United States Department of the Interior

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Memorandum

To: Assistant Regional Director, Migratory Birds and State Programs

From: Field Supervisor, Austin Ecological Services Field Office

Through: Texas State Administrator

Subject: Biological Opinion on Construction of a Dam and Pumping System at Phantom Lake Spring (Consultation No. 2-15-04-F-0284)

This document transmits the U.S. Fish and Wildlife Service's (Service) intraservice Biological Opinion (Opinion) based on our review of the proposed construction and operation of a dam and pumping system at Phantom Lake Spring located in Jeff Davis County, Texas, and its effects on the endangered Comanche Springs pupfish (*Cyprinodon elegans*), endangered Pecos gambusia (*Gambusia nobilis*), on two candidate species, Phantom Spring tryonia (*Tryonia cheatumi*) and Phantom Cave snail (*Cochliopa texana*), and one proposed candidate, diminutive amphipod (*Gammarus hyalelloides*) in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) (Act). Your September 2, 2004, request for formal consultation was received on September 13, 2004.

The U.S. Bureau of Reclamation, Albuquerque Area Office, (Reclamation) owns and manages Phantom Lake Spring and a surrounding area of about 17 acres (6.9 hectares). The proposed action was funded by an Act section 6 grant by the Service Division of Federal Assistance (FA) to Texas Parks and Wildlife Department (TPWD) and The Nature Conservancy (TNC). The proposed action was conceived, is being planned, and will be constructed and operated solely for the benefit of the endangered fishes and candidate invertebrates and their habitat.

This Opinion is based on information provided in the section 6 grant application and on information contained in a September 2, 2004, memorandum from FA, received on September 13, 2004, field investigations, and other sources of information. A complete administrative record of this consultation is on file at this office.

Because this action is being taken solely for benefit of endangered and candidate species, the Service will provide assistance in completing the population monitoring portion of the project description. Reclamation, TPWD, and TNC are being provided a copy of this Opinion.

TAKE PRIDE IN AMERICA

Consultation History

The Service was concerned about the status of adequate spring flows at Phantom Lake Spring in 1998. Early in 1999, the Service made several field visits and had discussions on this issue with members of the Rio Grande Fishes Recovery Team (Recovery Team), local water users, and state and Federal agency representatives, including Reclamation. The Service requested, by letter to Mr. Charles Calhoun, Regional Director of Reclamation, dated April 19, 1999, that Reclamation assist the Service in addressing the imminent endangered species habitat loss at Phantom Lake Spring. One specific request was for Reclamation to assess the feasibility of establishing a temporary, emergency pumping system to sustain surface water in the spring outflow. Reclamation completed formal section 7 consultation on a pumping system with a non-jeopardy Opinion dated May 10, 2000 (Consultation 2-15-00-F-679). That system was installed by May 2001. Since then, the operation of the dam and single pump system has maintained a small amount of aquatic habitat around the mouth of Phantom Cave, however, improvements are needed to increase system reliability and to expand the amount of habitat. To address this issue, FA funded an engineering study in 2002 as part of a previous section 6 grant. TPWD applied for the grant and was authorized for funding in 2003.

In a September 2, 2004, memorandum, received on September 13, 2004, FA provided details on the proposed project and determined that the project as proposed is likely to adversely affect the Comanche Springs pupfish, Pecos gambusia, Phantom Spring tryonia, Phantom Cave snail, and, diminutive amphipod. They requested formal intraservice section 7 consultation on the proposed project. The Service transmitted a draft Opinion to the FA on September 29, 2004.

BIOLOGICAL OPINION

Description of the Proposed Action

Although the current pump and dam system have maintained the fragile ecosystem of Phantom Lake Spring thus far, they are insufficient to maintain the current spring pool habitat. Problems with the current pumping system include: the water volume pumped is too large; the sand-bag check dam does not function properly (water flows underneath it); and there is not a backup power supply or pump in the event of malfunction. The pumping system needs significant improvement if the endangered animals and candidates are to be maintained in the wild.

The purpose of this proposed action is to provide improved, more reliable surface water flows and increase available aquatic habitat at Phantom Lake Spring for the benefit of two endangered species of fish, Comanche Springs pupfish and Pecos gambusia; two candidate species, Phantom Spring tryonia and Phantom Cave snail; and one proposed candidate, diminutive amphipod. The Service proposes to improve habitat at Phantom Lake Spring by rebuilding and improving the existing dam at the spring. The existing dam was built as part of a pumping and water retention system which maintains a pool of fresh water around the cave opening. The expected flow of 0.5 - 1.0 cubic feet per second (0.14 – 0.028 cubic meters per second) will be used to re-establish the shallow water habitat around the cave mouth and through about 250 feet (75 meters) of the refuge channel, significantly increasing the total available habitat for the endangered species. All pumped water will flow through the refuge channel and will be re-circulated to the spring opening.

Proposed Project Specifications

The proposed construction will increase distance the water is pumped out of the cave (to a distance of about 250 feet [75 meters]) and expand aquatic habitat around the spring to fully use the refuge channel. It will also provide a more reliable pumping system, with a generator to provide electricity to the pump in case of power failure. The proposed action will entail the following project components:

1. Check Dam: A reinforced concrete check dam, with re-moveable stop logs to control water elevation and return flow to the cave, will be constructed downstream of the current sand bag structure and metal cave gate.

2. Establish New Electrical Service: Single phase (230V) current will be delivered from a control box located in a 4-foot by 10-foot (1.2-meter by 3.0-meter) anchored storage building, to be placed on site. Electrical service will be delivered to the check dam through 1.5-inch (3.8-centimeter) PVC conduit attached to the cave wall above the water surface. Power will be supplied to the two submersible pumps located in the cave through individual wiring from this point. A back up generator driven by a propane engine and a 500-gallon (1893-liter) propane tank to supply it will also be installed.

3. Pump and Water Delivery: Purchase and installation (by certified SCUBA divers) of two 10 horsepower submersible electric pumps within the cave, a distance of about 250 feet (75 meters) from the cave mouth. The pumps will discharge into two, 2-inch (5.1-centimeter) PVC pipe, joined and expanded to a 3-inch (7.6-centimeter) single PVC pipe and conveyed to a discharge point downstream of the refuge channel.

4. Project Operation and Maintenance: Project operation and maintenance will consist of utility costs for continuous pumping, periodic maintenance as needed, and site visits to confirm pump operation. FA will coordinate with a local agency (Balmorhea State Park) and a private group (TNC) or individual to conduct site visits. Reclamation is going to pay the electric costs of pump operation.

If water surface elevation in the cave rises and provides natural spring flows over the check dam of greater than 0.5 cubic feet per second (0.014 cubic meters per second) downstream, then pumping could be discontinued. If this occurs, weekly monitoring of the habitat at Phantom Lake Spring should be continued. If spring flows remain consistent in the future, then the stop logs can be removed from the check dam to allow natural flow and stored on site for future use.

5. Flow Monitoring: Flows at the Phantom Lake Spring and San Solomon Spring, and Giffin Spring will be monitored. Flows at all three springs are currently measured about every 6 to 8 weeks by the U.S. Geological Survey (USGS).

6. Population Monitoring: Population monitoring of the Comanche Springs pupfish, Pecos gambusia, Phantom Spring tryonia, Phantom Cave snail, and diminutive amphipod at Phantom Lake Spring will occur about four times a year. The Austin Ecological Services Field Office of the Service (Austin Office) will conduct this monitoring. Monitoring will consist of visual counts of fish from observations and invertebrates from grab samples with small aquarium nets. We assume Comanche Springs pupfish, Pecos gambusia, and the candidate invertebrates currently inhabiting the cave mouth pool will re-colonize the refuge habitat. We do not foresee a need to augment the existing populations with hatchery stocks at this time.

Project Term

The Service recognizes the urgency of the low flow situation at the Phantom Lake Spring and the precarious position in which it places populations of the two federally listed fish species. Therefore, the project is proposed as a short term, emergency action to maintain flows at Phantom Spring. The current situation is symptomatic of a much larger problem of declining aquifer levels. Habitat for Comanche Springs pupfish, Pecos gambusia, Phantom Spring tryonia, Phantom Cave snail, and diminutive amphipod will be maintained in the hopes that a greater understanding is gathered of the factors that control the local hydrogeology and conservation actions will then be taken. However, pumping is not to be continued in perpetuity nor is this a long term solution for the conservation of the species or their ecosystem. Discontinuation of pumping may require reinitiation of intra-service section 7 consultation under the Act.

Project Evaluation

The Service, Reclamation, the Recovery Team, and the District will meet as necessary to evaluate the project based on, but not limited to the following factors:

1. Status of the endangered fish populations at Phantom Lake Spring.

2. A review of the Phantom Lake Spring hydrology (natural and artificial) and status of the aquifer and other local springs (stage, flow, and other impacts due to pumping).

3. A review of any new information regarding groundwater and surface water dynamics in the Trans-Pecos basin.

4. A review of project operation and maintenance, including operation costs, personnel time, effects (positive and negative) to local water users, impacts of pumping on the refuge channel and cave habitat, and project dependability.

Action Area

The action area includes the outflow area and downstream canal system at Phantom Lake Spring within the Reclamation property boundaries.

Status of the Species/Critical Habitat

The Comanche Springs pupfish and Pecos gambusia are small fishes endemic to spring ecosystems and both are listed as endangered. Critical habitat has not been designated for either species. Two candidate species, Phantom Spring tryonia and Phantom Cave snail, occur in the spring. The diminutive amphipod has been proposed as a new candidate species and also occurs in Phantom Lake Spring.

Comanche Springs pupfish (*Cyprinodon elegans*) - Endangered

Comanche Springs pupfish was listed as federally endangered in 1967 without critical habitat (32 FR 4001). In 1981, a recovery plan for the species was completed (Service 1981). Since then several updates of the recovery plan have been drafted but not yet completed. Comanche Springs pupfish is one of the most distinctive members of the genus *Cyprinodon* (Echelle et al. 2003). Males possess a unique speckled color pattern and all individuals have a relatively streamlined body shape. They lack the vertical bars on the sides of their bodies that are found in most other *Cyprinodon*. Comanche Springs pupfish are small fishes, individuals only attain a maximum size of approximately 2 inches (50 millimeters) standard length (Itzkowitz 1969, Echelle and Hubbs 1978, Service 1981).

Life history

Comanche Springs pupfish can breed in swifter water than all other known *Cyprinodon*. Males orient and maintain position upstream from their territories until a female enters the territory and positions herself near the algal mat substrate (Itzkowitz 1969). These territories are variable in size (averaging approximately 5.4 square feet [0.5 square meters]) and most often over algal mats. The males guard eggs until hatching and they aggressively defend their territories against intruders (Itzkowitz 1969). Courtship behaviors are similar to other species of *Cyprinodon* based upon the direct observations of Itzkowitz (1969) as well the existence of natural hybrids between *C. elegans* and introduced *C. variegatus* (sheepshead minnows) as documented by Stevenson and Buchanan (1973). Eggs are apparently laid singly onto the algal mat substrates of the male's territory (Itzkowitz 1969). Aquarium studies suggest females may lay 30 eggs per day and eggs hatch in 5 days at 68 ‹F (20 ‹C) (Cokendolpher 1978).

Comanche Springs pupfish are relatively short-lived fish with most individuals living approximately 1 year. This aspect, coupled with their reproductive biology, causes large fluctuations in population numbers. Gut analysis of 20 specimens by Winemiller and Anderson (1997) revealed Comanche Springs pupfish eat mostly filamentous algae and some snails (*Cochliopa texana*).

Water emanating from the springs is stenothermal, approximately 72-79 ‹F (22-26 ‹C) (Stevenson and Buchanan 1973, Gehlbach et al. 1978, Brune 1981), however, exposure to ambient temperatures makes the waters in which Comanche Springs pupfish occur more eurythermal. Temperature preference experiments indicate that habitat temperatures between 68-86 ‹F (20-30 ‹C) during August and September are optimal (Gehlbach et al. 1978). Comanche Springs pupfish have a critical thermal maximum of approximately 105 ‹F (40.5 ‹C), and there is significant diurnal variation in the critical thermal maximum (higher in afternoon than morning) (Gehlbach et al. 1978).

Population dynamics

Estimated adult population size of the pupfish in the 1970s was about 1,000 or more in the vicinity of San Solomon Springs and perhaps several thousand in the irrigation canals (Echelle 1975). Densities are considered sparse in the irrigation canals due to lack of suitable habitat (Echelle 1975). During a two-year sampling study (Garrett and Price 1993), population size in the pupfish canal on Balmorhea State Park was estimated to be as low as 968 (May 1990) and as high as 6,480 (September 1990). Construction of the modified canal at Phantom Lake Spring resulted in an increase in local abundance, with an average of 14.7 individuals per square meter (Winemiller and Anderson 1997). During 1999 to 2001, the population in San Solomon Ciénega in Balmorhea State Park averaged 270,000 in summer to approximately 18,000 in winter (Garrett 2003).

Status and distribution

Comanche Springs pupfish originally inhabited two isolated spring systems approximately 56 miles (90 kilometers) apart in the Pecos River drainage of western Texas (Baird and Girard 1853). The type locality, Comanche Springs, inside the city limits of Fort Stockton, Pecos County, Texas, is now dry and the population at this locality is extinct. The other population is restricted to a small series of springs, their outflows, and a system of irrigation canals historically interconnecting Phantom Lake Springs (located in easternmost Jeff Davis County, Texas), San Solomon Springs, Giffin Springs and Toyah Creek near Balmorhea, Reeves County, Texas (Echelle et al. 2003). The number of fish in the San Solomon Spring outflow has greatly increased in recent years as a result of the increased habitat availability from the San Solomon Ciénega (Garrett 2003).

Comanche Springs pupfish habitat has been markedly altered into an irrigation network of concrete-lined canals with swiftly flowing water and dredged earth-lined laterals. The area has been highly modified repeatedly over the past century for the benefit of irrigation agriculture (Bogener 1993). Waters from Phantom Lake Springs originally emerged from a cave and formed a ciénega that drained back into a cave. Subsequently water was captured in an irrigation canal as it emanated from the cave, but now there is no outflow from Phantom Lake Spring. Water from San Solomon and Giffin springs flows into additional irrigation systems, some of which is stored for irrigation supply in Lake Balmorhea. The aquatic habitat in the canals is highly impacted, ephemeral, and very dependent upon local irrigation practices and other water-use patterns. For the most part, the irrigation canals provide little suitable habitat for Comanche Springs pupfish (Service 1981). Also, in order to repair or re-dredge canals, flows are sometimes diverted causing mortalities of Comanche Springs pupfish (Davis 1979).

Primary threats to the Comanche Springs pupfish include the loss of aquatic habitat due to declining spring flows and hybridization with the introduced fish, sheepshead minnow. For example, flows from Phantom Lake Spring have been declining since measurements have been taken in the 1930s (Brune 1981, Sharp et al 1999). Also, it was the complete loss of spring habitat from Comanche Springs in Fort Stockton that extirpated the fish from its type locality. Comanche Springs pupfish readily hybridize with sheepshead minnow and are eventually replaced by the nonnative congener. A large population of sheepshead minnow occur in Lake Balmorhea (Stevenson and Buchanan 1973, Echelle and Echelle 1994) and expansion of the nonnative species into upstream areas of the spring outflows is a constant threat to the existence of the species in the wild.

Phantom Lake Spring ceased flowing during the summer of 1999 and has not recovered. There is now only a small pool remaining at the cave mouth and the water is provided by a pump system cycling water from inside the cave to the springhead and allowing flow back into the cave. The fish populations at this site are severely impacted from loss of habitat, resulting in extremely small population sizes. Less than 100 individuals of gambusia and 50 individuals of pupfish are likely present (N. Allan, Service, personal observation, 2003). Maintenance of the habitat for these gentically-unique populations is exclusively dependent on the pumping system. In July 2004, heavy local rainfall resulted in a large flow from Phantom Lake Spring. The duration and effects of the flows are not yet known. However, our knowledge of the spring's hydrology suggests flows will soon subside and return to pre-rainfall conditions.

The Service is maintaining captive stocks of Comanche Springs pupfish at the Dexter National Fish Hatchery and Technology Center, Dexter, New Mexico and the Uvalde National Fish Hatchery, Uvalde County, Texas. The Uvalde population originated from 73 individuals collected from the distinctive subpopulation at Phantom Lake Springs (Garrett and Price 1993). The Dexter population came from individuals taken from the Uvalde stock in 2003 following a genetic evaluation of the stock (Echelle and Echelle 2002).

Pecos gambusia (*Gambusia nobilis*) - Endangered

Baird and Girard (1853) described Pecos gambusia based on material from Leon and Comanche springs, Pecos County, Texas. Leon Springs was later designated the type locality (Hubbs and Springer 1957). This fish has been listed as federally endangered since 1970. The Pecos gambusia is a relatively robust *Gambusia*, with an arched back and a caudal peduncle depth that is approximately two-thirds of the head length. The margins of the scale pockets are outlined in black and spots are normally absent on the caudal fin, however, sometimes a faint medial row of spots may be present. The dorsal fin has a subbasal row of spots. Females have a prominent black area on the abdomen that surrounds the anus and anal fin. The male gonopodium has a number of unique features including elongated spines on ray 3, small rounded hooks on the tips of rays 4p and 5a, and an elbow on ray 4a consisting of 3 or 4 fused segments located opposite the serrae of ray 4p (Hubbs and Springer 1957, Koster 1957, Bednarz 1975, Echelle and Echelle 1986).

Populations in Toyah Creek (Texas) and Blue Spring (New Mexico) were found to be the most diverse morphologically and genetically, and the Toyah Creek population had the greatest genetic heterogeneity (Echelle and Echelle 1986, Echelle et al. 1989).

Life history

Pecos gambusia produce live young. Bednarz (1979) reported that the number of embryos was related to female size and that the mean number of embryos was 38 in the Blue Spring population. Hubbs (1996) found that the birth weight of Pecos gambusia from Texas populations ranged between 0.0012 and 0.0018 ounces (35 and 50 milligrams) and females had an interbrood interval averaging 52 days. Hybrids between Pecos gambusia and western mosquitofish (*Gambusia affinis*) or largespring gambusia (*G. geiseri*) are occasionally found, especially in habitats where one of the species is rare (Hubbs and Springer 1957, Service 1983).

Pecos gambusias inhabit stenothermal springs, runs, spring-influenced marshes (ciénegas), and irrigation canals carrying spring waters (Service 1983, Hubbs 2003). Some populations are also known from areas with little spring influence; these habitats generally have abundant overhead cover, and include sedge-covered marshes and gypsum sinkholes (Echelle and Echelle 1980). One or two other *Gambusia* may also be found in association with *G. nobilis*. Where the western mosquitofish is found, *G. nobilis* inhabits stenothermal waters and western mosquitofish is most often found in eurythermal habitats. Where the largespring gambusia has been introduced, the Pecos gambusia is much more likely to be found associated with vegetation or in deeper waters, while largespring gambusia tends to be at the surface or in open water over non-vegetated substrates (Hubbs et al. 1995, Hubbs 2001, 2003). Pecos gambusias feed relatively non-selectively, consuming a diversity of food types, including; amphipods, dipterans, cladocerans, filamentous algae, arachnids and mollusks (Hubbs et al. 1978, Winemiller and Anderson 1997).

Population dynamics

Where suitable habitats exist, Pecos gambusia populations can be dense. An estimated 27,000 individuals inhabit the Bitter Lake National Wildlife Refuge area, and 900,000 inhabit Blue Spring (Bednarz 1975, 1979). Approximately 100,000 Pecos gambusia are estimated to inhabit the Balmorhea springs complex and more than 100,000 in the Diamond Y springs and draw (Service 1983).

Status and distribution

The Pecos gambusia is endemic to the Pecos River basin in southeastern New Mexico and western Texas and originally ranged from near Fort Sumner, New Mexico to the area around Fort Stockton, Texas. At present, the species is restricted to four main areas, two in New Mexico and two in Texas. Populations live in various springs and sinkholes in Bitter Lake National Wildlife Refuge, near Roswell, New Mexico; Blue Spring, east of Carlsbad Caverns National Park, New Mexico; the Diamond Y springs and draw (=Leon Creek), near Fort Stockton, Texas; and the Toyah Basin (San Solomon springs complex) near Balmorhea, Texas. Extirpated populations include the Pecos River near Fort Sumner and North Spring River in New Mexico, and Leon and Comanche springs, which are now dry, in Texas.

The Pecos gambusia faces severe threats from spring flow declines and habitat modification throughout their range. Loss of outflow in Phantom Lake Spring (described earlier) has also affected the local population of Pecos gambusia. Currently, the total number of individuals persisting at Phantom Lake Spring is estimated to be less than 100 (N. Allan, Service, personal observation, 2003). Throughout their historic range, ciénegas, presumed to have supported large numbers of Pecos gambusia, have been systematically drained and spring flows diverted for irrigation. Additional stresses on the population may occur through competition with the introduced largespring gambusia.

Phantom Cave snail (*Cochliopa texana*) – Candidate (2001)

The Phantom Cave snail was first described by Pilsbry (1935). It is a very small snail, measuring only 0.039 to 0.55 inches (1 to 1.4 millimeters) in length (Dundee and Dundee 1969). Habitat of the species is found mostly on firm substrates (rocks and vegetation) on the margins of spring outflows (Taylor 1987).

In the desert Southwest, aquatic snails are distributed in isolated geographically-separate wetland populations (Hershler et al. 1999). They likely evolved into distinct species during recent dry periods (since the Late Pleistocene, within the last 100,000 years) from parent species that once enjoyed a wide distribution during wetter, cooler climates of the Pleistocene. Such divergence has been well-documented for aquatic and terrestrial macroinvertebrate groups within arid ecosystems of western North America (e.g., Taylor 1987, Metcalf and Smartt 1997, Bowman 1981). Hershler and Thompson (1992) described the systematics of the Subfamily Cochliopinae, Family Hydrobiidae, based on morphological characteristics.

Life history

The Phantom Cave snail only occurs in desert spring outflow channels. They are most abundant in the first few hundred meters downstream of spring outlets. Habitat of the species is found on both soft and firm substrates on the margins of spring outflows (Taylor 1987). They are also commonly found attached to plants, particularly in dense stands of submerged *Chara* beds. These snails likely have life spans of 9 to15 months and reproduce several times during the spring to fall breeding season (Taylor 1987, Pennak 1989, Brown 1991). Snails of the family Hydrobiidae are sexually dimorphic with females being characteristically larger and longer-lived than males. The snails are ovoviviparous, producing live young serially (as opposed to broods). They are presumably fine-particle feeders on detritus and periphyton associated with the substrates (mud and vegetation); Dundee and Dundee (1969) found diatoms to be the primary component in the digestive tract.

Population dynamics

Within its limited range, Phantom Cave snail can occur in very high densities.

Status and distribution

The Phantom Cave snail is an aquatic snail occurring in only three spring systems and associated outflows (Phantom Lake, San Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Taylor 1987). The snail may also occur at Giffin

Spring, in the same area, but information is not available from that site. There is no available information that indicates the species historic distribution was larger than the present distribution. However, other area springs may have contained the same species, but because these springs have been dry for many decades, there is no opportunity to determine the potential historic occurrence of the snail fauna.

The most significant threat to the continued existence of this snail is the degradation and eventual loss of spring habitat (flowing water) due to the decline of groundwater levels of the supporting aquifer. The San Solomon Spring System (System) is located in the Toyah Basin at the foothills of the Davis Mountains near Balmorhea, Texas. In addition to being an important habitat for rare aquatic fauna, area springs are also an important source of irrigation water for the farming communities in the Toyah Basin. Phantom Lake Spring is in Jeff Davis County, while the other major springs in this system are in Reeves County. The Reeves County Water Improvement District #1 (District) diverts water from the springs using a system of canals to irrigate area fields (RCWID#1 2001).

Another threat to snail habitat is the potential degradation of water quality from point and nonpoint pollutant sources. This can occur either directly into surface water or indirectly through contamination of groundwater that discharges into spring run habitats used by the snail. The primary threat for contamination comes from herbicide and pesticide use in nearby agricultural areas.

Dundee and Dundee (1969) described the conditions of Phantom Cave snail at Phantom Lake Spring in 1968. Despite the fact that Phantom Lake Spring has been drastically altered from its original state, the native snails (Phantom springsnail and Phantom Cave snail) occurred in the irrigation canal in such tremendous numbers that the sides of the canal appeared black from the cover of snails. Today the snails are limited to the small pool at the mouth of Phantom Cave and can not be found in the irrigation canal downstream (J. Landye, *in litt*, 2000). A similar situation occurs at San Solomon Spring, where Taylor (1987) reported the snail was abundant and generally distributed in the canals from 1965 to 1981. No recent information is available on the status of the species at San Solomon Spring.
In the summer of 2000, East Sandia Spring was surveyed for aquatic macroinvertebrates for the first time. A healthy abundance and diversity of snails and other macroinvertebrates were present in the spring head and small outflow channel (Lang et al. 2003). The entire available habitat is estimated at less than 492 feet (150 meters) in length, and usually 3 feet (1 meter) wide or less.

The natural ciénega habitats of the Balmorhea area have been mostly altered over time to accommodate agricultural irrigation. Two of the three known occurrences of the species are in degraded habitats (exception is East Sandia Spring) because the natural conditions of the springs have been substantially modified for human use. Any additional modifications to the spring flow habitats will further threaten the species.

Within the last 10 years, an exotic snail, *Melanoides* sp., has become established in Phantom Lake Spring (B. Fullington, *in litt*., 1993; McDermott 2000). The species has been at San Solomon Spring for some time longer, but is not found in East Sandia Spring. In many locations at San Solomon Spring, this exotic snail essentially is the substrate in the small stream channel. The effects of this introduction are not known. However, this exotic snail is likely competing with the native snails for space and resources. Other changes to the ecosystem from the dominance of this species are likely to occur and could have detrimental effects to the native invertebrate community.

Phantom Spring tryonia (*Tryonia cheatumi*) – Candidate (2001)
The Phantom springsnail was first described by Pilsbry (1935). It is a very small snail, measuring only 0.11 to 0.14 inches (2.9 to 3.6 millimeters) long (Taylor 1987). The shell is narrowly conical, with an obtuse apex and a broadly rounded anterior end (Taylor 1987). Whorls are 4.75 to 5.75 in larger males and 5 to 6 in larger females, regularly convex, and separated by a deeply incised suture (Taylor 1987). Snails of the family Hydrobiidae are sexually dimorphic with females being characteristically larger and longer-lived than males. The snails are ovoviviparous, producing live young serially (as opposed to broods). They are presumably fine-particle feeders on detritus and periphyton associated with the substrates (mud and vegetation); Dundee and Dundee (1969) found diatoms to be the primary component in the digestive tract.

In the desert Southwest, aquatic snails are distributed in isolated geographically-separate wetland populations (Hershler et al. 1999). They likely evolved into distinct species during recent dry periods (since the Late Pleistocene, within the last 100,000 years) from parent species that once enjoyed a wide distribution during wetter, cooler climates of the Pleistocene. Such divergence has been well-documented for aquatic and terrestrial macroinvertebrate groups within arid ecosystems of western North America (e.g., Taylor 1987, Metcalf and Smartt 1997, Bowman 1981).

Recent systematic studies (Hershler et al. 1999, Hershler 2001) of snails in the Family Hydrobiidae have been conducted using mitochondrial DNA sequences and morphological characters. These analyses support the unique taxonomic status of the Phantom springsnail. Phantom springsnail was assigned to a clade of "true *Tryonia*" made up of 16 species in southwestern North America (Hershler et al. 1999). A closely related congener, Gonzales springsnail (*T. circumstriata*), occurs at Diamond Y Spring in Pecos County. Gonzales springsnail is distinguished from Phantom springsnail by its narrower, more strongly sculptured shell and more numerous penial papillae (Hershler 2001).

Life history

The Phantom springsnail is an aquatic snail occurring in only three spring systems and associated outflows (Phantom Lake, San Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Taylor 1987). The snail may also occur at Giffin Spring, in the same area, but information is not available from that site. There is no available information that indicates the species' historic distribution was larger than the present distribution. However, other area springs may have contained the same species, but because these springs have been dry for many decades, there is no opportunity to determine the potential historic occurrence of the snail fauna.

The Phantom springsnail only occurs in desert spring outflow channels. They are most abundant in the first few hundred meters downstream of spring outlets. Habitat of the species is found on both soft and firm substrates on the margins of spring outflows (Taylor 1987). They are also commonly found attached to plants, particularly in dense stands of submerged *Chara* beds.

Population dynamics

Within its limited range, Phantom springsnail can have very high densities of abundance.

Status and distribution

The Phantom springsnail has essentially the same current distribution as the Phantom Cave snail. Dundee and Dundee (1969) described the conditions of Phantom springsnail at Phantom Lake Spring in 1968. Despite the fact that Phantom Lake Spring has been drastically altered from its original state, the native snails (Phantom springsnail and Phantom Cave snail) occurred in the irrigation canal in such tremendous numbers that the sides of the canal appeared black from the cover of snails. Today the snails are limited to low densities in the small pool at the mouth of Phantom Cave and can not be found in the irrigation canal downstream (J. Landye, *in litt*, 2000). A similar situation occurs at San Solomon Spring, where Taylor (1987) reported the snail was abundant and generally distributed in the canals from 1965 to 1981. No recent information is available on the status of the species at San Solomon Spring.
In the summer of 2000, East Sandia Spring was surveyed for aquatic macroinvertebrates for the first time. A healthy abundance and diversity of snails and other macroinvertebrates were present in the spring head and small outflow channel (Lang et al. 2003). The entire available habitat is estimated at less than 150 meters (492 feet) in length, and usually 3 feet (1 meter) wide or less.
The most significant threat to the continued existence of this snail is the degradation and eventual loss of spring habitat (flowing water) due to the decline of groundwater levels of the supporting aquifer. The San Solomon Spring System (System) is located in the Toyah Basin at the foothills of the Davis Mountains near Balmorhea, Texas. In addition to being an important habitat for rare aquatic fauna, area springs are also an important source of irrigation water for the farming communities in the Toyah Basin. Phantom Lake Spring is in Jeff Davis County, while the other major springs in this system are in Reeves County. The Reeves County Water Improvement District #1 (District) diverts water from the springs using a system of canals to irrigate area fields (RCWID#1 2001).

Another threat to snail habitat is the potential degradation of water quality from point and nonpoint pollutant sources. This can occur either directly into surface water or indirectly through contamination of groundwater that discharges into spring run habitats used by the snail. The primary threat for contamination comes from herbicide and pesticide use in nearby agricultural areas.

The natural ciénega habitats of the Balmorhea area have been mostly altered over time to accommodate agricultural irrigation. Most significant was the draining of wetland areas and the modification of spring outlets for development of human use of the water resources. Although the physical condition of the areas has changed dramatically over time from human actions, at least a portion of the native biota remain. Two of the three known occurrences of the species are in degraded habitats (exception is East Sandia Spring) because the natural conditions of the springs have been substantially modified for human use. Any additional modifications to the spring flow habitats will further threaten the species.

Within the last 10 years, an exotic snail, *Melanoides* sp., has become established in Phantom Lake Spring (B. Fullington, *in litt*., 1993; McDermott 2000). The species has been at San Solomon Spring for some time longer, but is not found in East Sandia Spring. In many locations at San Solomon Spring, this exotic snail essentially is the substrate in the small stream channel. The effects of this introduction are not known. However, this exotic snail is likely competing with the native snails for space and resources. Other changes to the ecosystem from the dominance of this species are likely to occur and could have detrimental effects to the native invertebrate community.

The snail may be more sensitive to changes in water quality or other habitat changes than the fish and are likely more directly threatened by the presence of the exotic *Melanoides* snail than the endangered fish.

Diminutive amphipod (*Gammarus hyalelloides*) - Proposed Candidate (2004)

The diminutive amphipod was first collected by W.L. Minckley from Phantom Lake Spring in 1967 and was formally described by Cole (1976). The name comes from the species being considered the smallest of the known North American fresh-water Gammarus amphipod. Adults range in size from 0.197 to 0.315 inches (5 to 8 millimeters). Some diagnostic features include more elongate and less setaceous than *G. pecos*; lacking setae on the posterior margin of the first peduncular segment of antenna 1; coxal plates 1-4 with fewer anteroventral setae, rarely more than a sum of 10 on one side; epimera 2 and 3 armed with spines, usually lacking anterior, ventral, and facial setae; and females without teeth in palmar concavities of gnathopods 1 and 2 (Cole 1976).

This is one species of a related group of amphipods from the Pecos River Basin, referred to as the *Gammarus-pecos* complex (Cole 1985, Lang et al. 2003, Gervasio et al. 2004). In Cole's (1985) description of these amphipods based on morphological measurements, he considered *G. hyalleloides* to be endemic to Phantom Lake Spring. Amphipods collected from San Solomon Spring were considered to be *G. pecos*, which would be the same species as the gammarid amphipods from Diamond Y Spring (Cole 1985). However, recent genetic analysis provides strong evidence that the Toyah Basin populations (Phantom Lake, San Solomon, Giffin, and East Sandia springs) form a separate, distinct group from *G. pecos* (Gervasio et al. 2004). Contrary to Cole's (1985) findings, genetic analysis suggests that *G. pecos* is a unique taxa that occurs only at Diamond Y Spring (Cole and Bousfield 1970) and diminutive amphipod and the other amphipod populations form an unresolved group from the Toyah Basin (Gervasio et al. 2004).

Based on the best available science, we consider the amphipod population at Phantom Lake Spring to be the same species as the other three Toyah Basin populations (San Solomon, Giffin, and East Sandia springs). These populations are being treated as one taxa. However, some genetic differences among these populations were detected, and more detailed phylogenetic analysis may lead to additional species being described from within this group (Gervasio et al. 2004). If future study separates these four populations into more than one taxa, each should still be considered warranted for inclusion as a candidate for listing, because of the high degree of threats to the habitat.

Life history

The diminutive amphipod only occurs in desert spring outflow channels. The small amphipods occur on substrates, often within interstitial spaces on and underneath rocks and within gravels (Lang et al. 2003), and are most commonly found in microhabitats with flowing water. They are also commonly found in dense stands of submerged vegetation, primarily *Chara* beds (Cole 1976). Because of their affinity for the constant water temperatures, they are most common in the immediate spring outflow channels, usually only a few hundred meters downstream of spring outlets.

Amphipods play important roles in the processing of nutrients in aquatic ecosystems (Gee 1988, Pennak 1989). Amphipods are considered sensitive to changes in aquatic habitat conditions (Covich and Thorpe 1991) and are often considered ecological indicators of ecosystem health (Lackey 1995) and integrity (Callicott 1994). Amphipods from the *G. pecos* complex are considered highly imperiled, suggesting a systemic deterioration of aquatic ecosystems in the desert springs where they occur, based mostly on declining spring flows (Lang et al. 2003).

Population dynamics

Within its limited range, diminutive amphipod can be very abundant. For example, in May 2001, Lang et al. (2003) estimated mean densities at San Solomon, Giffin, and East Sandia springs of 6,833 amphipods per square meter (standard error ±5,416), 1,167 (±730), and 4,625 (±804), respectively. No data is available for Phantom Lake Spring densities, as the amphipod was not found there at the time of these surveys.

Status and distribution

The diminutive amphipod is endemic to the Toyah Basin of the Pecos River drainage of Texas. It is one species of a distinct group of amphipods that are restricted to euryhaline (that is, having a wide range of salinities) desert spring systems in southeast New Mexico and west Texas (Cole 1985). It is thought that these freshwater amphipods are derived from a widespread ancestral marine amphipod that was isolated inland during the recession of the Late Cretaceous sea, about 66 million years ago (Bousfield 1958, Holsinger 1976, Lang et al. 2003). They likely evolved into distinct species during recent dry periods (since the Late Pleistocene, about 100,000 years ago) through allopatric speciation following separation and isolation in the remnant aquatic habitats associated with springs (Gervasio et al. 2004). Such divergence has been well-documented for aquatic and terrestrial macroinvertebrate groups within arid ecosystems of western North America (for example, Bowman 1981, Taylor 1987, Metcalf and Smartt 1997, Hershler et al. 1999).

The diminutive amphipod occurs in only four springs in Jeff Davis and Reeves counties, Texas: Phantom Lake, San Solomon, Giffin and East Sandia springs (collectively referred to here as the San Solomon Springs System) (Gervasio et al. 2004). These springs are all within about 8 miles (13 kilometers) of each other. There is no available information that the species historic distribution was larger than the present distribution. However, other area springs may have contained the same or similar species, but because these springs have been dry for many decades (Brune 1981), there is no opportunity to determine the potential historic occurrence of amphipods.

Prior to installation of the pumping system in 2001, it was suspected that the diminutive amphipod had been extirpated from Phantom Lake Spring. No records of the amphipods were available after the study by Winemiller and Anderson (1997) had collections of amphipods in pupfish stomachs in 1995. Surveys for amphipods in 1999 to 2001 found no evidence of amphipods (Allan 2000, Lang et al. 2003). In the fall of 2001, the amphipods were rediscovered and are currently locally abundant in the small pool at the cave mouth (Lang et al. 2003).

Another endemic aquatic amphipod may have occurred historically in lateral canals at Phantom Lake Spring (Cole 1976, 1985). This amphipod was only mentioned as a unique "form" and was never actually described as a separate species. The aquatic habitat where this form occurred (downstream and lateral canals that may have had a separate spring source) has been dry for many years and this other amphipod form is now extinct.
Within the last 10 years, an exotic snail, *Melanoides* sp., has become established in Phantom Lake Spring (McDermott 2000). The species has been at San Solomon Spring (and presumably Giffin) since at least the 1960s, but is not found in East Sandia Spring (McDermott 2000). In many locations at San Solomon Spring, this exotic snail essentially is the substrate in the small stream channel. The effects of this introduction are not known. However, this exotic snail is likely competing with the native macroinvertebrates for space and resources. Other changes to the ecosystem from the dominance of this species are likely to occur and could have detrimental effects to the native invertebrate community.

Environmental Baseline

<u>Status of the species within the action area</u>

Comanche Springs pupfish and Pecos gambusia

Phantom Lake Spring is very important for the conservation and recovery of both of these listed species. Although it contains only a small portion of the rangewide habitat for Pecos gambusia, Echelle and Echelle (1980) demonstrated that the Balmorhea population is the most genetically divergent of the extant populations. This increases the significance of preservation of the Phantom Lake Spring population and genome. Phantom Lake Spring represents a significant portion of the range of Comanche Springs pupfish, especially in light of the habitat lost at Comanche Springs and the proximity and common threats, such as decreased spring flows, of the remaining populations (San Solomon Springs, Balmorhea canals, and Giffin Springs).
Collections of fishes from Phantom Lake Spring demonstrate that both species have consistently occupied the spring outflow and irrigation ditches downstream (Garrett and Price 1993, Hubbs *in*

litt. 1998-2000, Winemiller and Anderson 1997). An intense study of fish populations in Phantom Lake Spring from 1993 to 1995 resulted in total abundance estimates of Comanche Springs pupfish as high as near 400 individuals and Pecos gambusia as high as 800 individuals during late summer collections (Winemiller and Anderson 1997).

Monthly collections (using minnow traps) at Phantom Lake Spring by Dr. Clark Hubbs during 1998-99 indicated that Pecos gambusia made up from 35 to 80 percent of the gambusia population (the introduced largespring gambusia, *Gambusia geiseri*, is the other primary species) (Hubbs and Karges 1999). This study also shows that Pecos gambusia, in the presence of largespring gambusia, tend to use habitats of deeper water with more current (Hubbs and Karges 1999).

A captive population of Comanche Springs pupfish from Phantom Lake Spring has been maintained at the Uvalde National Fish Hatchery in Uvalde, Texas, since 1990. The original stock came from 73 individuals and is maintained in one outdoor pond that holds several thousand individuals in the summer. In August 1999, the Service collected individuals of both species from Phantom Lake Spring for captive refugium at Dexter National Fish Hatchery and Technology Center in Dexter, New Mexico. The fish are being held in recirculating indoor tanks. One tank contains 50 adult pupfish and 50 adult Pecos gambusia, another tank has 45 adult gambusia and a third tank has 37 young-of-year gambusia (132 total gambusia) (pers. comm., Roger Hamman, Service, May 1, 2000). The Service is considering augmenting these stocks with additional wild fish.

The Service estimates, based on the best available scientific information, the populations of endangered fish remaining within the Phantom Spring outflow are likely in the range of about 100 to 200 individuals of Comanche Springs pupfish and 100 to 200 individuals of Pecos gambusia. The number of individuals may be even lower as conditions continue to deteriorate.

Factors affecting species environment within the action area

Historically, Phantom Lake Spring was a large desert ciénega with a pond of water more than several acres in size. The pristine condition of the spring outflow would have provided ideal habitat for the endemic native fishes and other fauna. During the 1940's, the spring outflow was modified into a concrete-lined irrigation ditch so that the total outflow from the spring could be captured and used for irrigation of agriculture lands. Both of the endangered species persisted in reduced numbers in the small pool of water at the mouth of the spring (Phantom Cave) and, to some extent, in the irrigation canals downstream.

The refuge channel that was built by Reclamation in 1993 (Young et al. 1993) has been an important improvement in available habitat. Winemiller and Anderson (1997) showed that the refuge channel was used by both species when water was available. Unfortunately, the refuge channel was constructed for a design flow down to 0.5 cubic feet per second (0.14 cubic meters per second) which at the time of construction was the lowest flow ever recorded out of Phantom Lake Spring (in 1984).

Phantom Lake Spring has experienced a long term, consistent decline in spring flows. Discharge data has been recorded from the spring six to eight times per year since the 1940's by the U.S. Geological Survey (Schuster 1997). The record shows a steady decline of flows, from greater than 10 cubic feet per second (0.28 cubic meters per second) in the 1940's to 0 cubic feet per second in 2000. The data also show that the spring can have short term flow peaks resulting from local rainfall events in the Davis Mountains (Sharp et al. 1999). These peaks are from fast recharge and discharge, not surface runoff because the spring is not within a drainage basin. However, after each increase, the "base flow" has returned to the same declining trend within a few months.

There have been extremely low flows from Phantom Lake Spring since summer 1998. Rainfall in the summer 1999 provided temporary increase in flow, but by fall, flow had returned to near zero. Only the small pool at the cave mouth continues to provide some endangered fish habitat. This last remaining habitat will be gone as the water surface elevation declines.

The exact cause or causes for this decline in spring discharge are unknown. Some of the obvious reasons are groundwater pumping of the supporting aquifer and decreased recharge of the aquifer from drought. Unfortunately, the supporting aquifer for the springs is not well defined. Recent studies (LaFave and Sharp 1987, Schuster 1997, Sharp et al. 1999) support that, although the spring is locally recharged by runoff from the Davis Mountains (resulting in the flow spikes), the "base flow" comes from a regional groundwater system. The source to the springs is likely from the aquifer of the Capitan Reef associated with the Apache Mountains, with recharge areas in the Wildhorse Flat Basin to the northwest of the Toyah Basin. Sharp et al. (1999) further proposed that the decline in flows is most likely the result of groundwater pumping in this region.

Ashworth et al. (1997) provided a cursory study to examine the cause of declining spring flows in the Toyah Basin. The conclusion from this study suggested that "recent declines in spring flows are more likely to be the result of diminished recharge due to the extended dry period rather than from groundwater pumpage" (Ashworth et al. 1997). Although it is certainly a factor, drought alone is unlikely the only reason for declines because the drought of record in the 1950s had no effect on the overall flow trend.

Exploration of Phantom Cave by cave divers has led to additional information about the nature of the spring and its supporting aquifer (pers. comm., Bill Tucker, Tucker's Dive Shop, 1999). Beyond the entrance, the cave is a substantial conduit that transports a large volume of water generally from the northwest to the southeast, consistent with regional flow pattern hypothesis. Over 8,000 feet (2,438 meters) of the cave conduit have been mapped so far. In addition, flows have been measured and are in the 25 cubic feet per second (0.71 cubic meter per second) range. The relatively small flow at Phantom Lake Spring is essentially an overflow of a larger underground flow system.

Although long term data are scarce, San Solomon Spring flows have declined somewhat over the history of record, but not as much as Phantom Lake Spring (Schuster 1997, Sharp et al. 1999). Some recent declines in overall flow have likely occurred due to drought conditions and declining aquifer levels. San Solomon Spring discharges are usually in the 25 to 30 cubic feet per second (7.08 to 0.85 cubic meters per second) range (Ashworth et al. 1997, Schuster 1997) and are consistent with the theory that the water bypassing under Phantom Lake are later discharged at the San Solomon Spring. Giffin Spring maintains a near constant 3 to 4 cubic feet per second (0.08 to 0.11 cubic meters per second) outflow (Ashworth et al. 1997). Similar water chemistry, and near constant temperatures of about 79 F (26 C), among these three springs also supports that their waters originate from the same source (Schuster 1997).

The implication is that water withdrawn from Phantom Cave could reduce the resulting flows at San Solomon and Giffin springs. Sufficient studies have not been conducted to be certain that Phantom Lake Spring is connected to other springs in the Toyah Basin, but there is some evidence suggesting this is the case. Phantom Lake is at a higher elevation than the other springs, and the outflow rates at San Solomon and Giffin springs are roughly similar to the underground discharge that has been measured by Tucker.

Water that discharges at East and West Sandia Springs is likely from a shallow groundwater source and water chemistry differences indicate it is not connected with the other Toyah Basin springs being considered. Therefore, East and West Sandia Springs are not expected to be affected by water pumped from Phantom Cave.

Populations of both Comanche Springs pupfish and Pecos gambusia occur at San Solomon Spring. The outflow from San Solomon Spring is within the Balmorhea State Park and is closely managed by TPWD for the benefit of the endangered fishes. A refuge channel was constructed within the park in the 1970s, and the San Solomon Ciénega was constructed in 1995, both to provide additional habitat for the listed species.

Giffin Spring and its outflow are privately owned, and less information is available on it. Collections in 1990 revealed the gambusia population was dominated by largespring gambusia; only one Comanche Springs pupfish was found.

One additional factor potentially affecting the listed fish at Phantom Lake Spring is the newly introduced *Melanoides* snail and associated gill parasite. This parasite has been documented in both listed fish, but the effects to the species, if any, are not yet known (pers. comm., Dr. Tom Brandt, Service, 2000).

Phantom Spring tryonia, Phantom Cave snail, and diminutive amphipod

Phantom Lake Spring is very important for the conservation and recovery of all of these invertebrate species. The Phantom Cave snail and the Phantom springsnail occur in only three spring systems and associated outflows (Phantom Lake, San Solomon, and East Sandia springs) in the Toyah Basin of Jeff Davis County and Reeves County, Texas (Taylor 1987). The snails may also occur at Giffin Spring, in the same area, but information is not available from that site. The dimunitive amphipod occurs in Phantom Lake, San Solomon, Giffin, and East Sandia springs

Phantom Lake Spring represents a significant portion of the known habitat for all three invertebrate species. The other spring systems known to be occupied are under the same threats of reduced flows as Phantom Lake Spring.

At present, captive propagation techniques have not been worked out for these species; if Phantom Lake Spring goes dry, the populations which occupy the spring these species will become extinct.

No population estimates are available for any of the invertebrate species in Phantom Lake Spring. The Service estimates, based on the best available scientific information, the populations of invertebrates within the Phantom Spring outflow are likely in the range of a few hundred to a few thousand individuals of each species.

Effects of the Action

Factors to be considered

The proposed action was conceived, is being planned, and will be constructed and operated for the benefit of the endangered fishes and candidate invertebrates and their habitat. Factors to be considered are some short term negative effects to both fish and invertebrates during the installation of the pumping system, construction of the check dam, and the potential for negative effects due to any unplanned failure of the pumping system. In addition, this Opinion will consider the potential for negative effects to other spring systems in the Toyah Basin that could potentially be affected by the withdrawal of water from Phantom Lake Cave and effects on the other candidate endemic aquatic invertebrates.

Analyses for effects of the action

<u>Beneficial Effects</u>

Beneficial effects to both species of endangered fish and the candidate invertebrates are expected by the pumping system providing surface water to the outflow of Phantom Lake Spring. This water will provide habitat for the fish and invertebrates and artificially support the environment that maintains fish and invertebrate populations. The proposed action is only planned to be a short term event, therefore, long term benefits will only be possible if this action saves the spring from complete failure and natural spring discharge returns in the future. This will only occur if future actions to conserve the supporting aquifer are undertaken by other agencies and individuals, concurrent with increases in rainfall in the region.

<u>Negative Effects</u>

Negative impacts may occur during the construction and installation of the pumping system. Given that the fish and invertebrate populations will already be under significant stress due to the limited water availability, the actions to access the cave mouth for construction of the check dam and any other facilities needed to support the pump, piping, and discharge point could impact the remaining habitat. This would be a temporary disruption of feeding behavior and territorial defense and a minor alteration of habitat. These direct effects could reach the level of “take” due to unintended harm and harassment from construction activities.

Construction equipment using gasoline, diesel fuel, motor oil, hydraulic fluids, and other possible sources of contamination may also be needed for installation of the system that would represent other possible sources of contamination. Although highly unlikely if appropriate precautions are taken, a spill of toxic substances into the water at Phantom Lake Spring could kill all the listed fish in the remaining habitat at the spring outflow and contaminate the cave and aquifer.

The Comanche Springs pupfish, Pecos gambusia, and the invertebrates may use the pool at the entrance of the cave, upstream of where the check dam is to be placed. Pupfish have been seen as far back as 100 feet (30 meters) from the cave entrance (pers. comm., Bill Tucker, Tucker's Dive Shop, May 2000), and the invertebrates may also occur there in low densities. The check dam will prevent the fish from using this area and may isolate any individuals trapped upstream of the dam when it is installed. This would be a loss of habitat for as long as the dam is in place, assuming the fish would not survive in the cave for long. This should not be a significant loss of habitat because the habitat quality in the cave is low due to lack of food and cover and low dissolved oxygen levels. Algae and other vegetation are also scarce because of low light levels. If the spring were to continue to decline in surface water elevation, this area would provide the last available water for both species if the check dam was not in place. A small amount of take could occur from placement of the check dam due to loss of habitat and isolation of individuals in the cave from the remaining population, likely resulting in death of those individuals.

The pumping system will be closely monitored to ensure its effective operation for as long as the project is viable. The backup system will be inspected and tested periodically to ensure it is working properly. Even under the best system, a potential exists for the system to fail due to a power outage, mechanical pump failure, break or clog in the pipe, or some other unplanned event. If the system fails and is not corrected in time, the spring outflow would decline rapidly, stranding fish in isolated pools in the refuge channel. If undetected for a longer time period, pump failure could result in the entire spring outflow drying up, including the isolated pools and the pool at the cave mouth. The loss of the endangered species habitat at Phantom Lake Spring would be significant to both species; although this would not result in immediate extinction, as both species occur in other locations in the wild and in captive populations. However, this would represent substantial habitat loss and reduce the unique Phantom Lake Spring genetic diversity to what is currently held in captive populations, and would significantly reduce the likely survival and recovery of both species.

Even under this "worst case scenario" the habitat would only revert to its current condition and, therefore, the effects are not attributable to the proposed action by the Service. If completely lost, attempts to reestablish fish populations at Phantom Lake Spring could be made using captive stocks, if flows were to return in the future, and assuming stocks in captivity survive and do not represent significant genetic bottlenecking. However, complete drying of the spring would significantly impact the overall plant and invertebrate community that, in addition to their inherent value for biodiversity, provide the food and cover for the fishes. Some of these critical ecosystem components could return with the water after some time, but some aquatic endemic species, such as amphipods and spring snails could be extinct and not recoverable. Since there are no captive stocks of the candidate invertebrates, the only option to restore them, would be to collect individuals from other springs where they occur and place them in Phantom Lake Spring. This action would not retain the possibly unique genetic make up of the Phantom populations.

The potential for reduction of flows at San Solomon Spring exists from the withdrawal of water from Phantom Cave. Since all water pumped from Phantom Cave will be returned to the cave, it is highly unlikely that flows will be reduced. The only water from the aquifer system will be from evaporation from the refuge canal. This very small amount of water has discountable effects on the water available to the other springs.

The long term stability of the hydrograph from Giffin Spring (Ashworth et al. 1997) would suggest that the water used at Phantom Lake Spring would not affect flows from Giffin Spring and therefore, have no effect on the listed fishes or their habitat. Flow will continue to be monitored by USGS and any noticeable declines would warrant additional monitoring at Giffin Spring.

Species' response to the proposed action

Both listed species and the candidate and proposed candidate invertebrates are expected to exhibit a positive response to the proposed action. Without the proposed action, the habitat is expected to be completely lost in the immediate future (within 30 to 60 days without rainfall) and the species will be extirpated from Phantom Lake Spring. The potential short term negative impacts are relatively minor from the construction activities and the likelihood of a contaminant spill is small. There are, however, inherent risks in artificially maintaining an aquatic habitat through pumping. Equipment malfunction and power outage are possible and could result in total habitat loss in the spring outflow, however, this loss would ultimately be caused by groundwater declines, not the failure of the pumping system, and in this case the benefits outweigh the risks. However, because both listed, candidate, and nonlisted species are in a precarious situation due to the loss of spring flow, special care and all attempts should be made to minimize risks of negative effects as much as possible.

Cumulative Effects

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this Opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act.

Without significant changes in groundwater use in the region, the Service anticipates that the practice of unregulated groundwater pumping by private entities will continue. Unless conservation practices are implemented, the loss of spring flow will likely persist at Phantom Lake Spring and, eventually, at other springs in the Toyah Basin as well. The Service is committed to working with other Federal, State, and local agencies and private groups to make changes in groundwater use practices to attempt to sustain natural spring flows. Additional information on the supporting aquifer is critically needed if future groundwater conservation is to be achieved.

CONCLUSION

After reviewing the current status of Comanche Springs pupfish and Pecos gambusia, the environmental baseline for the action area, the effects of the proposed emergency pumping system, and the cumulative effects, it is the Service's biological opinion that the action as proposed, is not likely to jeopardize the Comanche Springs pupfish and Pecos gambusia. No critical habitat has been designated for either of these species, therefore, none will be affected. The action is also not likely to jeopardize the continued existence of Phantom Spring tryonia, Phantom Cave snail, and diminutive amphipod.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The measures described below are non-discretionary, and must be undertaken by FA for the exemption in section 7(o)(2) to apply. FA has a continuing duty to regulate the activity covered by this incidental take statement. If FA fails to assume and implement the terms and conditions the protective coverage of section 7(o)(2) may lapse. To monitor the impact of incidental take, FA must report the progress of the action and its impact on the species to the Austin Office as specified in the incidental take statement.

Amount or Extent of Take Anticipated

The Service anticipates some take of Comanche Springs pupfish, Pecos gambusia, Phantom Spring tryonia, Phantom Cave snail, and diminutive amphipod in the Phantom Cave pool in the form of harassment during construction activities and harm from temporary disturbance of habitat from construction of the check dam and pumping facilities.

An estimated 400 square feet (37.2 square meters) of habitat will be disturbed for placement of the check dam and piping system. Although no population sizes of densities are available for the listed or candidate species that occur in Phantom Lake Spring. , we based our estimates on observations during multiple site visits. In the case of the candidate invertebrates, density estimates were only available for the diminutive amphipod. In the absence of information about the other candidates, we used the diminutive amphipod estimates for the other species. Estimated populations in Phantom Lake Spring are 50 Comanche Springs pupfish; 100 Pecos gambusia; 1,000 Phantom Spring tryonia; 5,000 Phantom cave snail; and 5,000 diminutive amphipod (pers. comm., Nathan Allan, Service, 2003). Based on these estimates, this harassment and harm would likely affect less than 50 Comanche Springs pupfish and less than 100 gambusia. Estimated numbers of individual invertebrates likely to be taken are less than 5,000 Phantom cave snail, 5,000 diminutive amphipod, and 1,000 Phantom Spring tryonia. Habitat disturbance would be mainly in the cave mouth from construction of the check dam and should affect no more than 400 square feet (37.2 square meters) of habitat.

Some minor incidental take could occur during project construction in the form of unintended harassment, if it became necessary to collect and move endangered fish for temporary holding. The need for this is action is unknown, however, it is likely involve less than 50 individuals of either species.

Effect of the take

In the accompanying biological opinion, the Service determined that the anticipated level of take attributable to FA's proposed action is <u>not</u> likely to result in jeopardy to the Comanche Springs pupfish, Pecos gambusia, Phantom Spring tryonia, Phantom Cave snail, or diminutive amphipod. Although the level of take could be substantial in the event of pump failure, the environmental baseline (status of the species without the proposed action) is certain to result in as much or more habitat loss and species impacts. It is the Service's opinion that the complete failure of the spring and resulting take of listed species is more likely to occur without the proposed action, and that the proposed action lessens the chance of this take.

<u>Reasonable and Prudent Measures</u>

The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize impacts of incidental take of Comanche Springs pupfish and Pecos gambusia, Phantom Spring tryonia, Phantom Cave snail, and diminutive amphipod:

1. Minimize the effects of disturbance of sediment and dam construction.

2. Minimize effects of pollutants.

<u>Terms and conditions</u>

1.

a. Implement all construction phases of the installation of the pipeline, pump, check dam, pad, building, and propane tank using methods to minimize the disturbance of the sediments and banks of the Phantom Cave pool and minimize the area to be disturbed.
b. After or during construction of the check dam, if feasible, move fish from upstream of the check dam to downstream of the check dam.

2.

a. Construct the pumping system so as to minimize any potential for pollutants to enter the water. Any refueling activities should occur downstream from the refuge channel and away from the water to avoid contamination.
b. No pollutants should be handled immediately over spring water. The portable pumps and generators used during construction will be placed in plastic lined, bermed depressions to prevent the loss of any potential pollutants. An emergency spill kit (personnel instructed in its use) should be on site to allow for an immediate response to any spill. The permanent generator will be placed in an impervious pit to prevent any potential pollutants from reaching the spring
c. Store any fuel or other contaminants and equipment that could pollute the water away from the springs or any source to the aquifer.

The Service believes that incidental take of Comanche Springs pupfish, Pecos gambusia, Phantom Spring tryonia, Phantom Cave snail, and diminutive amphipod habitat at Phantom Lake Spring will only occur from construction activities, check dam placement, and accidental spill of pollutants as a result of the proposed action. The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, incidental take exceeds that outlined in the Incidental Take Statement, or occurs for reasons other than those considered in this biological opinion, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided, FA must immediately provide an explanation of the causes of the taking and review with the Austin Office the need for possible modification of the reasonable and prudent measures.

Conservation Recommendations

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. FA should assist in determining the status and habitat needs of the aquatic invertebrate community of Phantom Lake Spring and cave.

2. FA should develop a specific monitoring plan for determining the effects of the action on the aquatic invertebrate community at Phantom Lake Spring.

3. FA should establish and implement long term monitoring of the aquatic invertebrate community of Phantom Lake Spring and Cave.

4. FA should install water temperature data recorders in the outflow of Phantom Lake to monitor water temperatures and establish a flow-temperature relationship to fish populations.

For the Service to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the Austin Office requests notification of the implementation of any conservation recommendations.

Reinitiation Notice

This concludes formal consultation on the action outlined in the request. As provided in 50 CFR § 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending re-initiation.

Thank you for proposing this action for the benefit of listed species. The Austin Office appreciates your willingness to plan and fund this project, and we look forward to working with you to successfully implement the pumping system. Please contact Nathan Allan at 512-490-0057, extension 237, for additional coordination on the project.

cc: Nick Carter, Texas Parks and Wildlife Department
Gary Dean, Bureau of Reclamation
John Karges, The Nature Conservancy

Literature Cited

Allan, N. L. 2000. Deterioration of Phantom Lake Spring, Jeff Davis County, Texas. Proceedings of the Desert Fishes Council 32:50-51.

Ashworth, J.B., D.B. Coker, and W. Tschirhart. 1997. Evaluation of diminished spring flows in the Toyah Creek Valley, Texas. Open File Report 97-03. Texas Water Development Board, Austin, Texas. 12pp.

Baird, S. F. and C. Girard. 1853. Descriptions of new species of fishes collected by Mr. John H. Clark, on the U. S. and Mexican Boundary Survey, under Lt. Col. Jas. D. Graham. Proc. Acad. Nat. Sci. Philadelphia 6:387-390.

Bednarz, J. 1975. A study of the Pecos gambusia. Endangered Species Program, New Mexico Dept. Game and Fish, Santa Fe, New Mexico.

Bednarz, J. 1979. Ecology and status of the Pecos gambusia, *Gambusia nobilis* (Poeciliidae), in New Mexico. The Southwestern Naturalist 24:311-322.

Bousfield, E. L. 1958. Fresh-water amphipod crustaceans of glaciated North America. The Canadian Field-Naturalist 72:55-113.

Bogener, S. 1993. Balmorhea Project (Second Draft). Research on Historic Reclamation Projects, U.S. Bureau of Reclamation History Program, Denver, Colorado. Accessed November 2003 online at http://www.usbr.gov/dataweb/html/balmorhe.html.

Bowman, T.E. 1981. *Thermosphaeroma milleri* and *T. smithi*, new sphaeromatid isopod crustaceans from hot springs in Chihuahua, Mexico, with a review of the genus. Journal of Crustacean Biology 1:105-122.

Brown, K. M. 1991. Mollusca: gastropoda. Pages 285-314 in J.H. Thorp and A.P. Covich, Eds. Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc. San Diego, California. 940 pp.

Brune, G. 1981. Springs of Texas. Vol. 1. Branch-Smith, Inc., Fort Worth, Texas.

Callicott, J. B. 1994. A brief history of American conservation philosophy. Pages 10-14, *in* Wallace W. Covington and Leonard F. DeBano, eds. Biodiversity and management of the Madrean Archipelago: the sky islands of southwestern United States and northwestern Mexico. U. S. Forest Service, Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-GTR-264.

Cole, G. A. and E. L. Bousfield. 1970. A new freshwater Gammarus (Crustacea: Amphipoda) from western Texas. American Midland Naturalist 83:89-95.

Cole, G. A. 1976. A new amphipod crustacean, *Gammarus hyalelloides* n. sp., from Texas. Transactions of the American Microscopical Society 89:80-85

Cole, G.A. 1985. Analysis of the Gammarus-pecos complex (Crustacea:Amphipoda) in Texas and New Mexico, U.S.A. Journal of the Arizona-Nevada Academy of Science 20(2):93-103.

Cokendolpher, J. 1978. *Cyprinodon elegans* (Cyprinodontidae). American Currents, Jan - March 1978:6-11.

Covich, A. P. and J. H. Thorp. 1991. Crustacea: introduction and Peracarida. Pages 665-689, *in* J. H. Thorp and A. P. Covich, eds. Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc., San Diego, California.

Davis, J. R. 1979. Die-offs of an endangered pupfish, *Cyprinodon elegans* (Cyprinodontidae). The Southwestern Naturalist. 24:534-536.

Dundee, D. and H. Dundee. 1969. Notes concerning two Texas molluscs, *Cochliopa texana* Pilsbry and *Lyrodes cheatumi* Pilsbry (Mollusca: Hydrobiidae). Transactions of the American Microscipical Society 88 (2):205-210.

Echelle, A. A. 1975. A multivariate analysis of variation in an endangered fish, *Cyprinodon elegans*, with an assessment of populational status. Texas Journal of Science. 26:529-538.

Echelle, A. A. and C. Hubbs. 1978. Haven for endangered pupfish. Texas Parks and Wildlife Magazine, June:9-11.

Echelle, A.A. and A.F. Echelle. 1980. Status of the Pecos gambusia (Gambusia nobilis). Endangered Species Report No. 10. USFWS. 73pp.

Echelle, A.A., A.F. Echelle, and D.R. Edds. 1987. Population structure of four pupfish species (Cyprinodontidae: *Cyprinodon*) from the Chihuahuan desert region of New Mexico and Texas: allozymic variation. Copeia 1987(3):668-681.

Echelle, A.F. and A.A. Echelle. 1994. Assessment of genetic introgression between two pupfish species, *Cyprinodon elegans* and *C. variegatus* (Cyprinodontidae), after more than 20 years of secondary contact. Copeia 1994:590-597.

Echelle, A.F. and A.A. Echelle. 2002. Genetic status of the captive stock of *Cyprinodon elegans* at Uvalde National Fish Hatchery. Report to U.S. Fish and Wildlife Service. 11 pp.

Echelle, A.A., A.F. Echelle, S. Contreras Balderas, and Ma. De L. Lozano Vilano. 2003. Pupfishes of the northern Chihuahuan Desert: status and conservation. *In*, G.P. Garrett and N.L. Allan, eds. Aquatic fauna of the northern Chihuahuan Desert. Museum of Texas Tech University, Special Publications 46:11-126.

Garrett, G.P. and A.H. Price. 1993. Comanche Springs pupfish (*Cyprinodon elegans*) status survey. Texas Parks and Wildlife Department, Section 6 Final Report. Project No. E-1-4. Job No. 2.1. 20 pp.

Garrett, G.P. 2003. Innovative approaches to recover endangered species. *In*, G.P. Garrett and N.L. Allan, eds. Aquatic fauna of the northern Chihuahuan Desert. Museum of Texas Tech University, Special Publications 46:151-160.

Gehlbach, F. R., C. L. Bryan and H. W. Reno. 1978. Thermal ecological features of *Cyprinodon elegans* and *Gambusia nobilis*, endangered Texas fishes. Texas Journal of Science 30:99-101.

Gervasio, V., D. J. Berg, B. K. Lang, N. L. Allan, and S.I. Guttman. 2004. Genetic diversity in the *Gammarus pecos* species complex: implications for conservation and regional biogeography in the Chihuahuan Desert. Limnology and Oceanography 49:520-531.

Hershler, R., and F.G. Thompson. 1992. A review of the aquatic gastropod family Cochliopinae (Prosobranchia: Hydrobiidae). Malacological Review Supplement 5:1-140.

Hershler, R., Hsiu-Ping Liu, and M. Mulvey. 1999. Phylogenetic relationships within the aquatic snail genus *Tryonia*: implications for biogeography of the North American Southwest. Molecular Phylogenetics and Evolution 13:377-391.

Hershler, R. 2001. Systematics of the North and Central American aquatic snail genus *Tryonia* (Rissooidea: Hydrobiidae). Smithsonian Contributions to Zoology 612. 53 pp.

Holsinger, J.R. 1976. The freshwater amphipod crustaceans (Gamaridae) of North America. Water Pollution Control Series 18050 ELD04/72 (second printing). 89 pp.

Hubbs, C. and V. G. Springer. 1957. A revision of the *Gambusia nobilis* species group, with descriptions of three new species, and notes on their variation, ecology, and evolution. Texas Journal of Science 9:279-327.

Hubbs, C., T. Lucier, E. Marsh, G. P. Garrett, R. J. Edwards and E. Milstead. 1978. Results of an

eradication program on the ecological relationships of fishes in Leon Creek, Texas. The Southwestern Naturalist 23:487-496.
Hubbs, C., A. F. Echelle and G. Divine. 1995. Habitat partitioning by two congeners (*Gambusia geiseri* and *Gambusia nobilis*) at Balmorhea State Park. Texas Journal of Science 47:325-326.
Hubbs, C. 1996. Geographic variation of *Gambusia* life history traits. Proceedings of the Desert Fishes Council 27:1-21.
Hubbs, C. and J. Karges. 1999. Additional data on habitat segregation between *Gambusia* spp. Texas Journal of Science 51:339-341.
Hubbs, C. 2001. Environmental correlates to the abundance of spring-adapted versus stream-adapted fishes. Texas Journal of Science 53:299-326.
Hubbs, C. 2003. Spring-endemic *Gambusia* of the Chihuahuan Desert. 2003. *In*, G.P. Garrett and N.L. Allan, eds. Aquatic fauna of the northern Chihuahuan Desert. Museum of Texas Tech University, Special Publications 46:127-134.
Itzkowitz, M. 1969. Observations on the breeding behavior of *Cyprinodon elegans* in swift water. Texas Journal of Science 21:229-231.
Koster, W. J. 1957. Guide to the Fishes of New Mexico. Univ. of New Mexico Press, Albuquerque, New Mexico.
Lackey, R. T. 1995. Ecosystem health, biological diversity, and sustainable development: research that makes a difference. Renewable Resources Journal, Summer 1995:8-13.
LaFave, J.I. and J.M. Sharp. 1987. Origins of groundwater discharging at the Springs of Balmorhea. West Texas Geological Society Bulletin 26:5-14.
Lang, B. K., V. Gervasio, D. J. Berg, S. I. Guttman, N. L. Allan, M. E. Gordon, and G. Warrick. 2003. Gammarid amphipods of northern Chihuahuan Desert spring systems: an imperiled fauna. Pages 47-57, *in* Aquatic Fauna of the Northern Chihuahuan Desert, G. P. Garrett and N. L. Allan, eds. Museum of Texas Tech University. Special Publications 46.
McDermott, K. 2000. Distribution and infection relationships of an undescribed digenetic Trematode, its exotic intermediate host, and endangered fishes in springs of west Texas. Unpublished Master=s Thesis, Southwest Texas State University, San Marcos, Texas. 26+ pp.
Metcalf, A.L. and R.A. Smartt. 1997. Land snails of New Mexico. New Mexico Museum of Natural History and Science. Bulletin No. 10. 145 pp.
Pennak, R. W. 1989. Fresh-water invertebrates of the United States: Protozoa to Mollusca. John Wiley & Sons, Inc.
Pilsbry, H.A. 1935. Western and southwestern Amnicolidae and a new *Humboldtiana*. Nautilus 48:91-94.
Reeves County Water Improvement District #1 (RCWID#1). 2001. Balmorhea Project, water management and conservation plan, drought contingency plan. January 2001, Balmorhea, Texas.
Schuster, S.K. 1997. Hydrogeology and local recharge analysis in the Toyah Basin Aquifer. Masters Thesis, Geological Sciences, University of Texas at Austin. 130 pp.
Sharp, J.M., Uliana, M.M., and R. Boghici. 1999. Fracture controls on regional groundwater flow in a semiarid environment and implications for long-term maintenance of spring flows. Water 99 Joint Congress, Inst. of Engineers. Australia, Brisbane. v. 2, p.1212-1217.

Stevenson, M. M. and T. M. Buchanan. 1973. An analysis of hybridization between the cyprinodont fishes *Cyprinodon variegatus* and *C. elegans*. Copeia 1973:682-692.

Taylor, D.W. 1987. Fresh-water molluscs from New Mexico and vicinity. Bulletin 116, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico. 50 pp.

U.S. Fish and Wildlife Service. 1981. Comanche Springs pupfish recovery plan. Albuquerque, New Mexico. 24 pp.

U.S. Fish and Wildlife Service. 1983. Pecos gambusia recovery plan. Albuquerque, New Mexico. 41 pp.

Young, D.A., K.J. Fritz, G.P. Garrett, and C. Hubbs. 1993. Status review of construction, native species introductions, and operation of an endangered species refugium channel, Phantom Lake Spring, Texas. Proceedings of the Desert Fishes Council 25:22-25.

Winemiller, K.O. and A.A. Anderson. 1997. Response of endangered desert fish populations to a constructed refuge. Restoration Ecology 5:204-213.