperial Reservoir and irrigate crops. Approximately 5000 acres are irrigated with Pecos River water (Newton, pers. comm.). Most cropland in Texas is irrigated from the Toyah alluvial aquifer which is heavily diminished and is a drain to the mainstem Pecos River (Grozier et al., 1966; Scudday, 1974; Brune, 1981; LaFave, 1987; Ashworth, 1990). However, stabilization and recovery within the Toyah aquifer has occurred since 1965, and flow intermittency in the Pecos River is less frequent and extensive than in the past (Fig. 3; LaFave, 1987).

The mainstem between Grandfalls and Girvin is downstream of the majority of withdrawals from the Pecos River and associated aquifers. Salinity is highest in this reach (7.0-11.0 ppt). Flow is so sluggish that Chara and pondweed choke the entire channel. Downstream of Girvin, flow increases and below Iraan, the Pecos River encounters Edwards-Trinity limestone which discharges freshwater (Thomas, 1972; Scudday, 1974; Brune, 1981).

The headwater springs of Salt Creek TX are in decline. Extensive wetlands were formerly present in the upper water courses. Alkali marshland in upper Salt Creek has declined and recently become dry (G. Garret, pers. comm.).

PRESENT DISTRIBUTION

Pecos pupfish are present along roughly 70 km of the Pecos River valley but populations are limited to specific localities, many of which are small and isolated. Formerly, Pecos pupfish were common along roughly 750 km of the Pecos River and habitat was extensive and integrated. The total area of wetland habitat that has been lost is reputedly great but was never quantified and cannot be estimated from available information. Habitats presently occupied by Pecos pupfish are described below.

♦ Riverine Habitat: Pecos River, Chaves County, NM

Pecos pupfish are sporadic but persistent in fish collections in the mainstem Pecos River between Salt Creek, NM and Brantley Reservoir (Appendix I). They colonize ephemeral pools and seeps in the river bed. They are most commonly collected at localities on or adjacent to BLNWR, BLSP, and BLMOW.

♦ Bitter Lake NWR: Sinkholes

On BLNWR, Pecos pupfish occupy 23 middle tract and three north tract sinkholes (Figs. 5 and 7; Appendix I). Most sinkholes are isolated and vary in physical property and salinity (Appendix I). Pecos pupfish are commonly sympatric with plains killifish and Pecos gambusia (*Gambusia nobilis*) in sinkholes <20 ppt but are usually the sole occupant of sinkholes >20 ppt (Appendix I). The highest recorded salinity in a sinkhole occupied by Pecos pupfish was 86.0 ppt (sinkhole 21, 19 June 1995). Pupfish were numerous at that time but appeared stunted and emaciated.

♦ Bitter Lake NWR: Bitter Lake Drainage

Pecos pupfish coexist with five fish species (Appendix I) in the headwaters of Bitter Lake (Bitter Creek and Sago Spring). They are present in Bitter Lake proper when salinity is low. Pupfish are abundant in the waterfowl lakes downstream where a variety of fish species occur. Habitat heterogeneity is high within waterfowl lakes and Pecos pupfish abundance varies between localities and sampling periods (Appendix I).

♦ Bitter Lake NWR: Salt Creek, NM

Pecos pupfish occupy a perennial pool in Salt Creek, NM (Fig. 8). However, the size and persistence of this population is poorly defined. This population may be associated with an undocumented Pecos River population (see below). Fish from Salt Creek apparently colonized Pren's Hole during a flood.

♦ Bottomless Lakes SP: Sinkhole Lakes

Pecos pupfish occupy five sinkhole lakes on BLSP (Appendix I). Lazy Lagoon is very large and maintains a large Pecos pupfish population. Lea Lake provides a stable refugia which flows into the BLMOW. Pecos pupfish are absent from all springs and lakes on private land adjacent to the BLSP (Appendix II).

♦ BLM Overflow Wetland

Pecos pupfish are abundant on the BLMOW (Appendix I). Spring discharge feeds a series of small sink depressions and maintains extensive marshland with lentic and lotic habitat. This habitat is poorly surveyed but appears important for Pecos pupfish conservation. Seasonality in the extent and abundance of this population should be more thoroughly documented.

♦ Salt Creek, TX

Salt Creek, TX contains the only known population of genetically pure Pecos pupfish outside of Chaves County, NM. The sequence of falls in lower Salt Creek may be a barrier to invasion by mainstem fish. A collection of Pecos pupfish from Salt Creek, TX in June 1991 appeared free of genetic contamination (Wilde and Echelle, 1992) as were collections from 1998 (Echelle pers. comm.). This habitat is impacted by heavy erosion, livestock trampling, saltcedar infestation, road construction, and drought. Salt Creek, TX should be considered heavily imperiled and a high priority in Pecos pupfish conservation.

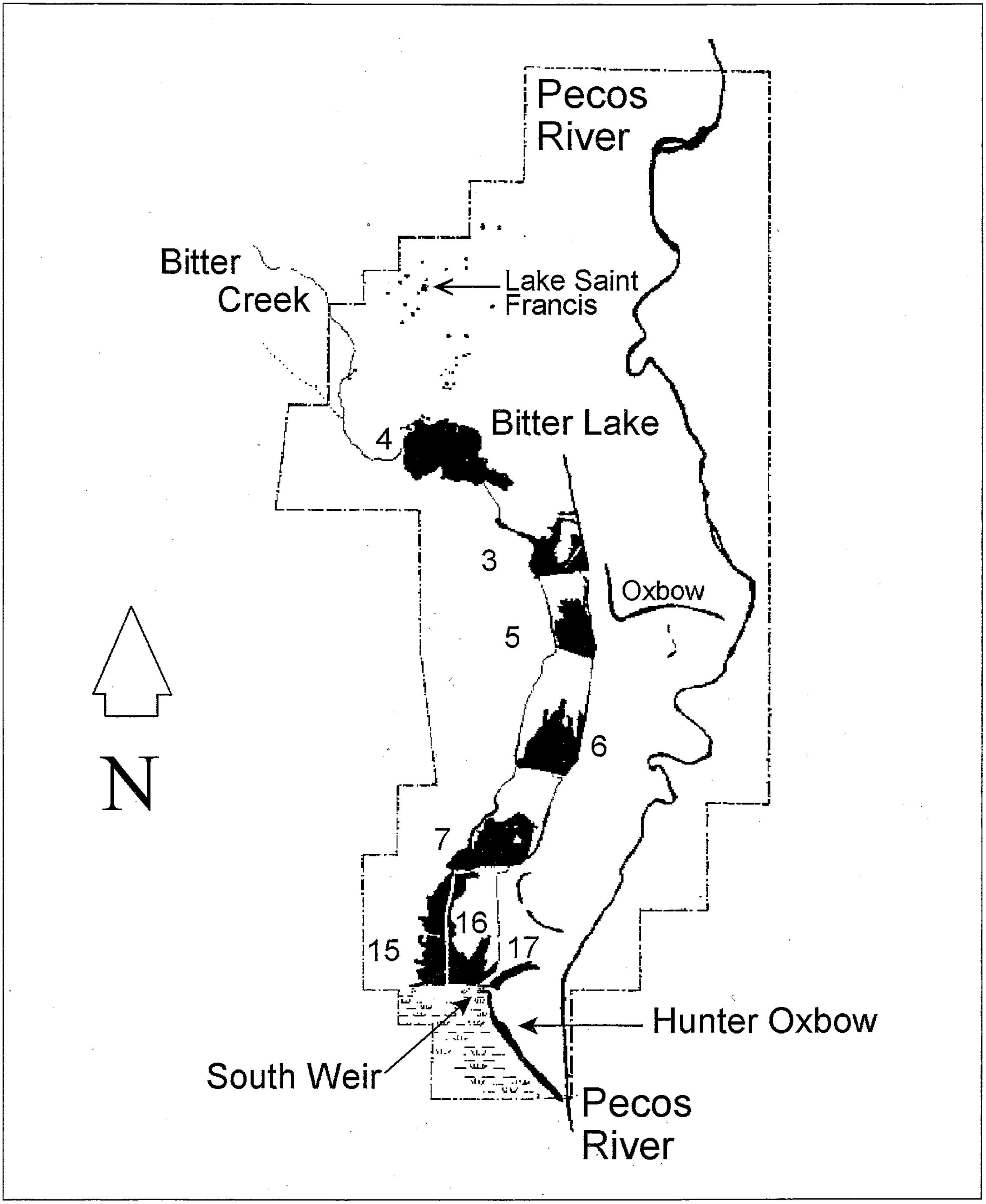


FIGURE 5. Map of the middle tract BLNWR.

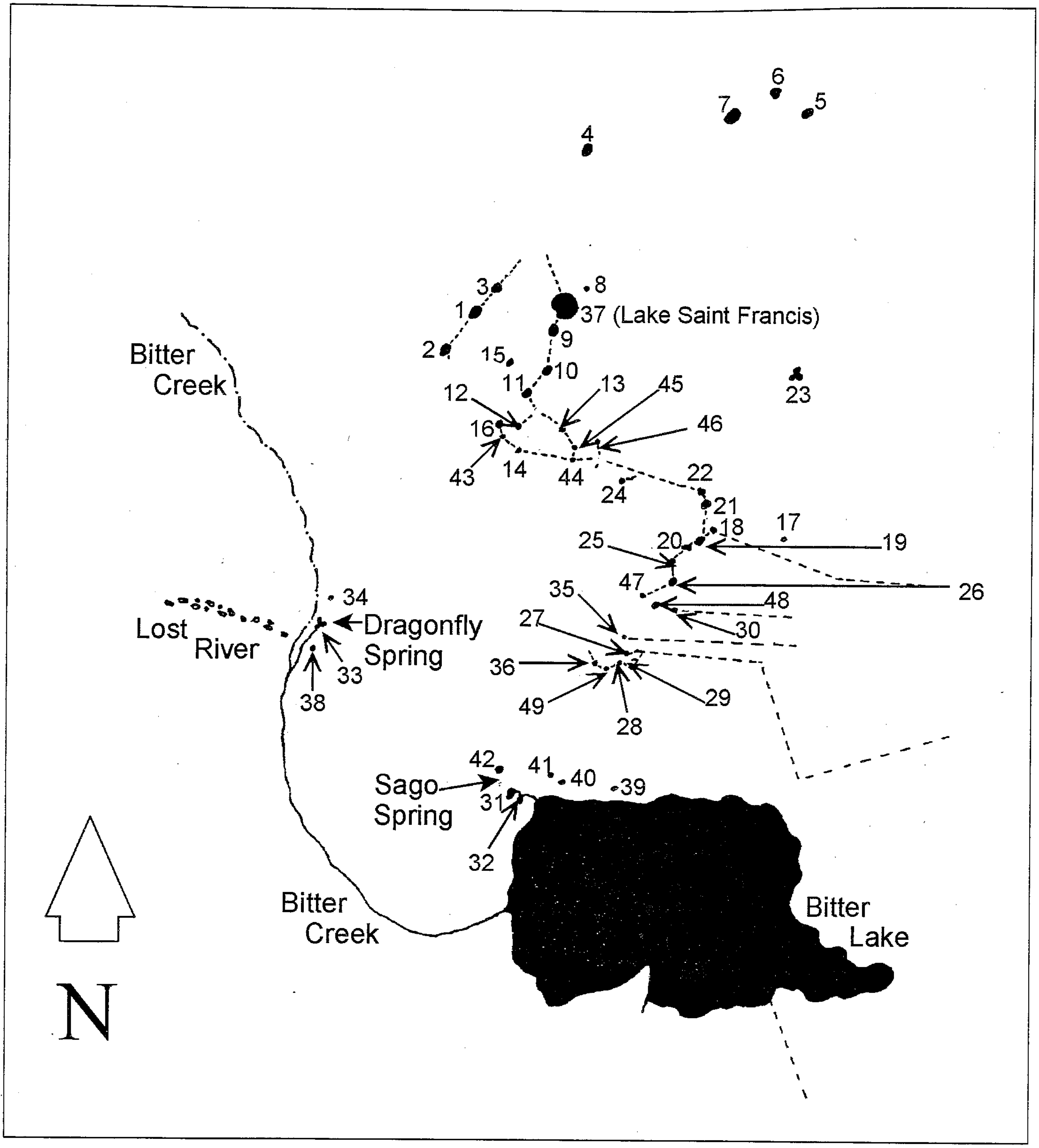


FIGURE 6. Map of Bitter Lake drainage and adjacent sinkholes.

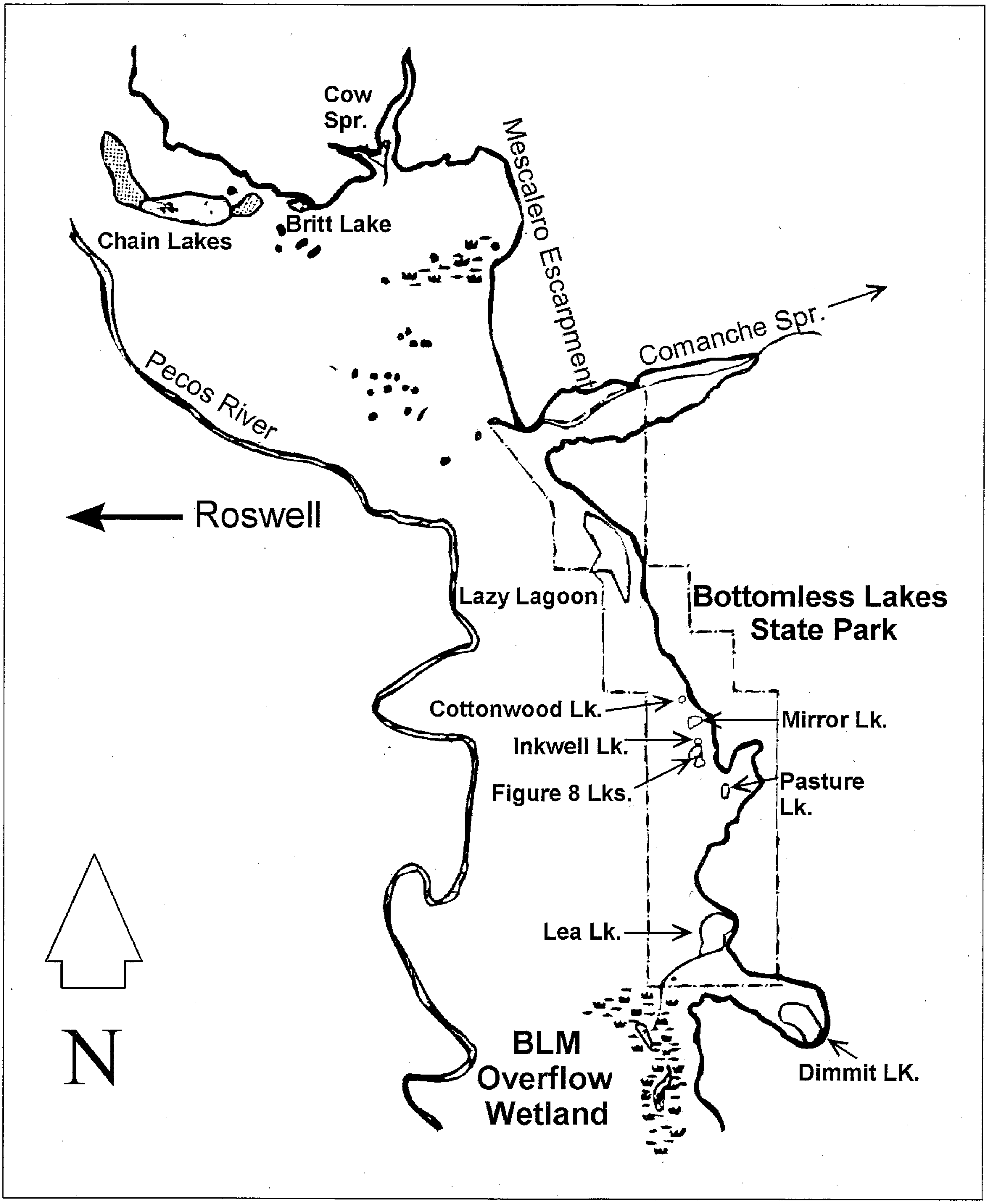


FIGURE 7. Map of BLSP and BLMOW.

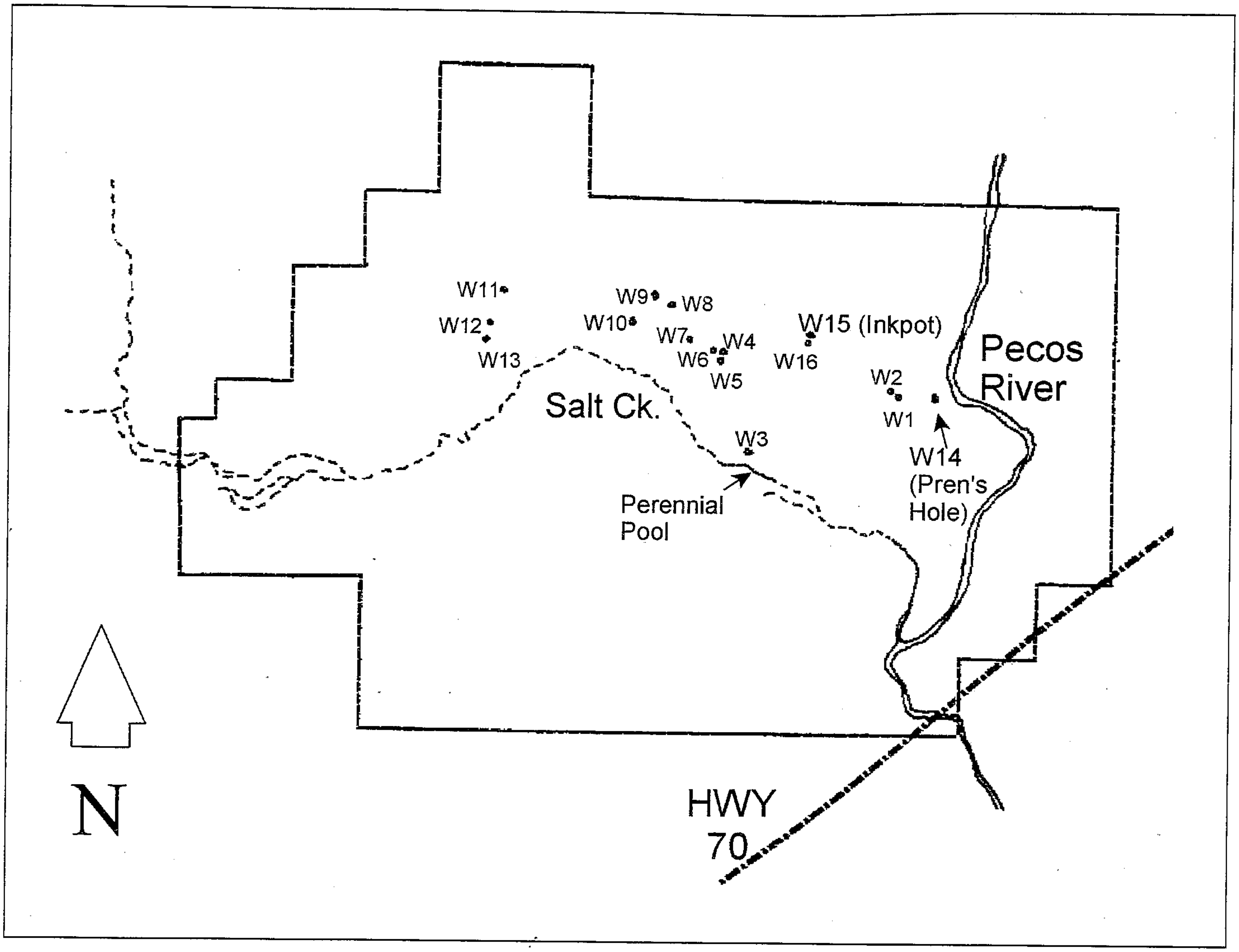


FIGURE 7. Map of north tract BLNWR

DISCUSSION

Much historic wetland habitat was lost to water and land development. Depletion of deep and shallow water reserves was greatest between 1910 and 1960 (Fiedler and Nye, 1933; Thomas, 1959; Scudday, 1974; Brune, 1981; LaFave, 1987; Hill, 1996). Exploitation of shallow aquifers eliminated perennial playas and marshes. Depletions were exacerbated by loss of Pecos River and tributary flood flows, the degradation of the Pecos River and tributary stream channels, and increased upland erosion. The geomorphic degradation of the Pecos River and tributaries along with the reduction in base flows eliminated pupfish habitat within stream beds.

It was difficult to determine the character of the "best" habitat for Pecos pupfish. In isolated habitat with salinity >20 ppt, Pecos pupfish were often abundant and were commonly the only fish species present but were typically stunted and in constant danger of desiccation and/or elevated salinity. In springfed habitat (<20 ppt), Pecos pupfish were often sympatric with other fish species but individuals were in robust physical condition. Fish populations in springheads were protected by the physical stability of the habitat.

A sequence of connected habitats (stable springs, spring fed wetlands, evaporative lakes) provides refugia for Pecos pupfish from habitat dessication, predation, and interspecific competition. Pecos pupfish are common from springheads to evaporative areas where surface flow dwindles. Contiguous springfed/evaporitic wetlands were only present on BLNWR (Fig. 5), BLSP/BLMOW (Fig. 7), and Salt Creek, TX (Fig. 4).

DYNAMICS OF MICRO-POPULATIONS

The origin of Pecos pupfish in upland sinkholes is unknown. Natural colonization may have occurred but is undocumented. The original source of pupfish would have theoretically been Bitter Creek which is currently isolated from and at a lower elevation than the sinkholes. However, perennial flow in Bitter Creek may have extended upstream bringing pupfish into closer proximity with sinkholes and making an overland flood connection more likely. The depression of the watertable via groundwater pumping isolated most sinkholes.

Alternatively, Pupfish may have gained access to sinkholes more recently through canals which connected multiple sinkholes with impoundments in the 1930's. If Pecos pupfish did not actively colonize via the canals, they may have been introduced incidentally during fish stockings. Extensive records at BLNWR headquarters indicated numerous efforts to stock and harvest sport- and baitfish species in and from sinkhole lakes.

During this study, Pecos pupfish gained access to uninhabited sinkholes through natural dispersal and experimental stocking (Appendix I). Sinkhole 39 was colonized during high Bitter Lake levels (Fig. 6). Pupfish apparently colonized Pren's Hole (W13) by overland dispersal from Salt Creek during a flash flood (Fig. 8). The active dispersal of Pecos pupfish between habitats illustrates the importance of habitat connectivity and flood events.

Extinctions of Pecos pupfish from sinkholes occurred historically and were observed during this study. Causes may have been low dissolved oxygen (DO), increased salinity, or desiccation. Drought and groundwater depletion reduced surface water on BLNWR between 1940 and 1980. Conditions may have become too severe to sustain pupfish in certain sinkholes. Heavy growths of Chara and algae may deplete DO in smaller sinkholes. The ephemeral nature of Pecos pupfish populations in certain habitats emphasizes the importance of stable refugia.

Pecos pupfish occupied a perennial pool in Salt Creek, NM, one half mile upstream of the Pecos River (Fig. 8). They were easily captured and often numerous in Salt Creek prior to 1994. The typical salinity of the pool was 15 to 20 ppt. However, on 2 August 1994, repeated seine hauls produced no Pecos pupfish and salinity was 200 ppt. The dramatic salinity increase was related to the influx of saltcedar ash during a rainstorm following a range fire. Pecos pupfish were again collected from the pool on 29 September 1994 when salinity was 32 ppt. The re-colonization method of Salt Creek was undocumented. Water from the Pecos River sometimes backed into Salt Creek during sustained high flows. However, the Pecos River was at high flow on 2 August 1994 and was not connected with the perennial pool. No Pecos pupfish populations were known upstream of the Salt Creek perennial pool, making colonization by overland flow unlikely.

It was possible that the Pecos pupfish in Salt Creek, NM survived high salinities by delaying egg hatching. However, salinity above 35 ppt retards egg and larvae development in pupfish (Kinne and Kinne, 1962). The large size of the pupfish collected on 29 September is further evidence against delayed egg hatching.

The amount of time that the pool in Salt Creek remained hypersaline is unknown but subsequent thunderstorms reduced salinity by 29 September. It is possible that *Cyprinodon* species can survive for short periods in substrate, even in anaerobic conditions (Deacon and Minckley, 1974). However, this is not documented for Pecos pupfish.

CONSERVATION OF WETLANDS

In Chaves County, NM certain wetlands have been managed by federal and state agencies for wildlife conservation and recreational use. On BLNWR levees were constructed with the purpose of enhancing waterfowl habitat by creating lakes (Fig. 5). Although the structure of the wetlands was altered, much aquatic habitat was maintained.

Lakes and impoundments on BLNWR and BLSP were repeatedly stocked with sportfish during the first half of this century (Navarre, 1959; Brooks and Wood, 1988). The salinity of BLNWR and BLSP waters limited the success of game fish introductions. Green sunfish (*Lepomis cyanellus*) were most successful in becoming established. Rainbow trout (*Onchorhynchus mykiss*) are currently stocked in four BLSP sinkhole lakes (D. Sharp, pers. comm.).

Outside of the Roswell Basin, aquatic habitat was generally owned or leased by private individuals. In the Carlsbad Valley and in Texas, groundwater use was less rigidly controlled and depletions were dramatic and are ongoing (Scudday, 1974; Brune, 1981; LaFave, 1987).

♦ Bitter Creek

A major component of BLNWR was Bitter Lake drainage (Figs. 5 and 6; Brooks and Wood, 1988). Perennial flow in this system initiated in upper Bitter Creek on the northwest portion of the middle tract. In the past there has been confusion in the designations of Bitter Creek and the subterranean Lost River (Brooks and Wood, 1988). Bitter Creek is an above-ground drainage, flowing mostly south, supplemented by springs (e.g. Dragonfly Spring, Lost River) and seeps. It enters Bitter Lake from the west. Lost River, flowing mostly east, is only detectable on the land surface by shallow depressions and a ribbon of saltcedar. It flows underground for its entire length, entering Bitter Creek via a cavern (Fig. 6). Springs in Bitter Creek are mildly saline (4-7 ppt) but Bitter Lake is typically very saline (as high as 100 ppt) since inflow evaporates within the lake bed. Former authors of BLNWR fish studies improperly referred to Bitter Creek as Lost River. Old collections also referred to Dragonfly Spring as Cottonwood Spring. Bitter Creek (including Dragonfly Spring and Lost River) and Sago Spring were the chief sources of water in Bitter Lake.

Although there was seldom a surface connection, Bitter Lake discharged east into the waterfowl lakes (Fig. 5). There was a large complex of springs and seeps within each waterfowl lake and flow was from north to south. Discharge from the refuge was chiefly through the south weir below units 15, 16, and 17. Water flowed over the weir and entered the Pecos River via Hunter Marsh.

♦ BLM Overflow Wetland

The BLMOW was supplied by outflow from Lea Lake, BLSP (Fig. 7). Discharge from Lea Lake flowed toward the Pecos River and created a series of shallow, marsh habitats. Salinity increased with distance from Lea Lake as effects of evaporation increased. The marsh was extensive and (aside from the presence of saltcedar) may be most representative of historic floodplain wetlands in the Roswell Basin.

PECOS PUPFISH CONSERVATION

Local extirpations of Pecos pupfish populations undoubtedly occur as natural events but, recolonization from adjacent populations during floods and wet conditions would have been much more common in the past. Loss of Pecos River flood flows makes connectivity of off-channel habitat crucial in maintaining Pecos pupfish populations. Because of habitat losses, only two populations remain. The Chaves County population is relatively large and is comprised of many habitats which are distributed for roughly 70 km adjacent to the Pecos River. However, some sub-populations within the Roswell Basin have become isolated from each other, making them susceptible to extirpation. The Salt Creek, TX population is restricted to a single arroyo and threatened by the loss of spring discharge and the invasion of sheepshead minnow. The recent loss of pupfish populations in Malaga Bend and Laguna Grande De la Sal demonstrates that habitat depletion remains a threat.

♦ Roswell Basin

In the Roswell Basin, habitat suitable for Pecos pupfish was most extensive and diverse on BLNWR and BLMOW. A surface-flow water right was recently acquired for Bitter Creek. This right provides protection for springflow in an area critical to Pecos pupfish conservation. Aquatic habitat in the Roswell Basin may increase if the watertable continues to rise. Restored wetlands may provide opportunity for the expansion of Pecos pupfish populations. Habitat in the vicinity of BLSP and the Dexter National Fish Hatchery and Technology Center holds the most potential for marshland recovery.

River restoration activities, planned for the middle tract BLNWR for conservation of federally threatened Pecos bluntnose shiner, may benefit Pecos pupfish. If the slope of the river channel is reduced, increased sediment retention may raise the watertable and create additional in-channel and floodplain habitat. One flood-prone playa already exists on BLNWR and could be enhanced by an elevated watertable and more frequent flooding.

Lazy Lagoon was the largest habitat on BLSP and supported a dense Pecos pupfish population. Other lakes (Cottonwood, Inkwell, Pasture, and Mirror Lakes) on BLSP, were seasonally stocked with rainbow trout but of these, only Mirror Lake supported Pecos pupfish. Live-bait fishing was permitted on BLSP (D. Sharp pers. comm.) which threatened Pecos pupfish with genetic contamination. If hybrid pupfish were transported from Red Bluff Reservoir and used at BLSP, they could easily escape or be discarded and become established.

♦ Delaware Basin

Pecos pupfish in the Delaware Basin are virtually unprotected. The complete decimation of aquatic habitat occurred between 1910 and 1970 through groundwater exploitation, river channel degradation, oil field contamination, potash waste disposal, and saltcedar proliferation. To date, there is no regulation of groundwater pumping. The Pecos pupfish population of Salt Creek, TX is the sole remnant of Delaware Basin populations and is critical to survival of the species. The population is imperiled by the threats of habitat loss and genetic contamination.

SHORT-TERM CONSERVATION MEASURES

1. Habitat Protection and Restoration:

Immediate, short term activities to restore Pecos pupfish habitat should focus on the protection of Pecos River floodplain and tributary habitat. Protection of groundwater from depletion and contamination will secure many habitats and may create others. The control of saltcedar may enhance springflow and increase surface water.

The physical condition of Salt Creek, TX is of great concern. Discharge from Salt Creek, water quality, and water chemistry should be regularly monitored. Pecos pupfish population status and dynamics should be monitored and analyzed. A stakeholders agreement to protect and enhance current Pecos pupfish habitat in Salt Creek may improve conservation potential. Erosion control and saltcedar control may stabilize spring flows in Salt Creek. Barriers to the upstream movement of Pecos River fishes could also serve as erosion control structures.

2. Protection From Genetic Contamination:

Monitoring for Pecos pupfish-sheepshead minnow hybrids and other species of pupfish should be performed regularly throughout the Pecos Basin. If hybrid pupfish are restricted to the Pierce Canyon confluence in New Mexico, then elimination by chemical treatment is a possibility.

The Salt Creek Pecos pupfish should be periodically monitored for genetic purity. Barriers to hybrid pupfish dispersal into Salt Creek from the Pecos River and Red Bluff Reservoir should be maintained and improved. If Salt Creek Pecos pupfish are declining or the habitat is in apparent jeopardy it would be critical to establish hatchery stocks to preserve the genetic diversity of the species.

LONG-TERM CONSERVATION MEASURES

1. Habitat Protection and Restoration:

Regulation of groundwater pumping in Chaves County, NM, which began in 1966, reversed the trend of habitat loss. Conservation of water for agriculture in the Roswell Basin benefitted Pecos pupfish by protecting springflows on BLNWR. Adoption of such measures elsewhere would increase the potential for habitat restoration.

Protection from groundwater and surface-water contamination is imperative. The Roswell artesian aquifer is recharged from a vast geographic area and flow through the cavernous limestone is relatively swift. Therefore, surface spills and direct aquifer spills are a serious threat to Pecos pupfish. Drilling for natural gas and petroleum should be strictly regulated. Pipelines should avoid BLNWR/BLSP and should be constructed in a manner that protects against longterm failure.

Control of saltcedar, control of erosion, and protection of riparian communities may assist in restoring wetland habitat. Removing saltcedar from spring heads and water courses may result in increased surface water. Discretion in allowing livestock use of springheads and riparian areas can improve riparian vegetation and aquatic habitat. Stabilization and repair of erosional head cuts and fill of eroded arroyos may also allow for the recovery of surface water and aquatic habitat in spring systems.

The Pecos River in Chaves County, NM is suitable for habitat recovery activities. Populations of pure Pecos pupfish occupy habitat adjacent to the river. Widening the river channel and removing saltcedar should increase habitat variability and decrease the slope of the channel by allowing the river to meander more widely. This would lead to increased sediment storage, allowing development of an active floodplain under the current flow regime. If standing-water habitat develops within the new floodplain it would be naturally populated by Pecos pupfish.

Restoration of aquatic habitat in the Delaware Basin for Pecos pupfish is complicated by the presence of pupfish hybrids in the Pecos River. Restored habitat in close proximity to hybrid pupfish populations must be protected from incidental introductions of pupfish hybrids by either the elimination of the hybrids or the establishment of substantial physical and political protection.

2. Non-native Fish Control

The introduction of non-native fish species must be curtailed. Bait-bucket introductions led to the establishment of sheepshead minnow, inland silverside (*Menidia beryllina*: from Roswell downstream), and gulf killifish (*Fundulus grandis:* from Carlsbad downstream) in the Pecos River. These species inhabit habitat similar to that preferred by Pecos pupfish. Inland silverside and gulf killifish are sympatric with sheepshead minnow in the Gulf of Mexico where they compete for forage (Harrington and Harrington, 1961).

Establishment of pupfish hybrids upstream of Red Bluff Reservoir is of great concern. In Texas, pupfish hybrids have expanded their range downstream of the historical Pecos pupfish range (Wilde and Echelle, 1992). In the middle Pecos River of TX, pupfish hybrids were common in riffle and run habitat not typically occupied by Pecos pupfish (Hoagstrom, 1994). If similar dispersal occurs in New Mexico, it will increase the likelihood of contact with pure Pecos pupfish populations.

Elimination of sheepshead minnow from the Pecos River would considerably enhance Pecos pupfish conservation status. Periodic blooms of golden algae (*Prymnesium parvum*) may provide opportunities for non-native fish control. The result of a fish kill was observed by one author in the Pecos River near Iraan, TX in October 1994. Fish of all species were extremely rare at two sites until April.

CONCLUSIONS

1. Historically, Pecos pupfish were widespread within the Roswell Basin of New Mexico and the Delaware Basin of New Mexico and Texas. The Chaves County population within Roswell Basin remains on public lands in the Roswell vicinity. These lands have been protected from direct agricultural impacts and are supplied by discharge from San Andres limestone. Wetlands downstream of Chaves County are unprotected and do not receive direct artesian discharge. The last Pecos pupfish population outside of Chaves County, NM occupies the headwaters of Salt Creek, TX. This habitat is not formally protected and is subject to direct impacts from agriculture and industry and non-native fish species.

2. Habitat loss and degradation caused the decline of Pecos pupfish and restricts the potential for recovery of wetland habitat and restoration of natural hydrologic processes upon which Pecos pupfish rely.

3. Genetic contamination has greatly reduced the range of pure Pecos pupfish and threatens remaining populations. The range of hybrid pupfish should be monitored and opportunities to reduce or control their range should be exploited. The artificial spread of hybrid-pupfish must be curtailed.

4. Pecos pupfish depend on the continued existence of suitable habitat. Habitat loss typically results from lowering of the water table (e.g groundwater pumping, saltcedar encroachment, erosion, flood control) or human alterations of rivers and wetlands (e.g. impoundment, dredging, draining, pollution). Habitat protection must be maintained through regulation of groundwater use, protection from groundwater and surface water contamination, river channel restoration, saltcedar control, proper range management, and protection and enhancement of occupied and suitable habitats.

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APPENDIX I

Known Extant Pecos Pupfish Locality Descriptions and Recent Survey Data

Section A - 1

Known Localities in Chaves County, New Mexico

All collections were made by the USFWS NMFRO.

NR = not recorded
NT = not trapped

BITTER LAKE NATIONAL WILDLIFE REFUGE

Sinkhole No. 1, Middle Tract, Chaves Co.; surface area ca. 0.11 ha, maximum depth 4 m, silt substrate, Chara and *Potamogeton* abundant covering 80% of the bottom; no other fish species present.

Sinkhole No. 1

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 Jul. 8	28.5	NR	NR	NR	56.0
1988 Jun. 15	29.0	20.5	34500	9.4	32.5
1993 Jul. 27	30.4	20.2	36300	7.7	132.25
1995 Mar. 21	16.0	17.2	27000	NR	NT
1995 Jun. 19	24.8	13.7	21000	NR	NT
1997 Jun. 18	25.0	21.2	33800	4.7	NT

Sinkhole No. 2, Middle Tract, Chaves Co.; maximum depth 5 m, silt substrate, Chara and *Potamogeton* abundant covering 80% of the bottom; no fish species present in 1981 and 1988. *Cyprinodon pecosensis* was collected from this locality in 1970. On 20 June 1995 approximately 350 *C. pecosensis* were reintroduced into this sinkhole from sinkholes 21 and 22.

Sinkhole No. 2

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1995 Jun. 20	24.2	8.9	14700	8.4	350 introduced
1995 Jul. 19	27.0	17.0	28800	6.3	17.5
1995 Aug. 14	29.0	15.3	26500	4.5	176.5
1995 Sep. 4	28.0	17.0	26000	8.4	262.5
1995 Dec. 7	11.0	12.9	15000	9.6	896.0
1996 Mar. 12	13.8	14.9	18300	5.9	65.5
1996 Jun. 11	25.0	15.0	24900	8.1	299.5
1996 Oct. 2	22.0	12.5	18500	7.5	569.5
1997 Jun. 18	25.0	13.8	23000	8.0	NT

Sinkhole No. 3, Middle Tract, Chaves Co.; maximum depth 4 m, silt substrate, Chara and *Potamogeton* abundant covering 80% of the bottom; no fish species present in 1981 and 1988. *Cyprinodon pecosensis* was collected from this locality in 1970. On 20 June 1995 approximately 490 *C. pecosensis* were reintroduced into this sinkhole from Bitter Creek.

Sinkhole No. 3

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1995 Jun. 20	24.0	13.0	18000	7.1	490 introduced
1995 Jul. 19	29.5	21.8	36100	6.5	9.5
1995 Aug. 14	29.0	22.7	33400	6.2	98.0
1995 Sep. 4	29.2	23.4	35200	10.1	148.0
1995 Dec. 7	11.3	16.4	19500	9.4	286.5
1996 Mar. 12	13.2	18.7	23400	6.5	90.5
1996 Jun. 11	26.0	20.0	33000	6.4	173.0
1996 Oct. 2	22.3	15.7	23600	7.4	311.5
1997 Jun. 18	25.2	18.2	29500	6.0	NT

Sinkhole No. 7, Middle Tract, Chaves Co.; surface area ca. 0.18 ha, maximum depth 8.5 m, silt/limestone bedrock substrate, Chara and *Potamogeton* abundant covering 90% of the bottom; other fishes present are *F. zebrinus* and *G. nobilis*.

Sinkhole No. 7

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 Jul. 8	28.0	NR	NR	NR	36 (total)
1988 Jun. 15	27.0	7.0	12200	8.4	24.5
1993 Jul. 27	29.6	8.0	12800	8.9	21.0
1995 Mar. 21	17.0	6.5	9000	NR	NT
1997 Jun. 19	23.9	6.5	11520	7.4	NT

Sinkhole No. 9, Middle Tract, Chaves Co.; surface area ca. 0.14 ha, maximum depth 7 m, silt/limestone bedrock substrate, Chara covers 60% of the bottom; no other fishes present.

Sinkhole No. 9

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 26	NR	NR	NR	NR	549 (total)
1988 Jun. 22	26.0	28.0	40500	10.1	10 (seine hauls)
1993 Jul. 20	28.0	19.5	33000	7.8	159.25
1995 Mar. 21	17.0	23.5	30000	NR	NT
1997 Jun. 17	24.4	22.1	35100	5.4	NT

Sinkhole No. 10, Middle Tract, Chaves Co.; surface area ca. 0.03 ha, maximum depth 2.5 m, silt/limestone bedrock substrate, Chara covers 80% of the bottom; other fish species present is *G. nobilis.*

Sinkhole No. 10

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Jun. 22	29.0	20.0	29000	3.2	5.5 (seine hauls)
1993 Jul. 21	27.7	17.2	28900	7.1	7.5
1995 Mar. 21	16.0	13.0	17000	NR	NT
1997 Jun. 17	21.3	12.8	21500	0.8	NT

Sinkhole No. 11, Middle Tract, Chaves Co.; surface area ca. 0.12 ha, maximum depth 7 m, silt/limestone bedrock substrate, Chara covers 90% of the bottom; no other fish species present.

Sinkhole No. 11

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 26	24.0	NR	NR	NR	51.5
1988 Jun. 22	27.0	33.3	45500	5.3	82 (seine haul)
1993 Jul. 21	29.8	22.0	36500	8.6	85.75
1995 Mar. 21	17.0	27.5	36000	NR	NT
1997 Jun. 17	23.8	27.5	42600	2.4	NT

Sinkhole No. 16, Middle Tract, Chaves Co.; surface area ca. 0.03 ha, maximum depth 3 m, silt/limestone bedrock substrate, Chara covers 70% of the bottom; no other fish species present.

Sinkhole No. 16

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Jun. 22	30.0	50.0	70000	7.4	315 (seine haul)
1993 Jul. 22	37.0	24.2	45500	3.4	115.5
1995 Mar. 21	18.0	31.5	45000	NR	NT
1997 Jun. 17	26.9	29.7	47300	1.5	NT

Sinkhole No. 19, Middle Tract, Chaves Co.; surface area ca. 0.08 ha, maximum depth 3m, *Potamogeton* covers much of the bottom; no other fish species present.

Sinkhole No. 19

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Aug. 24	31.0	44.0	78000	5.8	No Fish
1993 Jul. 22	32.1	13.9	25300	4.8	417.75
1995 Mar. 21	19.2	21.9	30010	NR	NT
1995 Jun. 19	28.1	36.1	47300	NR	NT
1997 Jun. 17	24.4	21.2	33800	7.8	NT

Sinkhole No. 20, Middle Tract, Chaves Co.; surface area ca. 0.06 ha, maximum depth 4 m, limestone bedrock/silt substrate, Chara covers 40% of the bottom; other fish species present are *C. lutrensis*, *G. affinis*, and *G. nobilis*.

Sinkhole No. 20

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 26	23.0	NR	NR	NR	47 (total)
1988 May 26	26.0	8.0	13000	NR	55 (seine haul)
1993 Jul. 22	29.8	8.2	14800	8.3	24.0
1995 Mar. 21	16.0	7.8	10800	NR	NT
1995 Jun. 19	25.0	9.5	13700	NR	NT
1997 Jun. 17	22.5	7.4	12950	4.8	NT

Sinkhole No. 21, Middle Tract, Chaves Co.; surface area ca. 0.17 ha, maximum depth 4 m, silt/limestone bedrock substrate, Chara covers 10% of the bottom, turbid-brown/yellow coloration; no other fish species present.

Sinkhole No. 21

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 May 26	26.0	40.0	50000	NR	22.5
1993 Jul. 22	25.8	39.2	Off Scale	3.8	153.0
1995 Mar. 21	21.8	Off Scale	Off Scale	NR	NT
1995 Jun. 19	30.1	86.0	128800	NR	NT
1997 Jun. 17	22.6	60.5	86500	6.9	NT

Sinkhole No. 22, Middle Tract, Chaves Co.; surface area ca. 0.01 ha, maximum depth 1.3 m; Chara is present, no other fish species present.

Sinkhole No. 22

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1993 Jul. 27	26.5	34.2	Off Scale	5.3	241.75
1995 Mar. 21	19.2	36.0	47900	NR	NT
1995 Jun. 19	29.0	50.0	79600	NR	NT
1997 Jun. 18	24.2	34.8	52700	4.7	NT

Sinkhole No. 24, Middle Tract, Chaves Co.; surface area ca. 0.01 ha, maximum depth 1.8 m, silt/limestone bedrock substrate, no aquatic vegetation; no other fish species present.

Sinkhole No. 24

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 May 26	27.5	26.0	40500	NR	31.5
1993 Jul. 22	25.4	19.7	32100	2.5	97.5
1995 Mar. 21	18.0	24.0	33000	NR	NT
1997 Jun. 17	22.6	24.7	38800	0.3	NT

Sinkhole No. 25, Middle Tract, Chaves Co.; surface area ca. 0.05 ha, maximum depth 2 m, silt substrate, Chara covers 60% of the bottom; no other fish species present.

Sinkhole No. 25

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 26	23.5	NR	NR	NR	256 (total)
1988 May 26	28.0	15.5	25200	NR	87.0
1993 Jul. 22	28.6	11.9	20900	6.1	27.5
1995 Mar. 21	19.0	12.2	17800	NR	NT
1997 Jun. 17	21.9	11.0	18700	0.5	NT

Sinkhole No. 26, Middle Tract, Chaves Co.; surface area ca. 0.08 ha, maximum depth 3.3 m, silt/limestone bedrock substrate, *Potamogeton* covers 10% of the bottom; no other fish species present.

Sinkhole No. 26

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 May 26	26.8	30.4	47000	NR	36.5
1993 Jul. 22	25.2	20.8	33200	4.4	56.0
1995 Mar. 21	18.2	26.6	35500	NR	NT
1997 Jun. 17	23.4	25.4	39800	9.3	NT

Sinkhole No. 27, Middle Tract, Chaves Co.; surface area ca. 0.06 ha, maximum depth 6 m, silt/limestone bedrock substrate, Chara covers 60% of the bottom; other fish species present are *F. zebrinus* and *G. nobilis*.

Sinkhole No. 27

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Jun. 22	32.0	21.0	31000	9.0	6 (seine haul)
1993 Jul. 27	27.1	16.4	28800	6.9	16.25
1995 Mar. 21	16.0	16.2	21800	NR	NT

Upper sinkhole No. 27, Middle Tract, Chaves Co.; immediately adjacent to (north of) sinkhole 27 and formerly adjoined. Similar to sinkhole 27 although smaller.

Upper sinkhole No. 27

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1995 Mar. 21	18.5	12.2	17200	NR	NT

Sinkhole No. 28, Middle Tract, Chaves Co.; surface area ca. 0.01 ha, maximum depth 2 m, silt/limestone gravel substrate, Chara covers 80% of the bottom; no other fish species present.

Sinkhole No. 28

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Jun. 22	29.0	31.3	43000	7.0	20 (seine haul)
1993 Jul. 27	26.4	22.3	38200	6.8	177.75
1995 Mar. 21	16.0	23.2	30000	NR	NT
1997 Jun. 17	22.6	23.3	36900	10.2	NT

Sinkhole No. 29, Middle Tract, Chaves Co.; surface area ca. 0.02 ha, maximum depth 2 m, silt/limestone bedrock substrate, Chara covers 70% of the bottom; no other fish species present.

Sinkhole No. 29

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Jun. 22	29.5	20.5	29000	10.8	9 (seine hauls)
1993 Jul. 27	27.0	19.0	30900	6.4	533.75
1995 Mar. 21	17.2	17.9	23400	NR	NT
1997 Jun. 17	19.1	13.2	22000	0.3	NT

Sinkhole No. 31, Middle Tract, Chaves Co.; this sinkhole is part of the Sago Spring complex, isolated except for seasonal high water levels; surface area ca. 0.02 ha, maximum depth 1 m, silt substrate, Chara covers 70% of the bottom; other fish species present is *G. nobilis.*

Sinkhole No. 31

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 22	23.0	NR	NR	NR	22 (seine haul)
1988 Jun. 14	24.0	7.5	12700	5.2	18.5 (seine haul)
1993 Jul. 19	27.5	5.4	10000	6.6	64.75

Sinkhole No. 32, Middle Tract, Chaves Co.; this sinkhole receives direct inflow from Sago Spring run; surface area ca. 0.02 ha, maximum depth 1.5 m, Chara, *Potamogeton,* and *Scirpus* cover 30% of the bottom; other fish species present are *D. episcopa, L. parva, G. nobilis,* and a single *G. affinis*, taken in 1987.

Sinkhole No. 32

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 22	NR	NR	NR	NR	184 (seine haul)
1988 Jun. 14	20.5	4.0	6000	7.2	588 (seine haul)
1993 Jul. 19	24.9	4.5	7800	4.6	8.0
1995 Mar. 21	19.0	7.2	10900	7.5	0
1997 Jun. 18	21.7	7.9	13700	6.3	NT

Sinkhole No. 37, (Lake Saint Francis), Middle Tract, Chaves Co.; largest and deepest sinkhole on the South Tract; surface area ca. 0.35 ha, maximum depth 14 m, silt/limestone bedrock substrate, Chara and *Batophora* cover 30% of the shoreline area; other fish species present are *F. zebrinus* and *G. nobilis*. Lake Saint Francis was a subject of the Fishery Resources Monitoring Program (FRMP) which attempts to document water quality and fish community conditions in relation to global climate. As a result there is a wealth of data on this sinkhole. Therefore, the table above summarizes data from the study. Column two refers to the number of times that water quality was taken in that year.

Sinkhole No. 37 (Lake Saint Francis)

Year	No. of WQ coll.	Mean Temp.	Mean Salinity	Mean Cond.	Mean DO	*C. pecosensis* per trap array
1991	7	12.29	9.42	13441.13	7.95	15.6
1992	13	16.22	8.10	10565.22	7.35	39.0
1993	9	17.05	8.16	10434.72	6.91	63.7
1994	4	15.58	7.82	11038.64	6.58	116.3
1995	11	16.91	7.46	10640.36	7.43	43.7
1996	10	15.76	7.17	9517.67	6.67	77.9
1997	5	13.10	5.30	6023.20	7.60	193.4

Sinkhole No. 38, Middle Tract, Chaves Co.; surface area ca. 0.002 ha, maximum depth 1 m, silt/limestone bedrock substrate, Chara covers ca. 50% of the bottom; this sinkhole appears to have a connection (karst - piping) to the Dragonfly Spring channel near the Bitter Creek confluence; other fish species present is *F. zebrinus*.

Sinkhole No. 38

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Jun. 15	25.0	3.0	5000	8.3	2
1993 Jul. 19	20.4	3.3	5200	2.6	0.5
1997 Jun. 18	17.5	4.1	7470	1.6	NT

Sinkhole No. W14 (Pren's Hole), North Tract (Salt Creek Wilderness), Chaves Co.; recently formed sinkhole between the refuge road and the Pecos River, unmeasured, Chara present; other fish species present: *F. zebrinus*.

Pren's Hole (North Tract)

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Jun. 29	28.0	11.0	20000	9.9	0
1988 Sep. 9	16.5	10.5	15500	8.1	0
1994 Aug. 3	27.7	7.2	13300	7.2	5.4
1995 Sep. 6	24.5	12.8	20600	NR	NT

Sinkhole No. W15 (Inkpot), North Tract (Salt Creek Wilderness), Chaves Co.; unmeasured, ca. 40 m diameter, maximum depth 19.8 m, land surface to water surface distance 10 m in 1990, 6 m in 1995; no aquatic vegetation observed; bedrock banks beneath water surface near vertical; other species present are *F. zebrinus* and *C. lutrensis*. Three *G. nobilis* were taken in 1988 and may still persist as well. On 5 and 6 December 1995, NMFRO personnel applied 7 units of Fintrol to this sinkhole in an effort to remove *C. lutrensis* and restore *C. pecosensis* and *G. nobilis* as the major ichthyocomponents. Inkpot was subsequently trapped to insure that no *C. lutrensis* survived. On 28 June 1996 *C. pecosensis* and *G. nobilis* were reintroduced into both Inkpot and the adjacent sinkholed w16 (Little Inkpot) from sinkhole 37 (Lake Saint Francis). Since no fish were observed or captured in October 1996 and May 1997, additional fish were introduced in July 1997 from Sago Spring, Dragonfly Spring, and Lake Saint Francis. However, at that time, fish were observed in Inkpot.

Sinkhole No. W15 (Inkpot, North Tract)

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Aug. 11	18.5	9.5	13800	6.2	0
1988 Dec. 14	NR	NR	NR	NR	0.1
1994 Aug. 2	24.9	5.1	8900	5.7	0.67
1995 Sep. 5	24.5	8.3	13800	7.3	2.0
1996 Jan. 11	7.0	7.5	8300	NR	0
1996 Jun. 11	22.5	8.9	14200	7.4	0
1996 Jun. 28	23.5	4.5	NR	NR	150 reintroduced
1996 Oct. 6	22.5	7.5	13000	5.8	0
1997 May 21	20.0	2.5	3920	NR	0
1997 Jul. 10	NR	NR	NR	NR	177 introduced
1998 Jun. 8	NR	NR	NR	NR	5.25
1998 Jun. 9	NR	NR	NR	NR	8.50

Sinkhole No. W16 (Little Inkpot), North Tract (Salt Creek Wilderness), Chaves Co., dimensions unmeasured. This pool appears to have received outflow from w15 historically. During drought periods it may become dry or extremely salty. There is an abundance of *Tamarisk* which has become enundated and provides a high level of structure. Chara is also present. *Cyprinodon pecosensis* and *G. nobilis* were introduced into this sinkhole on 28 June 1996 from sinkhole 37. Even though trap captures were low in 1997, high numbers of *C. pecosensis* were observed.

Sinkhole No. W16 (Little Inkpot)

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1994 Aug. 2	26.2	5.3	9500	NR	NT
1995 Sep. 5	24.1	10.6	12200	NR	NT
1996 Jun. 28	NR	NR	NR	NR	134 introduced
1996 Oct. 6	22.5	4.5	7000	6.8	18
1997 May 21	20.0	2.8	4250	NR	2
1997 Jul. 10	26.0	8.5	14200	NR	0.5
1998 Jun. 8	NR	NR	NR	NR	9.0
1998 Jun. 9	NR	NR	NR	NR	6.0

Salt Creek, North Tract (Salt Creek Wildnerness), Chaves Co.; located ca. 1 km upstream of Pecos River confluence, primarily pool habitats connected by short runs and riffles, flow estimated at <0.03 cms, silt substrate, 0.2-0.8 m deep, 1-2 m wide, incised up to 2 m, total length of pupfish habitat ca. 100 m, large drainage area and past extensive flooding evident; moderate *Tamarix* riparian; other species present are *F. zebrinus* and *G. affinis*.

Salt Creek (North Tract)

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1988 Aug. 31	NR	NR	NR	NR	341.9
1994 Aug. 3	34.0	200.0	328000	2.1	0
1994 Sep. 29	21.4	32.4	Off Scale	NR	2
1994 Oct. 31	14.8	31.2	31200	8.3	0
1995 Dec. 6	7.8	40.0	50000	NR	NS

Dragonfly Spring, Middle Tract, Chaves Co.; the spring head is a an oblong pool measuring 2 - 4 m wide X 9 - 10 m long, 0.2 - 0.5 m deep, the channel downstream is 0.5 - 1.0 m wide and 0.1 - 0.3 m deep and travels ca. 100 m to confluence with Bitter Creek, shoreline areas are dominated by dense growths of *Tamarix* and *Phragmites*, substrate is composed primarily of fine silt and organic debris, Chara and *Potamogeton* stands covering >20% of the pool bottom; other fish species present include *G. nobilis*, *L. parva*, and *D. episcopa*.

Dragonfly Spring

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Jun. 15	22.0	3.5	6000	3.2	27 (seine hauls)
1993 Jul. 19	19.5	4.5	7300	2.8	60.5
1997 Jul. 8	24.5	7.5	13300	NR	2

Sago Spring, Middle Tract, Chaves Co.; this spring system begins as a series of dry and wet solution depressions before entering a ca. 50 m long spring run that terminates at Sinkhole No. 32, substrate is silt and organic debris, channel width is uniform at 1.5 m and incised with vertical banks near 1 m high, shoreline vegetation is dense and dominated by *Tamarix* and *Phragmites*, an unidentified green algae is common throughout the habitat, salinity 3.5 ppt, other fish species present are *D. episcopa*, *L. parva*, *E. lepidum*, and *G. nobilis*.

Sago Spring, pools and run

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 22	18.0	NR	NR	NR	1 (seine)
*1987 May 22	16.6	NR	NR	NR	1 (seine)
*1988 Jun. 14	17.5	3.4	5500	4.0	8 (seine haul)
1993 Jul. 19	17.8	3.5	5300	4.8	27.0
1995 Mar. 21	18.2	4.8	7200	NR	NT
1995 Jun. 19	18.9	4.5	6800	NR	0.5
1996 Mar. 12	17.2	3.8	6500	10.9	87.25
1997 Jul. 8	29.1	5.3	9900	NR	56.4

*Run

Bitter Creek, Middle Tract, Chaves Co.; spring stream flowing North to South with permanent water beginning 50 m above confluence with Dragonfly Spring, wetted stream channel ca. 500 m long before entering Bitter Lake, Lost River enters ca. 100 m below Dragonfly Spring and appears only as a cave-like opening in the West bank, substrate is silt and organic debris, channel width varies from 1 to 2 m, channel incised up to 2 m, shoreline areas densely vegetated with *Tamarix*, *Elaeagnus* (Russian-olive), and *Phragmites*, Chara and *Potamogeton* cover 40-50% of the bottom; other fishes present are *D. episcopa*, *L. parva*, *E. lepidum*, and *G. nobilis*. *Gambusia affinis* are present in lower Bitter Creek.

Bitter Creek above Lost River Confluence

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 May. 26	18.0	6.0	9000	NR	0.2 (seine hauls)
1995 Mar. 21	17.8	5.2	6900	6.1	6.5
1995 Jun. 19	21.8	4.1	6500	NR	4.0
1995 Sep. 6	22.1	4.5	7050	3.6	2.0
1995 Dec. 7	12.0	4.5	5500	9.0	2.5
1996 Mar. 12	17.0	5.0	7200	8.1	0
1996 Jun. 11	19.9	4.9	7100	5.1	2.5
1996 Oct. 2	17.9	4.2	6300	5.8	0.5
1997 Feb. 26	11.0	6.8	8710	6.0	0
1997 Jun. 19	17.0	4.2	8900	2.9	0
1998 Apr. 22	18.2	5.0	7200	NR	0

Bitter Creek at Lost River Confluence

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 22	16.1	NR	NR	NR	6.0 (seine)
1987 Jul. 8	20.5	NR	NR	NR	84.0 (seine/dipnet)
1987 Aug. 19	23.0	NR	NR	NR	34.0 (dipnet)
1988 Jun. 15	21.0	5.0	7500	6.0	1.6 (5 dipnets)
1993 Jul. 20	17.6	4.9	7300	3.5	0
1995 Mar. 21	18.0	4.2	5230	3.5	196.0
1995 Jun. 19	17.9	6.7	9900	NR	0.5
1995 Sep. 6	21.5	5.1	8050	2.4	9.0
1995 Dec. 7	11.5	5.0	6000	8.4	11.0
1996 Mar. 12	17.4	5.3	7800	6.4	47.5
1996 Jun. 11	18.0	5.0	8000	2.0	0
1996 Oct. 2	18.1	4.5	6800	2.5	14.0
1997 Feb. 26	14.5	6.1	8450	4.5	11.0
1997 Jun. 19	17.0	4.8	8000	2.1	0
1998 Apr. 22	17.5	4.8	7100	NR	0

Bitter Creek below Lost River Confluence (above flume)

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1993 Jul. 27	25.6	NR	NR	8.9	6.0 (seine hauls)
1995 Mar. 21	19.5	5.3	8300	10.6	82.5
1995 Jun. 19	24.0	5.1	8100	NR	18.5
1996 Sep. 6	22.8	4.4	7100	5.9	0
1995 Dec. 7	11.0	4.5	5500	9.7	0.5
1996 Mar. 12	17.3	4.4	6400	6.7	1.5
1996 Jun. 11	21.0	4.9	7900	8.8	2.0
1996 Oct. 2	19.3	4.3	6400	8.2	2.0
1997 Feb. 26	10.2	6.5	8160	6.8	0
1997 Jun. 19	16.9	4.0	7200	3.2	5.5
1998 Apr. 22	20.0	5.0	7000	NR	0

Bitter Creek near Bitter Lake Inflow (below flume)

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1987 May 22	20.0	NR	NR	NR	43 (total by seine)
1995 Mar. 21	19.5	5.2	7800	12.3	375
1995 Jun. 19	25.1	4.4	7400	NR	236.5
1995 Sep. 6	23.0	4.3	7100	8.9	8.0
1995 Dec. 7	10.5	4.5	5500	9.8	60.0
1996 Mar. 12	18.2	5.0	7400	8.4	110.0
1996 Jun. 11	19.9	5.0	7900	9.5	3.0
1996 Oct. 2	20.0	4.0	6400	6.3	23.5
1997 Feb. 26	9.4	6.6	8080	9.1	3.5
1997 Jun. 19	17.0	4.1	7200	4.2	31.0
1998 Apr. 22	21.9	4.8	7500	NR	6.5

Bitter Lake (Unit 4), Middle Tract, Chaves Co.; a large, shallow basin lake varying in size and depth according to local precipitation and season, maximum surface area and depth are ca. 200 ha and 1.5 m, delta of Bitter Creek inflow dry except for wet and winter seasons, substrate is primarily silt but with small areas of sand and gravel near inflowing arroyos, shoreline areas immediately adjacent to lake edge are void of vegetation but *Sporobolus* and *Disticlis* densely cover the nearby upland, Chara and *Potamogeton* cover ca. 10% of the lake bottom; no other fish species collected.

Bitter Lake at Bitter Creek Inflow

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1993 Jul. 14	27.4	4.8	8800	3.9	181

Bitter Lake

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 22	22.0	NR	NR	NR	1406 (total)
1988 Jun. 14	26.5	62.0	104000	12.2	407
1993 Jul. 13	31.4	117.0	Off Scale	5.4	0

Unnamed spring at NW corner of Unit 3, Middle Tract, BLNWR, Chaves Co.; shallow spring system emerging from hillside bordering west side of waterfowl Unit lakes, channel 1-3 m wide and <0.4 m deep, total spring length ca. 75 m and flow terminates in upper lake body; *Scirpus* and *Phragmites* stands dense and throughout habitat, no aquatic vegetation; other species present is *G. affinis*.

Spring at upper end of Unit 3

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1988 Jun. 23	25.0	4.0	6000	3.6	23
1993 Jul. 27	34.8	NR	NR	8.0	23

Unit 3 Waterfowl Lake, Middle Tract, BLNWR, Chaves Co.; surface area variable but usually >20 ha, maximum depth <1.5 m, silt/organic mud bottom, gravel dike; dense stands of *Potamogeton* and Chara, dense *Tamarix* riparian; other species present are *Dorosoma cepedianum, Cyprinus carpio, G. affinis,* and *L. parva.*

Unit 3

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 20	22.0	NR	NR	NR	64 (total)
1988 Jun. 23	29.0	13.2	23100	7.4	9.25
1993 Jul. 13	32.2	17.0	27500	7.9	13.7
1995 Jun. 19	27.1	14.3	23900	NR	3.5/trap

Unit 5 Waterfowl Lake, Middle Tract, BLNWR, Chaves Co.; surface area variable but usually >25 ha, maximum depth <1.5 m, silt/organic mud bottom, gravel dike; *Potamogeton* and Chara cover ca. 10% of area, dense *Tamarix* riparian; other species present are *C. carpio, E. lepidum, F. zebrinus, G. affinis,* and *L. parva.*

Unit 5

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 19	22.0	NR	NR	NR	28 (total)
1988 Jun. 23	29.0	10.0	18500	8.0	7.2
1993 Jul. 13	28.0	11.8	19800	7.2	3.7

Unit 6 Waterfowl Lake, Middle Tract, BLNWR, Chaves Co.; surface area variable but usually >30 ha, maximum depth <2 m, silt/organic mud bottom, gravel dike; dense stands of *Potamogeton* and Chara, moderate *Tamarix* riparian; other species present are *F. zebrinus, G. affinis, L. parva,* and *E. lepidum.*

Unit 6

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 19	22.0	NR	NR	NR	5 (total)
1988 Jun. 23	32.0	14.0	24000	8.0	30.7
1993 Jul. 13	25.5	12.8	21000	6.3	49.7

Unit 7 Waterfowl Lake, Middle Tract, BLNWR, Chaves Co.; surface area variable but usually >30 ha, maximum depth <2 m, silt/organic mud bottom, gravel dike; dense stands of *Potamogeton* and Chara; other species present are *G. affinis, L. parva, E. lepidum, L. cyanellus, C. lutrensis, F. zebrinus,* and *C. carpio.*

Unit 7

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 18	23.0	NR	NR	NR	3 (total)
1987 Aug. 19	28.5	NR	NR	NR	0
1988 May 26	24.0	8.0	13000	NR	0
1988 Jun. 23	30.0	13.0	15500	7.9	0
1988 Jul. 30	26.8	8.0	14000	9.4	0.5
1988 Aug. 24	28.0	8.5	15100	6.0	0
1993 Jul. 12	27.3	10.0	17200	6.8	11.3

Canal between U7 and U17

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 19	21.0	NR	NR	NR	26 (total)

Unit 15 Waterfowl Lake, Middle Tract, BLNWR, Chaves Co.; surface area variable but usually >30 ha, maximum depth <1.5 m, silt/organic mud bottom, gravel dike; dense stand of *Potamogeton*; species present were *F. zebrinus, L. parva, G. affinis, C. lutrensis, L. cyanellus, E. lepidum,* and *C. carpio.*

Unit 15

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 18	24.0	NR	NR	NR	13 (total)
1987 May 20	NR	NR	NR	NR	0
1987 May 21	22.0	NR	NR	NR	0
1987 Jul. 1	NR	NR	NR	NR	0
1988 Jun. 21	24.0	9.0	10400	6.0	6
1993 Jul. 12	26.4	9.3	15800	6.1	62.3

Marsh South of U15 and U16

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 20	NR	NR	NR	NR	1 (total)

Unit 16 Waterfowl Lake, Middle Tract, BLNWR, Chaves Co.; surface area highly variable with near dry conditions frequently occurring in late summer, depths <0.5 m, silt bottom, gravel dike; minimal *Potamogeton* growth; other species present are *G. affinis, F. zebrinus,* and *L. parva.*

Unit 16

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 19	22.5	NR	NR	NR	46 (total)
1987 May 20	NR	NR	NR	NR	73 (total)
1987 Jul. 1	NR	NR	NR	NR	1.5
1988 Jun. 23	32.0	35.0	29000	NR	661.3
1993 Jul. 12	30.0	24.9	42500	10.4	115.5

Unit 17 Waterfowl Lake, Middle Tract, BLNWR, Chaves Co.; surface area highly variable with near dry conditions frequently occurring in late summer, depths <1 m, silt bottom, earthen dike; dense *Potamogeton* stands, dense *Tamarix* riparian; other species present are *G. affinis, F. zebrinus,* and *L. parva.*

Unit 17

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 21	27.0	NR	NR	NR	69 (total)
1988 Aug. 24	32.0	10.0	19000	14.0	3

Hunter Marsh and South Weir, Middle Tract, Chaves Co.; a marshy area encompassing ca. 50-75 ha, primary source of water is from "Honey Creek" which formerly delivered treated effluent from the Roswell sewage treatment plant, depths reach a maximum of 2 m and substrate is comprised entirely of organic muck, outflow from the marsh is into South Weir which enters an isolated Pecos River oxbow that is seasonally dry, *Typha* stands are dense throughout the marsh while the channel is 3-5 m wide and depths reaching 0.5 m, Chara and *Potamogeton* occur infrequently; other fishes collected are *C. lutrensis, C. carpio, F. zebrinus, L. parva,* and *G. affinis.*

South Weir (including Hunter Marsh)

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 20	20.0	NR	NR	NR	238 (total)
1988 Aug. 24	25.0	15.0	23000	0.3	3
1993 Jul. 27	32.4	NR	NR	6.3	5

Hunter Oxbow, Middle Tract, Chaves Co.; isolated Pecos River oxbow ca. 1 km in length and 50-75 m wide, maximum depth ca. 1.5 m, silt and organic debris substrate, shoreline densely vegetated with *Tamarix*, Chara and *Potamogeton* cover ca. 80% of the bottom; no other fish species collected.

Hunter Oxbow

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 2	22.0	NR	NR	NR	241 (total)
1988 Aug. 24	28.0	36.0	60000	10.3	27
1993 Jul. 14	39.5	17.3	34500	6.5	88.5

Isolated Pecos River Oxbow East of Unit 5, Middle Tract, Chaves Co.; the largest oxbow on the Refuge measuring ca. 1 km long by an average width of ca. 30 m, depths rarely exceed 2 m, substrate is primarily silt and organic debris but includes sand and gravel where flow exits through a culvert at a road crossing, shoreline areas are densely vegetated with *Tamarix*, *Phragmites*, Chara, and *Potamogeton* stands are dense and cover ca. 90% of the bottom and grow throughout the water column except in deeper portions; other fish species collected are *Carpiodes carpio*, *L. cyanellus*, *D. cepedianum*, *C. lutrensis*, *L. parva*, *Lepisosteus osseus*, and *G. affinis*.

Oxbow East of Unit 5

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1987 May 20	21.0	NR	NR	NR	27 (total)
1988 Jun. 14	25.0	9.3	15500	11.0	44
1995 Mar. 21	20.4	5.7	14800	8.0	0

Isolated Pecos River Oxbow 50 m west of channel, east of Unit 3, Middle Tract, Chaves Co.; this habitat appears to be permanently isolated despite close proximity to main river channel, 15-25 m wide X 75 m long, depths <1.5 m, silt/sapropel substrate; surrounded by dense *Tamarix* riparian, *Potamogeton* stands cover >90% of the bottom; other fish species present *F. zebrinus* and *L. parva*.

Oxbow East of Unit 3

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1989 Jun. 8	29.0	23.0	39000	13.4	38.8
1995 Mar. 21	20.1	12.7	19000	8.2	0

Power Line Playa, Middle Tract, Chaves Co.; this playa is on the east side of the Pecos River, immediately north of the power line crossing. It is a catchbasin and may receive seepage inflow. At high flow the Pecos River is connected to the playa by a backwater. The substrate is silt and encrusted salt. *Tamarix* are prevalent.

Power Line Playa

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per seine haul
1997 Jun. 18	NR	NR	NR	NR	30.3

Bottomless Lakes State Park

Lazy Lagoon, maximum surface area ca. 19.6 ha although very variable, the largest of three connected sinkholes is has a surface area ca. 0.99 ha, maximum depth 21 m. The remaining sinkholes surface areas ca. 0.46 ha and 0.13 ha, maximum depth ca. 12.8 and 14.0 m respectively. The rest of the lagoon consist of a playa that floods and dries periodically, *Ruppia, Chaetophora,* and Chara are present; other fish species present include *F. zebrinus, G. affinis, L. parva,* and *L. cyanellus.*

Lazy Lagoon

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Feb. 12	12.7	27.5	33000	4.6	0
1994 Jul. 28	26.5	10.6	18200	5.9	127.0
*1994 Jul. 28	26.9	9.8	17200	4.5	141.5
*1994 Dec. 9	7.3	27.8	29500	6.0	84.0
1995 Jul. 19	29.9	33.7	Off Scale	5.8	190.0
1997 Jun. 17	23.9	26.5	41600	4.5	58.3

*Traps set on flooded playa

Mirror Lake, BLSP, Chaves Co.; sinkhole located against 30-50 m high limestone escarpment, surface area ca. 1.5 ha, maximum depth 15 m, gradual sloping shoreline, substrate is silt dominated; Chara and *Potamogeton* are abundant; other fishes include *F. zebrinus* and *G. affinis.*

Mirror Lake

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Nov. 16	15.0	20.5	?	8.7	26.3
1994 Jul. 27	27.2	13.7	24100	10.0	83.0
1994 Dec. 9	9.0	21.4	23800	4.5	45.0
1995 Jul. 19	28.0	21.0	35100	6.1	106.0
1997 Jun. 17	24.2	21.0	33700	6.7	96.3

Upper Figure Eight Lake, BLSP, Chaves Co.; north sinkhole of pair historically connected, 0.6 ha, maximum depth 11 m, silt substrate, Chara and *Potamogeton* common; other fishes include *F. zebrinus.*

Upper Figure Eight Lake

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Nov. 16	16.0	15.5	21500	7.4	17.0
1994 Jul. 27	28.5	11.4	20500	7.3	236.5
1994 Dec. 9	10.1	15.7	18800	6.2	26.5
1995 Jul. 19	29.3	19.8	33100	5.9	76.5

Lower Figure Eight Lake, BLSP, Chaves Co.; south sinkhole of pair historically connected, 0.3 ha, maximum depth 7 m, silt substrate, Chara common; no other fish species collected.

Lower Figure Eight Lake

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Nov. 16	15.0	20.8	27000	3.7	16.3
1994 Jul. 27	28.0	15.0	26800	1.0	2.5
1994 Dec. 9	9.9	21.4	24400	4.5	62.0
1995 Jul. 19	30.2	22.4	38900	1.5	9.5

Lea Lake, BLSP, Chaves Co.; sinkhole located against 50 m high limestone escarpment, surface area ca. 0.31 ha, maximum depth 27 m, Chara is common; other fish species include *F. zebrinus, G. affinis, and A. mexicanus.*

Lea Lake

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Nov. 16	12.5	7.0	11500	7.5	0
1994 Jul. 27	26.7	6.3	11200	4.9	3.5
1994 Dec. 9	13.1	7.8	10100	7.0	0
1995 Jul. 19	28.8	8.0	10400	6.5	0

Lea Lake outflow, BLSP, Chaves Co.; spring marsh area flowing south and west from Lea lake (reported at 90,720 m 3/24 hrs) toward BLM waterfowl area, substrate is silt; Chara, *Eleocharis,* and *Potamogeton* are abundant and widespread; depth 1-3 m; other species fish species present include *F. zebrinus, G. affinis, L. parva,* and *A. mexicanus.*

Lea Lake Outflow

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish per trap
1988 Nov. 16	11.5	8.0	11000	5.6	0.5
1994 Jul. 27	26.5	6.3	11100	7.4	1.0
1994 Dec. 9	12.3	7.8	10200	6.6	197.0
1995 Jul. 19	27.2	7.8	13800	6.9	2.0

BLM Waterfowl Management Area

BLM Waterfowl Management Unit, lowland area between Lea Lake and Pecos River, Chaves Co.; large marsh (ca. 8 km2) that is ca. 30% open water, water source is outflow (reported at 90,720 m 3/24 hrs) from Lea Lake; large (ca. 3-5 ha), shallow (<0.5 m) lakes connected by narrow (<1 m), short (<50 m) runs dominate the habitat composition; substrate is silt; Chara, *Eleocharis*, and *Potamogeton* are abundant and widespread; salinity 6-21 ppt; other fishes include *L. parva*, *F. zebrinus*, and *G. affinis*.

Marsh Adjacent to Bottomless Lakes State Park

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Total Pupfish
1988 Nov. 21	17.5	21.0	26200	8.7	46
1994 Jul. 28	23.6	6.2	10300	9.5	22 (4 hauls)

Mainstem Pecos River

Species of fish potentially found at all sites in Chaves County include: *C. lutrensis*, *Notropis girardi*, *N. jemezanus*, *N. simus pecosensis*, *N. stramineus*, *Hybognathus placitus*, *Cyprinus carpio*, *Carpiodes carpio*, *G. affinis*, *F. zebrinus*, *I. punctatus*, *Macrhybopsis aestivalis*, and *D. cepedianum*.

Lake Arthur Falls, RM 520, Chaves Co.; major features of the stream channel here are a travertine ledge that crosses the entire stream channel, with a large backwater on river left and channel braiding through and around a 100 m long riffle over travertine cobble/boulder into a 1-2 m deep laminar run below; low numbers of pupfish have been taken in collections, including y-o-y; the ledge acts as a barrier to upstream movement and often congregates large numbers of fish, mostly stream cyprinids, during low to medium flows; stream channel is 6-30 m wide, depths range from 0.3 to >3 m, substrate in the plunge pool below the ledge and associated backwaters and the downstream run is primarily sand; aquatic plants are generally absent except for *Cladophora* growing in the riffle and on the ledge; salinity varies from 1.8-5.2 ppt.

Lake Arthur Falls

Date	Number of *C. pecosensis* collected
1989 Aug. 16	8
1990 May. 2	5
1990 Jul. 10	2

Rio Felix confluence, RM 540, Chaves Co.; the stream bed is adjacent to a near vertical limestone bluff ca. 10 m high; the majority of this segment is comprised of a 1-3 m deep run against the bluff to downstream shallow (<0.5 m) runs and riffles; although pupfish are sometimes collected in the mainstream river, most are taken from the lower end of a 1 km long pool in the Rio Felix, 0.5-2 m deep and silt/sand substrate; river channel is 10 - 15 m wide and contains numerous large boulders along bluff face; salinity 1.2-4 ppt; aquatic plants are generally absent except for seasonal *Cladophora* occurrences and shoreline *Phragmites* stands.

Rio Felix Confluence

Date	Number of *C. pecosensis* collected
1986 May 21	3
1986 Jul. 14	4
1990 Aug. 22	1
1994 May. 3	1

Dexter Bridge, generally upstream 0.5-1 km, RM 549, Chaves Co.; river channel here contains a large oxbow on river left that contains water year-round; early pupfish collections were from the oxbow, but small numbers of fish are routinely collected downstream to the bridge; the river channel is 6-30 m wide, substrate is primarily sand, and depths range 0.2-2 m; the oxbow is ca. 1 km in length, width 10-75 m, substrate primarily silt; salinity 1-4 ppt in river and 1-5 ppt in oxbow; Chara, *Potamogeton*, and *Typha* common in oxbow.

Dexter Bridge

Date	Number of *C. pecosensis* collected
1986 Jul. 15	1
1989 Jun. 6	4
1990 Jul. 10	1
1991 Jul. 12	2
1993 Feb. 10	1
1995 Feb. 15	1
1995 May 17	2
1996 Nov. 11	1

Sallee Ranch, RM 560, Chaves Co.; river channel makes a large horseshoe bend under a cut bank ca. 5 m high, the channel is 8-12 m wide, substrate is sand, depths vary from 0.1-3 m, salinity ranges from 1.3-5.3 ppt.

Sallee Ranch

Date	Number of *C. pecosensis* collected
1993 Jun. 25	4
1994 Feb. 3	1
1997 Apr. 8	18
1997 Jul. 8	2
1997 Sep. 11	7

Rio Hondo confluence, RM 566, Chaves Co.; river channel is a 1-15 m wide, sandy bottomed, shallow (0.1-0.5 m) run with steep-sided cut banks 2-4 m high; at high flows channel is 1-2 m deep and velocities exceed 1 m/s; this reach is near, or possibly at, the upstream limits of permanent flowing water during drought conditions; salinity 1-8 ppt; *Spyrogyra* and *Cladophora* seasonally common; numerous debris (concrete slabs, tree trunks, other anthropogenic waste) piles along river bank on either side).

Rio Hondo Confluence

Date	Number of *C. pecosensis* collected
1989 Aug. 18	3
1990 Jul. 10	3
1995 Mar. 22	1
1996 Apr. 23	1

U.S. Highway 380 Bridge, RM 568.8, Chaves Co.; river channel is 3-30 m wide, sand substrate; at high flows 1-2 m deep and velocities ca. 1 m/sec, at low flow restricted to a narrow channel 1-2 m wide and generally <0.3 m deep; extreme disturbance from bridge reconstruction activities including isolation of a large oxbow formerly connected at high flows; salinity varies from 1.1-5 ppt.

U.S. 380 Bridge

Date	Number of *C. pecosensis* collected
1990 Aug. 22	1
1990 Sep. 26	1
1991 Feb. 27	1
1992 Feb. 6	2
1992 Feb. 6	27
1993 Oct. 27	3
1994 Oct. 20	11
1995 Feb. 15	13
1995 May 31	13
1995 Nov. 2	1
1996 Nov. 19	11

Bitter Lake NWR, RM 575.3, Chaves Co.; river channel is 10-30 m wide, sandy bottomed, 0.2-1 m deep, cut banks 1-2 m high; dries to intermittent pools during late summer when drought conditions present; minimal habitat diversity, primarily a shallow, medium velocity run reach; no aquatic vegetation; sparse *Tamarix* riparian; salinity 1-3 ppt.

Low Water XG East of U3, BLNWR

Date	Number of *C. pecosensis* collected
1989 Jun. 8	42
1997 Dec. 1	6

U.S. 70 Bridge, RM 585.7, Chaves Co.; river channel is 1-35 m wide, sandy bottomed, 0.1-1.5 m deep, cut banks 1-3 m high; habitat is primarily shallow runs and short (<10 m), shallow (<0.5 m) riffles; pools 1-2 m deep are present around bridge pilings and provide for apparently permanent pools during drought conditions when this reach of the river is reduced to 5-10 intermittent pools per river km; no aquatic plants; moderate riparian community; salinity 0.8-3.9 ppt.

U.S. 70 Bridge

Date	Number of *C. pecosensis* collected
1986 Jul. 15	159
1989 Jun. 8	1
1989 Aug. 16	27
1990 May 3	1
1991 Jun. 13	6
1991 Jul. 12	10
1992 Feb. 6	89
1992 Jun. 24	10
1992 Oct. 8	7
1993 Jan. 26	14

Gasline crossing, 3 km downstream of Eightmile Draw confluence, RM594.7, Chaves Co.; total channel width 25-50 m, sandy bottomed; wide, deep (1-1.5 m), and fast (1 m/sec) at high flows, otherwise generally intermittent with >95% of channel dry; moderate riparian community, including seep willow, *Baccharis glutinosa;* pupfish were documented at this site by a collection from an isolated pool during nonflow, temperature >30 C; salinity ranges between 0.9-2.9 ppt.

Gasline Crossing

Date	Number of *C. pecosensis* collected
1986 Aug. 21	1
1990 Jul. 9	3
1991 Jul. 12	4
1992 Jul. 8	1
1992 Aug. 25	1
1995 May 31	1

Section A - 2

Known Localities in Eddy County, New Mexico

All collections were made by the USFWS NMFRO.
NR = not recorded

MAINSTEM PECOS RIVER

Species of fish potentially found at all sites in Eddy County (excluding Brantley Inflow) include *M. beryllina, Fundulus grandis, C. lutrensis, D. cepedianum, P. promelas, L. parva,* and *G. affinis.*

Pierce Canyon Crossing, RM 425, ca. 8 km downstream of Malaga, Eddy Co.; stream channel 5-25 m wide, depths reaching 2 m in pools, substrate primarily silt/sand; this reach of the river is dominated by long (1-2 km) pools and short (<50 m) riffles, minimal backwater habitat; salinity is 2.3-7.0 ppt; *Tamarix* riparian.

Pierce Canyon Crossing

Date	Number of *C. pecosensis* collected
1989 Aug. 23	1
1990 Aug. 29	38
1994 Jul. 29	1
1994 Sep. 20	1

Malaga Crossing, RM 430, Eddy Co.; stream channel 3-5 m wide, depths rarely exceed 1 m except along cut bank in swift runs and pools; the channel here is split into two channels above the road crossing; pupfish are found in most low velocity habitats below the crossing, but primarily occur in the western channel; the western channel is more similar to a connected backwater except with minimal outflow through a small (ca. 100 m2) marsh pool into the main channel; depths of the pool are 0.1-0.3 m, substrate is silt, *Eleocharis* and *Charex* are common; salinity 3.8-4 ppt; *Tamarix* riparian.

Malaga Bend Crossing

Date	Number of *C. pecosensis* collected
1989 Aug. 23	6
1989 Aug. 23	37
1990 Aug. 29	154
*1994 Sep. 20	5
^1995 Jul. 17	16

*Taken from an isolated pool
^hybrid pupfish

Brantley Inflow, RM 484, Eddy County; stream channel 4-10 m, widening as it enters the lake, width varies greatly with lake depth; depth 1-3 m, habitat is generally slow run with various embayments and backwaters as the lake rises, substrate is deep silt; this fish was probably washed downstream from the Bitter or Bottomless lakes area and was unable to escape from the main channel during high flows.

Brantley Inflow

Date	Number of C. pecosensis collected
1994 Mar. 23	1
1997 Jun. 17	1
1997 Jul. 8	1

Laguna Grande

Unnamed Spring, T. 23S, R. 29E, sec. 10, Eddy Co.; emerging spring system from upland at edge of Laguna Grande, majority of habitat limited to two pools in excavated holes, flow over silt/salt encrusted bottom into holes, depths of flows generally <2 cm and in holes >2 m; no riparian nor aquatic vegetation; no other species present. Many pupfish were visually observed in 1992. Pupfish were visually rare in 1995.

Laguna Grande excavated holes

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish collected
1992 May 5	21.0	43.0	89000	NR	2
1995 Feb. 14	12.5	Off Scale	Off Scale	7.3	3
1995 Jul. 18	NR	89.1	128700	NR	2
1997 Jun. 5	23.5	92.8	120000	NR	0

Unnamed Spring, T. 23S, R. 29E, sec. 10, Eddy Co.; emerging spring system from upland at edge of Laguna Grande, habitat varies from sheet flow <50 mm deep to a single channel <0.5 m wide and depths <10 cm; silt/salt encrusted substrate, slightly undercut channel with overhanging terrestrial vegetation; riparian community consisting of *Tamarix, Sporobolus, Distictlis,* and *Allenrolfia,* no aquatic vegetation; salinity 60 ppt; no other species present. Appeared diminished and devoid of fish on 14 February 1995.

Section B

Known Localities inTexas

Collections were made by USFWS NMFRO or A.A. Echelle, Oklahoma State University.

NR = not recorded

Phipps Sand and Gravel Co. Gravel Pit Pond, 3 km NW of Grand Falls, Ward Co.; land ownership private; large (ca. 100 ha), inactive gravel pit filled with water from underground seepage; loose sand-gravel substrate, depths exceeding 5 m; water quality - visibility >2 m, salinity - 17 ppt, conductivity - 28,300 umhos; *Potamogeton* and Chara abundant; other fish species present include *G. affinis, L. parva,* and *M. beryllina.* Not sampled in 1994.

Phipps Gravel Pit

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish
1988 Jul. 28	30.0	16.9	28300	8.2	0
1988 Aug. 20	NR	NR	NR	NR	30

Salt Creek, enters the Pecos River from the west ca. 1 km downstream of Red Bluff Reservoir, Reeves Co.; land ownership is private, state, and BLM; it is a small Chihuahuan desert stream with a relatively large drainage area (ca. 1900 km2) capable of substantial seasonal flooding; wetted stream channel during summer is 1 to 5 m wide, depths rarely exceeding 0.5 m except in pools where depths may reach 2 m; substrate composition varies from silt dominated cienega habitats in the headwater region to a typical Chihuahuan desert stream of runs, riffles, and pools in the middle and lower reaches; the headwater region includes several shallow (1-2 m) lakes and marshes; physical barriers to upstream movement of fishes occur at the downstream end of the cienega headwater region (3 m fall incised through clay alluvium) and downstream of the Red Bluff Reservoir spillway confluence (<1 m); water quality varies and is more saline in the headwater region with salinities exceeding 15 ppt in the headwater region and declining to 6-8 ppt near the confluence with the Pecos; *Typha* and *Scirpus* stands are abundant in the headwater region, *Potamogeton* and Chara present throughout the drainage, *Tamarix* dominated riparian; other fish species present include *C. lutrensis, G. affinis, L. parva, F. zebrinus, M. beryllina, M. chrysops X saxatillis,* and *C. pecosensis X variegatus.* Most recent collections in June 1991 by A. A. Echelle who found no sign of hybridization with *C. variegatus.*

Incline Draw confluence

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish
1989 Aug. 30	31.0	15.8	30900	10.2	>200

TX Farm Road 652 bridge

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish
1988 Sep. 9	26.0	18.5	27000	8.5	30

U.S. Highway 285 bridge

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish
1988 Jun. 9	NR	NR	NR	NR	24
1989 Aug. 29	NR	NR	NR	NR	357

1 km downstream of U.S. Highway 285 bridge

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish
1989 Aug. 29	NR	NR	NR	NR	357

Red Bluff road crossing, east of Orla

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish
1988 Jun. 9	31.0	8.5	14500	NR	125

Red Bluff spillway confluence

Date	Temperature	Salinity	Conductivity	Dissolved Oxygen	Pupfish
1988 Aug. 20	NR	NR	NR	NR	366
1989 Aug. 30	NR	NR	NR	NR	559

APPENDIX II

Localities in which Pecos Pupfish were not extant

All collections made by USFWS NMFRO except when cited in tables.

Chaves County, NM. Habitats sampled in which Pecos pupfish were absent. Collections from 1979 are from Echelle and Echelle, 1980; those from 1981 are from Bouma,1984; collections from 1988 and later were made by J.E. Brooks and NMFRO personnel. NM = Not measured.

Site	Habitat Type	Date(s) Sampled	Salinity	fish species present
Rock House Spring	spring	12 Jun. 1998	2.7	none
Alkalai Spring	spring	09 Jun. 1998	28.8	none
Bosque Draw	spring	1979	NM	none
Bob Crosby Draw	spring	1979	NM	none
		10 Jun. 1998	3.4	*Fundulus zebrinus*
Lloyd's Canyon Spring	spring	10 Jun. 1998	13.0	none
Dallas Ranch Seep	spring	10 Jun. 1998	11.3	none
Sinkhole # W1, BLNWR	sinkhole	09 Nov. 1988	>40	none
Sinkhole #W2, BLNWR	sinkhole	09 Nov. 1988	Dry	none
Sinkhole #W3, BLNWR	sinkhole	08 Nov. 1988	26.0	*Fundulus zebrinus*
Sinkhole #W4, BLNWR	sinkhole	08 Nov. 1988	>40	none
Sinkhole #W5, BLNWR	sinkhole	08 Nov. 1988	>40	none
Sinkhole #W6, BLNWR	sinkhole	08 Nov. 1988	22.5	none
Sinkhole #W7, BLNWR	sinkhole	08 Nov. 1988	Dry	none
Sinkhole #W8, BLNWR	sinkhole	08 Nov. 1988	Dry	none
Sinkhole #W9, BLNWR	sinkhole	08 Nov. 1988	12.5	none
Sinkhole #W10, BLNWR	sinkhole	08 Nov. 1988	Dry	none
Sinkhole #W11, BLNWR	sinkhole	30 Jun. 1988	Dry	none
Sinkhole #W12, BLNWR	sinkhole	30 Jun. 1988	54.0	none
Sinkhole #W13, BLNWR	sinkhole	30 Jun. 1988	20.5	none
Sinkhole #4, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	24.5	
		19 Jun. 1997	20.3	
Sinkhole #5, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1992	33.0	
		19 Jun. 1997	31.4	
Sinkhole #6, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	32.4	
Sinkhole #8, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	25.5	
		17 Jun. 1997	24.2	
Sinkhole #12, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	28.0	
		17 Jun. 1997	39.3	
Sinkhole #13, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	off scale	
Sinkhole #14, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	37.0	
		17 Jun. 1997	31.5	
Sinkhole #15, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	16.0	
		17 Jun. 1997	30.2	
Sinkhole #17, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	32.5	
		17 Jun. 1997	33.1	

Chaves County, NM, continued

Site	Habitat Type	Date(s) Sampled	Salinity	fish species present
Sinkhole #18, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	13.2	
		17 Jun. 1997	24.3	
Sinkhole #23, BLNWR	sinkhole	1981	NM	none
		19 Jun. 1997	34.9	
Sinkhole #30, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	10.2	
		17 Jun. 1997	35.4	
Sinkhole #33, BLNWR	sinkhole	1981	NM	none
		18 Jun. 1997	DRY	
Sinkhole #34, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	17.0	
		18 Jun. 1997	14.0	
Sinkhole #35, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	13.2	
		17 Jun. 1997	13.1	
Sinkhole #36, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	NM	
		17 Jun. 1997	15.1	
Sinkhole #39, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	15.4	
		18 Jun. 1997	DRY	
Sinkhole #40, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	15.5	
		18 Jun. 1997	DRY	
Sinkhole #41, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	13.3	
		18 Jun. 1997	6.6	
Sinkhole #42, BLNWR	sinkhole	1981	NM	none
		21 Mar. 1995	34.0	
		18 Jun. 1997	DRY	
Sinkhole #43, BLNWR	sinkhole	21 Mar. 1995	21.0	none
Sinkhole #44, BLNWR	sinkhole	21 Mar. 1995	37.5	none
Sinkhole #45, BLNWR	sinkhole	21 Mar. 1995	30.0	none
Sinkhole #46, BLNWR	sinkhole	21 Mar. 1995	20.5	none
Sinkhole #47, BLNWR	sinkhole	21 Mar. 1995	10.0	none
Sinkhole #48, BLNWR	sinkhole	21 Mar. 1995	39.5	none
Sinkhole #49, BLNWR	sinkhole	21 Mar. 1995	10.0	none
Lake Next to Skull and U.S. Hwy. 70	sinkhole	29 Jun. 1988	25.5	none
Skull, north of U.S. Hwy. 70	sinkhole	29 Jun. 1988	27.0	none
Highway Sink, north of U.S. Hwy. 70	sinkhole	29 Jun. 1988	27.0	none
NW Most Rio Hondo Oxbow ,BLNWR	oxbow	18 Aug. 1989	5.3	eight species
Hagerman Canal, BLNWR	canal	18 Aug. 1989	4.5	*Gambusia affinis*
				Fundulus zebrinus
				Cyprinella lutrensis
				Astyanax mexicanus
				Pimephales promelas

Chaves County, NM, continued

Site	Habitat Type	Date(s) Sampled	Salinity	fish species present
Rio Hondo 2 km Upstream of Pecos R.	tributary stream	18 Aug. 1989	5.0	*Gambusia affinis* *Fundulus zebrinus* *Cyprinella lutrensis* *Pimephales promelas* *Notropis jemazanus* *Notropis stramineus*
Rio Hondo 0.5 km Upstream of Pecos R.	tributary stream	18 Aug. 1989	4.5	*Gambusia affinis* *Cyprinus carpio* *Cyprinella lutrensis* *Notropis jemezanus* *Pimephales promelas*
Britt Lake, North of BLSP	sinkhole	05 Sep. 1990	4.0	*Gambusia affinis* *Lepomis cyanellus*
Pump Lake, North of BLSP	sinkhole	05 Oct. 1990	1.5	*Gambusia affinis*
Enclosure Lake, North of BLSP	sinkhole	05 Oct. 1990	1.7	*Lepomis cyanellus*
Pretty Lake, North of BLSP	sinkhole	05 Oct. 1990	3.4	none
Chain Lakes, North of BLSP	sinkhole	05 Oct. 1990	2.3	*Fundulus zebrinus* *Lepomis cyanellus*
Cow Spring, North of BLSP	spring	05 Oct. 1990	NM	none
Comanche Spring, North of BLSP	spring	05 Oct. 1990 10 Jun. 1998	2.5 3.4	none *Gambusia affinis* *Lepomis cyanellus*
Cottonwood Lk., BLSP	sinkhole	16 Nov. 1988 27 Jul. 1994 09 Dec. 1994	6.0 8.1 5.8	*Lepomis cyanellus* *Pimephales promelas* *Cyprinella lutrensis* *Fundulus zebrinus*
Devils Inkwell (Inkwell Lake), BLSP	sinkhole	16 Nov. 1988 27 Jul. 1994 09 Dec. 1994	3.1 3.0 3.8	*Lepimis cyanellus*
Pasture Lake, BLSP	sinkhole	16 Nov. 1988 27 Jul. 1994 09 Dec. 1994	7.0 4.0 5.3	*Gambusia affinis* *Lucania parva*
Garnsey Spring	spring	10 Jun. 1998	2.11	none
Dimmit Lake-South of BLSP	sinkhole	21 Nov. 1988	4.2	*Lucania parva* *Lepomis macrochirus*
Sinkhole east of Pecos River, 2.5km South of Dexter	sinkhole	24 May 1988	15.5	none
Zuber Reservoir	lake	24 May 1988	6.2	*Cyprinella lutrensis* *Lepomis cyanellus* *Gila pandora*
Lake Tolliver	playa	1979	NM	*Fundulus zebrinus*
Pritchard Lakes	playa	1979	NM	none

Eddy County, NM. Habitats sampled in which Pecos pupfish were absent. Collections from 1977-1979 represent multiple collections in the Black River drainage, reported by Cowley and Sublette, 1987; collection labeled 1979 are from Echelle and Echelle, 1980; collections from 1988 and later were made by J.E. Brooks and NMFRO personnel. NM = Not measured.

Site	Habitat Type	Date(s) Sampled	Salinity	fish species present
Cottonwood Spring	spring	12 Sep. 1988	1.0	*Dionda episcopa* *Astyanax mexicanus* *Etheostoma lepidum* *Lepomis megalotis*
	spring	3 Jun. 1997	0.3	*Micropterus punctulatus* *Lepomis megalotis* *Gambusia affinis* *Etheostoma lepidum* *Ameiurus melas*
Cottonwood Ck. @ Bittersweet Rd.	spring	12 Sep. 1988	NM	*Lepomis megalotis* *Pimephales promelas* *Etheostoma lepidum* *Gambusia affinis*
Cottonwood Ck. @ Funk Rd.	tributary stream	12 Sep. 1988	NM	riverine species
Cottonwood Ck. @ State Park	tributary stream	12 Sep. 1988	NM	riverine species
Staple Canyon (Spencer Draw)	spring	1979	NM	*Dionda episcopa* *Fundulus zebrinus* *Micropterus salmoides* *Lepomis cyanellus*
Pecos River, east of Otis	riverine	29 Jul. 1994 18 Jul. 1995	2.9	riverine species
Pecos River @ the Rock House Crossing	riverine	29 Jul. 1994	3.6	riverine species
(El Paso Gasline)		21 Sep. 1994 17 Jul. 1995 28 Sep. 1995 10 Sep. 1996	4.3	
Pecos River @ Red Bluff Draw Confluence	riverine	29 Jul. 1994 17 Jul. 1995	3.9	riverine species
Pecos River @ Black River Confluence	riverine	29 Jul. 1994 22 Sep. 1994 18 Jul. 1995 26 Sep. 1995 9 Sep. 1996	2.2 3.0	riverine species
Geyser Spring (Grapevine Draw)	spring	1977-1979 1979	NM NM	*Dionda episcopa* *Lepomis cyanellus* *Micropterus salmoides*
Headwaters (Washington Spring)	tributary stream	1977-1979 22 Sep. 1988	NM 1.5	*Micropterus salmoides* *Lepomis cyanellus* *Lepomis megalotis* *Dionda episcopa*
Rattlesnake Springs, Eddy Co.	spring	13 Sep. 1988	0.5	*Lepomis cyanellus*
Chosa Draw	tributary stream	22 Sep. 1988	1.7	*Fundulus zebrinus*
Blue Spring	spring	1977-1979 22 Sep. 1988	NM 1.0	*Dionda episcopa* *Astyanax mexicanus* *Etheostoma lepidum* *Gambusia nobilis* *Gambusia affinis* *Ambloplites rupestri*

Eddy County, NM., continued

Site	Habitat Type	Date(s) Sampled	Salinity	fish species present
Castle Spring (Black River Village)	spring	1977-1979	NM	*Gambusia affinis*
		1979	NM	*Lepomis cyanellus*
				Lepomis megalotis
				Micropterus salmoides
Sinkhole Southeast of Bottomless Lake	sinkhole	22 Sep. 1988	1.5	none
Bottomless Lake	sinkhole	22 Sep. 1988	1.5	*Lepomis cyanellus*
between Blue Spring and diversion dam	riverine	1977-1979	NM	riverine species
between diversion dam and Pecos River	riverine	1977-1979	NM	riverine species
		18 Jul. 1995	2.6	
Cottonwood Ck. @ headwaters	spring	1979	NR	*Fundulus zebrinus*
Ben Slaughter Draw, Jumping Spring	spring	1979	NR	*Fundulus zebrinus*

APPENDIX III

Known Extant Pupfish Hybrid Locality Descriptions and Recent Surveys

Section A

Collections of pupfish hybrids in New Mexico

All collections were made by the USFWS NMFRO.
NR = not recorded

Mainstem Pecos River Downstream of 10-mile Reservoir, The 10-mile dam, located northeast of Loving, north of NM highway 31, is an old diversion structure which formerly fed water into the Harroun Canal. The canal parralells the Pecos River on the east. The upstream-most collection of *C. variegatus* x *pecosensis* was at the "Loving Bridge", ca. 3 river km downstream of 10-mile dam. In the absence of upstream transport by humans, the 10-mile dam may provide a barrier to upstream hybrid movement.

Loving Bridge

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
29 Jul. 1994	29.0	2.0	3490	9.5	7
18 Jul. 1995	25.0	1.7	2820	10.4	17

Pierce Canyon Confluence (WQ reported from isolated pool)

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
5 Jun. 1997	31.8	29.5	off scale	NR	52
9 Mar. 1998	21.0	20.3	30000	NR	16
22 Oct. 1998	17.0	32.4	41300	NR	41

Malaga Bend

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
17 Jul. 1995	26.0	2.1	3520	6.9	16
27 Sep. 1995	24.2	3.5	6100	6.9	17
10 Sep. 1996	27.0	5.5	10000	6.9	1

Delaware River Confluence

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
11 Aug. 1986	NR	NR	NR	NR	60
29 Aug. 1990	NR	NR	NR	NR	337
20 Sep. 1994	NR	NR	NR	NR	2
17 Jul. 1995	27.5	2.9	5000	7.1	1

Red Bluff Reservoir

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
8 Sep. 1988	31.0	5.3	8500	8.3	34
9 Sep. 1988	28.0	4.5	7900	7.6	45
9 Sep. 1988	26.0	4.2	7500	7.2	130
9 Sep. 1988	27.0	4.5	8200	6.2	18
9 Sep. 1988	NR	NR	NR	NR	33
24 Aug. 1989	NR	NR	NR	NR	44

Section B

Collections of pupfish hybrids in Texas

Collections were made by A.A. Echelle, Oklahoma State University; Hoagstrom, 1994; Larson, 1994; Linam and Kleinsasser, 1996; or were referenced from the Texas Natural History Collection, Austin, TX.

NR = not recorded

Mainstem Pecos River, TX, the hybrid pupfish swarm has expanded its range beyond that documented for pure *C. pecosensis*. The hybrids also occupy a wide variety of habitats, including riffles and fast runs which are not typically occupied by *C. pecosensis*.

Texas Farm Road 652 crossing near Orla

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
14 Oct. 1987	20.4	3.4	8624	7.3	3

TX Hwy. 302 bridge near Mentone

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
11 Aug. 1986	NR	NR	NR	NR	71
14 Oct. 1987	19.1	3.4	8736	7.87	2

Brush Dam, 10 km southwest of Mentone

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
11 Aug. 1986	NR	NR	NR	NR	76

TX Farm Road 3398 crossing, NE of Pecos

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
12 Aug. 1986	NR	NR	NR	NR	85

U.S. Hwy. 80 bridge near Pecos

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
12 Aug. 1984	NR	NR	NR	NR	65
14 Oct. 1987	20.8	3.5	8848	8.94	30
20 Aug. 1988	NR	NR	NR	NR	54

U.S. Interstate 20 bridge

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
12 Aug. 1986	NR	NR	NR	NR	47

TX Farm Road 1776 bridge near Coyanosa

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
12 Aug. 1986	NR	NR	NR	NR	101
13 Oct. 1987	20.6	4.4	11172	8.7	2
16 Oct. 1992	15.0	NR	NR	NR	36
6 Feb. 1993	8.5	NR	NR	NR	2
24 Apr. 1993	21.0	NR	NR	NR	1
3 Jul. 1993	25.0	NR	NR	NR	1
31 Jul. 1993	26.0	NR	NR	NR	4
4 Sep. 1993	25.0	NR	NR	NR	4
26 Sep. 1993	23.0	NR	NR	NR	13
20 Nov. 1993	10.0	NR	NR	NR	1
14 Jul. 1994	28.4	NR	14670	9.6	14

TX Hwy. 18 bridge

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Aug. 1986	NR	NR	NR	NR	76

TX Farm Road 11 bridge

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Aug. 1986	NR	NR	NR	NR	63
20 Aug. 1988	NR	NR	NR	NR	40

Texas Farm Road 1053 bridge northreast of Imperial

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Oct. 1987	19.6	5.4	13272	8.3	168

Salt Crossing, 8.1 km east of Imperial, 6.5 km downstream of Farm Road 1053

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
6 Feb. 1993	6.5	NR	NR	NR	60
4 Apr. 1993	15.0	NR	NR	NR	157
1 May. 1993	22.0	NR	NR	NR	12
3 Jul. 1993	27.5	NR	NR	NR	94
31 Jul. 1993	29.0	NR	NR	NR	80
4 Sep. 1993	26.0	NR	NR	NR	70
26 Sep. 1993	25.0	NR	NR	NR	35
20 Nov. 1993	11.0	NR	NR	NR	556
16 Apr. 1994	19.0	NR	NR	NR	2

Horsehead Crossing

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Aug. 1986	NR	NR	NR	NR	117
20 Aug. 1988	NR	NR	NR	NR	99

U.S. Hwy. 67 bridge northeast of Girvin

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Oct. 1987	18.5	5.8	14224	7.9	136
3 Aug. 1994	27.8	NR	18200	4.8	482

Crossing 3.3 km upstream of Farm Road 1901

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
14 Feb. 1993	9.0	NR	NR	NR	15
4 Apr. 1993	14.0	NR	NR	NR	34
1 May. 1993	24.0	NR	NR	NR	29
3 Jul. 1993	28.5	NR	NR	NR	8
31 Jul. 1993	29.0	NR	NR	NR	13
4 Sep. 1993	25.0	NR	NR	NR	17
26 Sep. 1993	26.0	NR	NR	NR	58
20 Nov. 1993	12.0	NR	NR	NR	42
11 Feb. 1994	13.5	NR	NR	NR	15
16 Apr. 1994	21.0	NR	NR	NR	42

TX Farm Road 1901 bridge near Mentone

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Aug. 1986	NR	NR	NR	NR	81
20 Aug. 1988	NR	NR	NR	NR	51

TX Hwy. 305 bridge

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Aug. 1986	NR	NR	NR	NR	58

Texas Hwy. 349 bridge northwest of Iraan

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
12 Aug. 1984	NR	NR	NR	NR	62
12 Oct. 1987	21.4	3.9	10080	9.7	26
20 Aug. 1988	NR	NR	NR	NR	102

U.S. Hwy. 190 bridge

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Aug. 1986	NR	NR	NR	NR	74

Crossing 3.0 km downstream of Iraan

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
12 Oct. 1987	21.5	NR	12936	9.1	65

Crossing 6.4 km upstream of U.S. Interstate Hwy. 10

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
14 Feb. 1993	10.0	NR	NR	NR	2
4 Apr. 1993	14.0	NR	NR	NR	45
2 May 1993	21.0	NR	NR	NR	27
3 Jul. 1993	28.5	NR	NR	NR	52
31 Jul. 1993	29.0	NR	NR	NR	82
4 Sep. 1993	25.0	NR	NR	NR	105
26 Sep. 1993	26.0	NR	NR	NR	55
16 Apr. 1994	22.0	NR	NR	NR	76

Fourmile Draw confluence, approximately 3.0 km north of U.S. Interstate Hwy. 10

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
31 Jul. 1993	31.0	NR	NR	NR	5
4 Sep. 1993	25.0	NR	NR	NR	25
26 Sep. 1993	26.0	NR	NR	NR	67
16 Apr. 1994	24.0	NR	NR	NR	2

U.S. Hwy. 290 bridge east of Sheffield

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
13 Aug. 1986	NR	NR	NR	NR	83
13 Oct. 1987	20.2	NR	12080	7.1	45
27 Jul. 1994	27.8	NR	16800	8.3	144

Upstream of the Independence Creek confluence

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
14 Aug. 1986	NR	NR	NR	NR	40
14 Mar. 1987	NR	NR	NR	NR	1
26 Sep. 1987	NR	NR	NR	NR	28
21 Dec. 1987	NR	NR	NR	NR	3

Independence Creek confluence, on Joe Chandler Ranch

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
26 May 1987	NR	NR	NR	NR	5
21 Jun. 1987	NR	NR	NR	NR	12
31 Aug. 1987	NR	NR	NR	NR	6

Downstream of Independence Creek confluence

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
14 Aug. 1986	NR	NR	NR	NR	13
27 Feb. 1987	NR	NR	NR	NR	1
14 Mar. 1987	NR	NR	NR	NR	1
26 Sep. 1987	NR	NR	NR	NR	2
25 Oct. 1987	NR	NR	NR	NR	20
30 Jan. 1988	NR	NR	NR	NR	1
10 Apr. 1988	NR	NR	NR	NR	2
24 Jul. 1988	NR	NR	NR	NR	5

Downstream of Richland Canyon confluence

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
14 Oct. 1987	19.6	NR	11230	6.9	1

Downstream of Geddis Canyon confluence, near Val Verde County line

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
26 Jul. 1994	30.4	NR	4940	8.3	1

Pandale Crossing

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
16 May 1987	NR	NR	NR	NR	30
20 Jun. 1987	NR	NR	NR	NR	8
24 Jul. 1987	NR	NR	NR	NR	10
30 Aug. 1987	NR	NR	NR	NR	15
26 Sep. 1987	NR	NR	NR	NR	15
14 Oct. 1987	20.9	NR	NR	8.9	14
25 Oct. 1987	NR	NR	NR	NR	42
22 Nov. 1987	NR	NR	NR	NR	31
21 Dec. 1987	NR	NR	NR	NR	32
30 Jan. 1988	NR	NR	NR	NR	12
25 Feb. 1988	NR	NR	NR	NR	5
10 Apr. 1988	NR	NR	NR	NR	16
24 May 1988	NR	NR	NR	NR	6
24 Jul. 1988	NR	NR	NR	NR	NR
20 Aug. 1988	NR	NR	NR	NR	69

Ose Canyon confluence

Date	Temp. (°C)	Salinity (ppt)	Conductivity (μmhos)	Dissolved Oxygen (mg/L)	Pupfish Hybrid
15 Oct. 1987	19.9	NR	6270	8.7	47

Collections From Salt Creek, TX

Date	Location	Pupfish Hybrid
9 Jun. 1988	below waterfalls, 2.4 km upstream of Pecos River	23
20 Aug. 1988	below waterfalls, 2.4 km upstream of Pecos River	30

Collections from irrigation canals and impoundments

Date	Location	Pupfish Hybrid
20 Aug. 1988	canal below W.I.D. No. 2 diversion dam	30
13 Aug. 1986	Imperial Reservoir West Shoreline	36
21 Feb. 1993	Imperial Reservoir Outflow	417
28 Mar. 1993	Imperial Reservoir Outflow	10
24 Apr. 1993	Imperial Reservoir Outflow	4
3 Jul. 1993	Imperial Reservoir Outflow	11
31 Jul. 1993	Imperial Reservoir Outflow	17
26 Sep. 1993	Imperial Reservoir Outflow	10
20 Nov. 1993	Imperial Reservoir Outflow	16
11 Feb. 1994	Imperial Reservoir Outflow	571
16 Apr. 1994	Imperial Reservoir Outflow	1

Collections from Texas Gravel Pits

Date	Location	Pupfish Hybrid
28 Jul. 1988	Porter's Gravel Pit	30
11 Mar. 1998	Phipps' Gravel Pits	6

Collections from Independence Creek

Date	Location	Pupfish Hybrid
11 Apr. 1987	Pecos River confluence	3
22 Nov. 1987	Pecos River confluence	1
30 Jan. 1988	Pecos River confluence	5
10 Apr. 1988	Pecos River confluence	2
21 Jun. 1987	Joe Chandler Ranch	3
25 Jul. 1987	Joe Chandler Ranch	1

APPENDIX IV

Historic Pecos Pupfish Collections

Section A

Historic Collections in New Mexico

Historic Collections in New Mexico Collection records were taken from the Museum of Southwestern Biology, UNM, Albuquerque, NM and the New Mexico Department of Game and Fish data base.

Collections from Bitter Lake National Wildlife Refuge

Date	Location	Pupfish
30 Oct. 1970	Sinkhole No. 2	81
1 Jun. 1971	Sinkhole No. 31	130
2 Jun. 1971	Sinkhole No. w15 (Inkpot)	12
20 Jun. 1947	Salt Creek near Cottonwood Rd.	33
15 Aug. 1971	Dragonfly Spring	23
18 Nov. 1971	Dragonfly Spring	37
23 Mar. 1965	Sago Spring	49
1 Jun. 1971	Sago Spring	120
15 Aug. 1971	Sago Spring	41
21 Jun. 1947	Bitter Creek	6
4 May 1971	Lost River Confluence	12
29 Apr. 1967	Unit 5 Waterfowl Lake	1
6 Nov. 1976	Unit 6 Waterfowl Lake	2
25 Sep. 1976	Unit 7 Waterfowl Lake	22
2 Sep. 1944	Unit 15 Waterfowl Lake	247
11 Sep. 1975	Unit 16 Waterfowl Lake	5
17 Aug. 1984	Hunter Oxbow	63

Collections from Bottomless Lakes State Park

Date	Location	Pupfish
29 Jul. 1940	Lazy Lagoon	1028
Apr. 1972	Lazy Lagoon	83
31 Jul. 1973	Lazy Lagoon	6
17 Aug. 1984	Lazy Lagoon	39
29 Jul. 1940	Mirror Lake	1040
11 Jul. 1973	Mirror Lake	4
31 Jul. 1973	Mirror Lake	4
29 Jul. 1940	Upper Figure Eight Lake	33
Apr. 1972	Upper Figure Eight Lake	88
29 Jul. 1940	Lea Lake	954
16 Aug. 1952	Lea Lake	316
18 Jun. 1960	Lea Lake	20
3 Aug. 1967	Lea Lake	66
20 Apr. 1970	Lea Lake	119
28 Oct. 1970	Lea Lake	63
13 Jun. 1975	Lea Lake	7
20 Aug. 1975	Lea Lake	48

Collections from the Mainstem Pecos River

Mainstem Pecos River

Date	Location	Pupfish
3 Sep. 1944	U.S. highway 70 bridge	1
30 Nov. 1975	U.S. highway 70 bridge	2
8 Sep. 1979	U.S. highway 70 bridge	1
4 Apr. 1972	Bitter Lake NWR	81
6 Feb. 1966	U.S. highway 380 bridge	3
27 Apr. 1968	U.S. highway 380 bridge	13
27 Oct. 1936	Dexter Bridge	5
31 Dec. 1938	Dexter Bridge	2
15 Jul. 1986	Dexter Bridge	1
27 Feb. 1950	Major Johnson Springs	2
17 May 1979	Black River Confluence	2
15 Jul. 1978	Loving Bridge	23
15 Aug. 1947	Malaga Bend	25
31 Mar. 1972	Malaga Bend	51
17 Jul. 1978	Malaga Bend	7
19 Mar. 1978	Pierce Canyon Crossing	81
1 Jun. 1978	Pierce Canyon Crossing	16
15 Aug. 1978	Pierce Canyon Crossing	26
11 Nov. 1978	Pierce Canyon Crossing	15
15 May 1979	Pierce Canyon Crossing	1
30 May 1979	Pierce Canyon Crossing	14
1 Dec. 1979	Pierce Canyon Crossing	5
5 Jan. 1980	Pierce Canyon Crossing	1
16 Jul. 1978	Red Bluff Draw Confluence	32
29 Nov. 1975	Rock House Crossing	4
3 Jan. 1978	Rock House Crossing	7
22 Mar. 1978	Rock House Crossing	1
21 May 1978	Rock House Crossing	39
15 Aug. 1978	Rock House Crossing	13
23 Sep. 1979	Rock House Crossing	5
5 Jan. 1980	Rock House Crossing	1
13 Nov. 1974	Delaware River Confluence	17
21 Nov. 1974	Delaware River Confluence	7
16 Mar. 1975	Delaware River Confluence	1
10 Mar. 1976	Delaware River Confluence	14
16 Jul. 1978	Delaware River Confluence	6

Collections From Unique Localities in New Mexico

Date	Location	Pupfish
6 Apr. 1916	Rio Ruidoso near San Patricio	35
6 Apr. 1916	Rio Hondo near Hondo	6
30 Jul. 1940	Rio Felix near current U.S. highway 285 crossing	3
Aug. 1948	Manda Lake near the Chaves / Eddy County Line	3
16 Mar. 1975	Delaware River upstream of the RRXG	1
24 Apr. 1975	Pupfish Spring @ Laguna Grande	3
19 May 1975	Pupfish Spring @ Laguna Grande	23
4 Jan. 1978	Pupfish Spring @ Laguna Grande	56
19 Mar. 1978	Pupfish Spring @ Laguna Grande	32
21 Mar. 1978	Pupfish Spring @ Laguna Grande	25
1 Jun. 1978	Pupfish Spring @ Laguna Grande	22
30 Nov. 1978	Pupfish Spring @ Laguna Grande	10

Section B

Historic Collections in Texas

Collections were made by A.A. Echelle, Oklahoma State University or were referenced from the Texas Natural History Collection, Austin, TX.

Collections from the Mainstem Pecos River

Date	Location	Pupfish
13 Jul. 1954	TX Hwy. 652 Bridge	91
19 Jul. 1954	TX Hwy. 302 Bridge	56
19 Jul. 1954	U.S. Hwy. 80 Bridge	43
30 Jul. 1952	TX Hwy. 18 (82?) Bridge	100
6 Sep. 1964	TX Hwy. 18 Bridge	6
26 Mar. 1972	TX Hwy. 1053 Bridge	50
19 Jul. 1954	U.S. Hwy. 67 Bridge	71
14 Apr. 1960	U.S. Hwy. 67 Bridge	21
23 Mar. 1965	U.S. Hwy. 67 Bridge	18
28 Jul. 1976	U.S. Hwy. 67 Bridge	18
8 Mar. 1980	U.S. Hwy. 67 Bridge	0
19 Jul. 1954	TX Hwy. 305 Bridge	45
20 Jul. 1954	TX Hwy. 349 Bridge	64
24 Mar. 1972	2 km south of Iraan	31
27 Jul. 1952	U.S. Hwy. 290 Bridge	100
12 Jul. 1976	U.S. Hwy. 290 Bridge	30
8 Mar. 1980	U.S. Hwy. 290 Bridge	0

Collections from Off-Channel Localities

Date	Location	Pupfish
11 May 1929	Artesian Well Near Pecos	4
10 Aug. 1986	Phipps' Gravel Pits	30
10 Aug. 1987	Phipps' Gravel Pits	68

Collections From Salt Creek drainage, Reeves County, Texas

Date	Location	Pupfish
13 Apr. 1976	Virginia Draw near sulphur mine	29
13 Apr. 1976	Maverick Draw near sulphur mine	29
25 Jul. 1975	7.4 km southwest of Orla	261
16 Aug. 1971	TX Hwy. 652 Bridge	248
13 Apr. 1976	TX Hwy. 652 Bridge	10
20 Apr. 1980	TX Hwy. 652 Bridge	0
17 Sep. 1975	U.S. Hwy. 285 Bridge	1656*
9 Mar. 1980	U.S. Hwy. 285 Bridge	0
19 Jul. 1954	Red Bluff Crossing	73
12 Mar. 1985	Red Bluff Crossing	187*
11 Aug. 1986	1.7 km upstream of Pecos River	53
9 Jun. 1988	Pecos River confluence	10

*combined two collections from the same date


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