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Mexican blindcats genus *Prietella* (Siluriformes: Ictaluridae): an overview of recent explorations

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Synopsis

The ictalurid genus *Prietella* was described from a single locality in northern México (Coahuila) in 1954, and until very recently went largely unstudied. Cave explorers have recently uncovered new localities and a second species much farther to the south (México: Tamaulipas). Our team visited over 50 sites, including all of the previously known sites possible, and explored many new sites, expanding the known range of *Prietella* and describing their habitat. We identified geological units and mapped caves, identified associated troglobitic invertebrates, estimated population sizes and measured water chemistry parameters. We also comment on laboratory diet, parasites, sensory biology, behavior (such as jaw locking and periods of inactivity), reproduction and systematics based on preliminary genetic data. *Prietella phreatophila* is listed as endangered, and due to the recent discovery of many more sites (formerly documented from three localities, now known from twelve sites, though some are hydrologically connected) we recommend threatened status, with careful attention to growing threats such as over pumping and contamination of the aquifer it lives in. Should these patterns continue unchecked, re-listing this species as endangered may be called for. *Prietella lundbergi* was also described from one site but is now known from two, though it is quite rare at both (only five specimens have ever been seen). *P. lundbergi* was described after the most recent revision of the Mexican endangered species list and should probably be considered as endangered.

Introduction

Twenty-three of the 85 known hypogean fishes are catfishes. Thus 0.96% of siluriforms are hypogean, a proportion surpassed at the ordinal level only by cypriniformes with 1.28% hypogean (based on Nelson 1994, Axel et al. 1999, and G. Proudlove personal communication). Among the eight catfish families with hypogean species, the exclusively North American Ictaluridae have an especially high proportion of hypogean representatives, with 3 (37.5%) of its eight genera and four (8%) of its 50 or so species being exclusively hypogean (Lundberg 1992). The four stygobitic ictalurids, *Prietella lundbergi*, *P. phreatophila*, *Satan eurystomus*, and *Trogloglanis pattersoni*, all live in North America's largest karst region (Carillo-Bravo 1971, Smith & Veni 1994, Fish 1977, Walsh 2000, Culver et al. 2000), the Cretaceous limestones surrounding the northwestern Gulf of México.

The distribution of *Prietella* now is known to extend from the very northern part of the state of Coahuila, México, very near the international boundary, to southernmost Tamaulipas, 750 km away to the southeast. In the 600 km between *P. lundbergi* and the closest populations of *P. phreatophila* at Múzquiz, Coahuila, are substantial mountain ranges, making hydrologic connections between the ranges of the two species, even ancient ones, seemingly quite improbable, and posing interesting questions about the biogeography and evolutionary history of the genus.

Across this great area, blindcat localities lie alongside and within the edges of the Sierra Madre Oriental, known for its deep, active, and extensive karst systems (e.g. Russell & Raines 1967, Lesser & Lesser 1988). Though much of the surface is desert, caves harboring *P. lundbergi* are surrounded by mesic, semi-tropical vegetation. Throughout the region, considerable portions of many drainages are subterranean, forming sinkholes, pits, cave passages, and springs that resurge along the bases of the mountains, and the entire region, including the karst of adjacent Texas, is well known for its rich subterranean fauna (Culver et al. 2000).

None of the hypogean ictalurids are well studied, but our recent explorations and laboratory observations provide new insights into ecology, biology and biogeography of the genus *Prietella*, and we are optimistic that our studies might shed light on regional hydrologic relationships among aquifers, something which is very little understood in this region. We review previous studies and collections of this genus, and relate our own explorations and collections, which have added nine new sites to the formerly documented three for *P. phreatophila* and one more to the range of *P. lundbergi*, previously known from only a single specimen. We also provide a general discussion of our laboratory observations and conclude with a discussion of the conservation status of the two species in this genus.

Previous collections

Prietella phreatophila was described by Carranza in 1954, based on collections made in the same year at El Potrero de Doña Mariana, near Múzquiz, Coahuila. His specimens all came from this single spring cave locality, though he reported that locals advised that the species occurred elsewhere in the immediate area. The type series consisted of sixty-six specimens, of which Carranza (1954) indicated that eighteen were deposited as paratypes in major collections, three each to IPN, BMNH, MNHN, USNM, UMMZ, and Stanford (now CAS) (Museum symbolic codes follow Leviton et al. 1985 and Leviton & Gibbs 1988). Forty-six specimens, including the holotype, were indicated to have been kept in his personal collection, and two were given to co-collector, C. Bolivar. Our inquiries verified that all paratypes except those at BMNH and MNHN are extant, and it would appear that specimens perhaps intended for the two European collections were later given instead to Tulane [TU 10810, three specimens and TU (OC) 178, one skeleton] (Bart & Taylor 1993) and Universidad Autónoma de Nuevo León (UANL 1014, three specimens). Carranza later deposited what he referred to as the remaining eleven specimens (paratypes) in his possession, plus the holotype, at the Instituto Biológico of the Universidad Nacional Autónoma de México (IBUNAM-P 97, six paratypes; IBUNAM-P 8833 holotype) (H. Espinosa personal communication, IBUNAM, 1995) and UMMZ (223109, five paratypes).

Subsequent collections of specimens from the type locality were made in 1961 (TU 43872, 43879, 84464), 1969 (UMMZ 187684), 1984 (UANL uncatalogued), and 1989 (UANL 9009 (from 'near Múzquiz'). In 1984, local residents' contention that the species also could be found at El Socavón, 5.15 km west of the plaza in Melchor Múzquiz, was confirmed by the capture of a single specimen (TCWC 5144.01) (Amemiya et al. 1986).

The distribution of the species was extended further north with the 1986 collection of a single specimen (TNHC 12100) from 48 km NW of Múzquiz, and a 1992 collection of nine specimens (IBUNAM 7557) from Sótano de Amezcua, about 180 km N of Múzquiz and 50 km W of Ciudad Acuña, Coahuila, just across the Río Grande from Del Río, Texas. It was these specimens, delivered live to the first author, which initiated our studies. A specimen at UANL documenting an eastern extension of the range, to near the town of Morelos, Coahuila, about 80 km NE of Múzquiz, was apparently lost (S. Contreras-Balderas personal communication).

As the known distribution of *P. phreatophila* was being extended to the north, a second species of the genus was being analyzed following the 1989 collection of a single specimen far to the south by a recreational cave diver, Tom Morris. Based on this, the only specimen available, Walsh and Gilbert (1995) described *P. lundbergi* from the small spring cave at San Rafael de los Castro, 15 km WNW of Ciudad Mante, Tamaulipas.

The fact that *P. lundbergi* had not been reported before was somewhat surprising. The area had been very thoroughly explored for cave fishes for years by the many biologists and cavers studying what has become probably the most studied cave fish in the world, *Astyanax fasciatus*, in the plethora of caves in Tamaulipas (e.g. Mitchell & Elliott 1977). Caves with populations of blind *Astyanax* are located within 20 km to both north and south of San Rafael de los Castro (Mitchell & Elliott 1977, Borowsky 1996). Additionally, cave divers seeking SCUBA depth records have spent probably hundreds of man hours in a large, hydrologically and morphologically very similar spring, Nacimiento del Río Mante, only 8 km south of San Rafael de los Castro, and thoroughly explored other promising cave dives in the area (Exley 1979), without ever reporting blindcats.

Recent explorations

Since 1993, working with a variable, but always highly trained team of cave explorers and cave divers, we have searched for *Prietella* and associated stygobitic invertebrates throughout the known, and what we believe to be the potential, range of the genus in Tamaulipas, Nuevo León and Coahuila, México, as well as in the adjacent south Texas border area, United States. All localities explored by our team are listed in Table 1.

The first author first collected *Prietella phreatophila* at Sótano de Amezcua in 1993, about one year after the species was discovered there by cavers from Austin, Texas, who brought live specimens to him. About the same time, news of discovery of *P. lundbergi* reached us, and the first author took cave divers to the type locality for this species in April 1994. Two divers spent approximately two hours in the cave, penetrating an estimated 213 m horizontally and 40 m maximum depth, collecting invertebrates, but observing no cave fishes. On the same expedition, divers also explored the previously little-explored large submerged caves of San Felipe springs in Del Rio, Texas (locally rumored to have blind fishes and not far from Sótano de Amezcua) and the Nacimiento del Rio Sabinas, not too far north of the known distribution of *P. lundbergi*, failing to find cave fishes at both sites. This expedition met with misfortune in the form of a nearly disastrous vehicle accident, forcing us to abandon additional collection plans extending throughout much of Coahuila.

In 1996, the third author, a geohydrologist previously well acquainted with regional aquifers and springs, having conducted water supply and well surveys throughout the region for many years, spent a total of about two weeks on several trips with the first author, searching for potential blindcat habitats in Coahuila and Nuevo León. In the same year, the first author made several additional trips with the same objectives, either alone or with small crews. All trips focused on mapped springs, caves and sinks and surrounding areas and relied heavily on interviews with local residents. Several potential new localities requiring vertical descents and SCUBA were located during these surveys, and landowner permissions were obtained in preparation for a major expedition in 1997, which included participation of crews specifically trained in both vertical cave exploration and cave diving. Since then, the authors and collaborating cave divers and cavers have continued to make occasional, shorter (3–5 day) exploration of selected areas of southern Texas, northern Coahuila, Nuevo León and Tamaulipas. Results of all of these expeditions are discussed, site by site, below.

Methods

Methods used to explore and sample subterranean habitats in the range of *Prietella* are often extremely technical and require special training in vertical cave exploration techniques and cave diving (Padgett & Smith 1987, Prosser & Grey 1992). All collecting was by hand using a small plastic vial during a dive, or by dipnets deployed from banks. Water chemistry data were taken by a Hydrolab Data Sonde 3 Multiprobe Logger. Cave mapping was done using standard techniques (Dasher 1994).

In order to facilitate a broad range of research, specimens were taken alive to the laboratory, frozen in the field in liquid nitrogen, or preserved in 10% buffered formalin or 95% ethanol. All fish specimens collected by us are catalogued and housed in the Texas Natural History Collection (TNHC) of the Texas Memorial Museum at the University of Texas at Austin,[1] though part of our collections will be transferred in the near future to Mexican collections.

Unless otherwise noted, each site was visited by our team only a single time. Three sites are considered here as proven *P. phreatophila* localities though museum specimens do not exist. We do this on the basis of extremely convincing accounts of presence of blindcats as related to us by local residents who have perfectly described the species. Additionally, their reports of occasional sightings of blindcats after floods are congruent with our expectations that they occasionally are pushed out of their deeper, more inaccessible habitat during extreme spates.

[1] (http://www.utexas.edu/depts/tnhc/)

Table 1. List of localities with word descriptions. The numbers correspond to Figure 1, and the site names correspond to descriptions in text. Italicized sites are documented blindcat sites (asterisks indicate no museum specimens are available, as they have only been reported from these sites – see text in Methods section for explanation). Abbreviations: Cd. = Ciudad; Co. = County; Coah. = Coahuila; Mex. = México; Tamps. = Tamaulipas; Tx. = Texas. When descriptions of localities are within 15 km of a town, the distance is given from the center of the town.

1.	Dandridge Spring and Richter Cave	40 km SW Sonora, Sutton Co., Tx.
2.	Devil's Sinkhole	10 km NE Rocksprings, Edwards Co., Tx.
3.	Big Tree Cave and Emerald Sink	5 km NNE Langtry, Val Verde Co., Tx.
4.	Emilio's Cavern	Comstock, Val Verde Co., Tx.
5.	Goodenough Springs	38 km NW of Del Rio, Val Verde Co., Tx.
6.	San Felipe Springs	Del Rio, Val Verde Co., Tx.
7.	*Sótano de Amezcua* and La Rajada	40 km W of Ciudad Acuña, Coah., Mex.
8.	*Noria de San Pedro**	32 km WSW of Santa Eulalia, Coah., Mex.
9.	La Vinata Well	18 km SW of Santa Eulalia, Coah., Mex.
10.	Cueva de Rancho Las Pilas	90 km SW of Ciudad Acuña, Coah., Mex.
11.	El Abra and Tinaja Azul	75 km W of Piedras Negras, Coah., Mex.
12.	*Ojo del Yermo*	60 km N of Melchor Múzquiz, Coah., Mex.
13.	Poza San Miguel	35 km NW of Allende, Coah., Mex.
14.	*El Consuelo**	16 km NW of Allende, Coah., Mex.
15.	*La Tembladora**	5 km SW of Allende, Coah., Mex.
16.	Nacimiento Kikapoo and Falcón well	33 km NW of Melchor Múzquiz, Coah., Mex.
17.	*Cueva de Juana*	22 km W of Melchor Múzquiz, Coah., Mex.
18.	*El Socavón area: El Socavón, above El Socavón 1 and 2, El Cedral*	5 km SW of Melchor Múzquiz, Coah., Mex.
19.	*El Potrero area: 1 and 2*, Tiro Palmito, and vertical mine shaft near El Potrero	8 km SE of Melchor Múzquiz, Coah., Mex.
20.	Cueva Cabrito	9 km WSW of Estación Obayos, Coah., Mex.
21.	Cueva La Zumbadora	4 km NW of La Madrid, Coah., Mex.
22.	Cueva El Venado	El Venado, 22 km SE of Cuatro Ciénegas, Coah., Mex.
23.	Mojarral East and West, La Campana	15 km SSE of Cuatro Ciénegas, Coah., Mex.
24.	Gruta de Carrizal	Candela, Coah., Mex.
25.	Cueva de El Tule and Cueva de la Espantosa	Lampazos, Nuevo Leon, Mex.
26.	El Ebanito	15 km SW of Linares, Nuevo León, Mex.
27.	Purificacion area Caves	30 km NW of Cd. Victoria, Nuevo León and Tamps., Mex.
28.	El Sótano	3 km ENE of El Carrizo, Tamps., Mex.
29.	Ojo Encantado	30 km W of Cd. Victoria, Tamps., Mex.
30.	Manantial La Penita and Cueva del Manantial La Penita	5 km W of Cd. Victoria, Tamps., Mex.
31.	Guayalejo Spring	Juamave, Tamps., Mex.
32.	*Cueva del Nacimiento del Río Frío* and Nacimiento del Río Frío	32 km NW of Cd. Mante, Tamps, Mex.
33.	Springs near San Rafael de los Castro	San Rafael de los Castro, Tamps., Mex.
34.	*Manantial de San Rafael de los Castro* and Cueva del Manantial de San Rafael de los Castro	11.5 km W of Cd. Mante, Tamps., Mex.

Descriptions of *Prietella* habitats

Locations of wells, springs, caves, and mines we have explored are mapped in Figure 1 and listed in Table 1. Access varies from extremely remote and requiring pack animals and/or long hikes on foot over rugged terrain, and often technical vertical ascent and descent techniques as well as cave diving, to others to which one can easily drive within meters and simply walk in. Site descriptions begin with passage configuration and geological information, then continue with a habitat and biota section that describes exactly where at each site blindcats were found, including microhabitat and biotic associations. Water chemistry parameters are given when available.

Sites listed in Table 1 are only those visited by our team. Many neighboring sites harboring aquatic cave organisms, including habitats of the best-studied

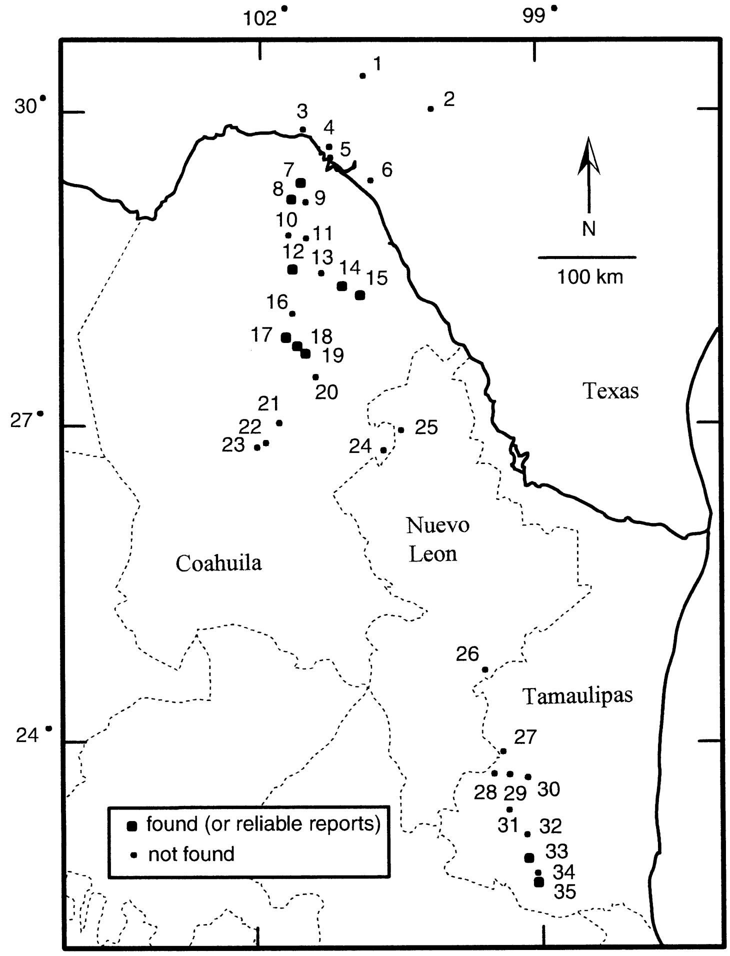

Figure 1. Map of south Texas and Northeastern México showing *Prietella* localities, also summarized in Table 1.

cave fish, *Astyanax fasciatus* (Mitchell et al. 1977), have been thoroughly collected by others, but *Prietella* was not reported. It is likely that most of these other aquatic cave sites are not blindcat sites, since presumably a biologist collecting a stygobitic crustacean or *Astyanax* would also report blindcats if seen or taken. We have not included any of these sites as 'negatives', however, since in our experience for at least some sites, specimens were not at the surface and collections required cave diving. Few caves in the range of *Prietella* have been explored by divers.

While the configuration and genesis of each site is variable, habitats of the blindcats share many characteristics. Most specimens were taken well into the dark zone, in habitats that likely have relatively little short-term fluctuation in environmental parameters. For the most part blindcats are found in still pools; they have never been seen in shallow running water, but are sometimes in high-flow systems such as El Socavón. Often they are associated with a silt substrate, but this may be simply a correlate of preference for still water. All documented blindcat localities are at relatively low elevations as compared to surrounding, and often adjacent mountain ranges. Careful observations made in the Sistema Purificación area, and in higher altitude areas of Coahuila (e.g. Cueva la Zumbadora) failed to find them. Water chemistry ranges we measured in waters occupied by blindcats sites are: temperature $= 21 - 31.5°C$, $pH = 7.45 - 7.9$, dissolved oxygen $= 0.75 - 5.4\,mg\,l^{-1}$, specific conductivity $= 0.425 - 0.75\,mS\,cm^{-1}$, redox potential $= 335 - 362\,mV$.

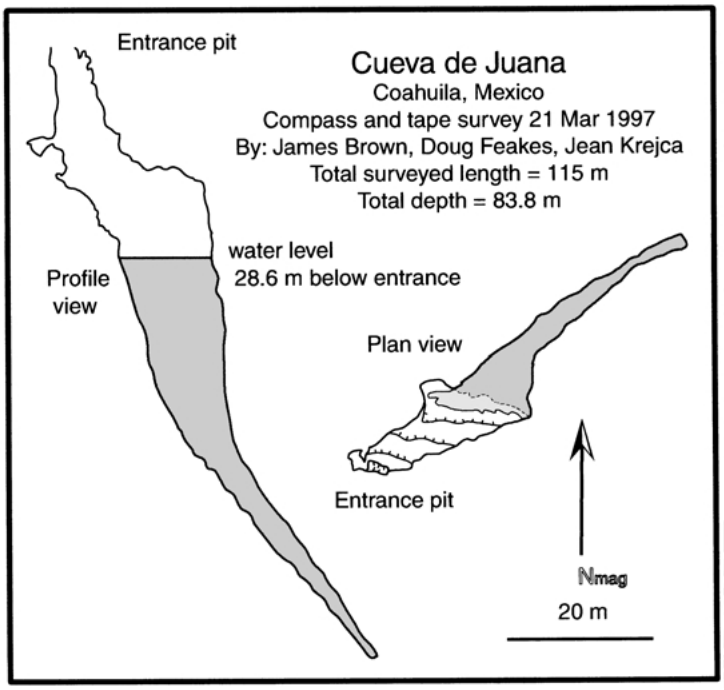

Figure 2. Map of Cueva de Juana.

Prietella phreatophila **localities**

Included in this list are all sites from which specimens have been collected and deposited in museum collections, as well as three sites (marked by asterisks) where we consider there to be extremely convincing reports of presence of the species.

Cueva de Juana

This cave is formed in lower Cretaceous limestone of the Aurora formation. The entrance is a 3 m diameter vertical shaft that enlarges and continues nearly vertically to the water surface, which was 30 m below the entrance during our visit. The shaft continues underwater 2–12 m in diameter at a nearly vertical angle to a water depth of 55 m (85 m below the entrance). The underwater passage consists of a complicated maze of connecting vertical shafts where great care should be taken in navigation (Figure 2). The walls and ledges are bedrock, with some silt. No flow was detected and ceiling debris was quickly dislodged by divers' bubbles. Blindcats were found in the shallower areas (20 m or less), possibly due to the fact that visibility was quickly reduced at depth. Also because most of the food input is probably from entrance debris, this shallower area may be where the fish forage. Water chemistry was essentially homogeneous from the water surface to a depth of 45 m as follows: temperature = 21°C, pH = 7.81, dissolved oxygen = 5.4 mg l^{-1} (the highest recorded for any blindcat localities), specific conductivity = 0.425 mS cm^{-1} (the lowest recorded for any blindcat localities), redox potential = 335 mV.

El Cedral

This site is located in the barite and zinc mining area of El Potrero 1 and 2 (below), in the lower Cretaceous limestone and barite of the Cupido formation (= Sligo formation in Texas). Connections among these sites (El Cedral and El Potrero 1 and 2) are not documented, but possible given their relative proximity. The entrance to this site is a 3.5 m diameter concrete-walled vertical shaft located in a building that has been used as a chlorination tank for water that is currently used in a coal-washing plant in nearby Palau. A ladder descends approximately 20 m to the water surface. Water depth in the tank was 6 m during our visit, with a horizontal conduit at 5 m in depth and 1–2 m in diameter through which water flows into the tank. The horizontal conduit can be followed for 100 m, at the end of which it intersects a natural cave passage. All of the blindcats from this site were taken from the side passage that has walls of concrete, metal, and excavated rock. No flow was noticeable. In March of 1997 it was reported to not have been used for chlorination for about one year.

**El Consuelo*

This is a hand-dug, vertical well round in cross section and approximately 10 m deep and 1 m in diameter. At the time of our visit, the water level was about 6 m below ground level, and accesible submerged passage continued another 3 m or so. The well's walls are shored up with stones, and a few meters below the stone work an inaccessible natural cavity, about 0.3 m in diameter, can be seen continuing downward, with no noticeable flow. The natural cavity had bedrock walls and ledges with a layer of silt. Some organic debris had fallen in from the well entrance. The owner reports blindcats used to be captured in well buckets, but since a pump was installed about 30 years ago, no specimens have been seen. On one occasion in the 1950s lime was added to the well in an attempt to sterilize it after a goat fell in and drowned. Large numbers of dead blindcats were seen shortly afterward. Our dive here yielded only the collection of a single, apparently troglobitic snail and a toad.

El Potrero area

This is a region of barite and zinc mines in lower Cretaceous limestone and barite of the Cupido formation (= Sligo formation in Texas). What we call El Potrero 1 and El Potrero 2 are within 100 m of one another. Hydrologic connections seem likely, but differences in water chemistry indicate perhaps otherwise, at least during low-flow periods.

El Potrero 1: This is the type locality for *P. phreatophila* (Carranza 1954). The entrance has been modified since Carranza's visit in 1954, being now covered by large steel doors adjacent to a steel shed and windmill. The first 5 m of vertical shaft are walled in concrete (3 m in diameter, matching Carranza's description) and ladders descend to water, approximately 7 m from the ground surface at the time of the team's visit. Earlier inspections by the first author found water level to vary as much as 3–4 m above, to several meters below, this level. Carranza described the water level 2.5 m below the surface in 1954. Several electrical pumps are now installed below water level in the modified area, being moved regularly up and down as water levels fluctuate. The pumps typically reside in a natural crevice that continues downward from the modified area.

Carranza (1954) based his description of the species on 66 specimens taken from here using traps baited with decomposing frog legs. We did not find any fishes in two dives during the team's visit, but the first author had previously left traps with the local caretaker, who collected two specimens of *P. phreatophila* by baiting traps with commercial pet foods and locally caught insects. Local residents report seeing blindcats after floods, sometimes even outside of the cave following extremely high discharges. At no time, however, did we see blindcats so abundant that we could ever collect anywhere near 66 specimens in two days, as Carranza apparently did, nor do local residents indicate that they are ever so abundant.

The substrate is bedrock and some breakdown, covered by fine silt. Water flow has been unnoticeable during all of our visits, and we did not detect any hint of the relatively intense cross-current described by Carranza as being 2 m from the 'pozo'. As mentioned above, however, the system occasionally has large discharges to the surface, and clearly at such times, considerable currents. Visibility was initially clear, but quickly silted with divers in the narrow passage. A constriction at 8 m in water depth was passed to an ultimate depth of 14 m. The passage was seen to continue downwards from here, but visibility was too poor to continue the descent.

Carranza (1954) reported temperatures ranging here from 27–31.0°C, pH = 7, and total hardness = 366 ppm $CaCO_3$. Our single sample taken during the team's visit from a shallow point was temperature = 31.12°C, pH = 7.73, dissolved oxygen = 1.58 mg l^{-1}, specific conductivity = 0.72 mS cm^{-1}, redox potential = 345.8 mV (Botosaneanu et al. 1998). A temperature data logger recording at two hour intervals from 20 March to 15 June 1997 recorded a range of 27.25–31.5°C (the highest we recorded at any blindcat site).

Water level now seems to be consistently lower than described by Carranza, but historic data on water levels other than that from Carranza's description are not available. Carranza mentioned that the site was pumped during times of water scarcity to supply the town of Nueva Rosita. Water from here is now used on a more consistent, but not continual, basis to supply a large coal washing plant in Palau. Aquatic organisms collected here and at El Potrero 2 include snails and the troglobitic cirolanid isopod, *Speocirolana thermydronis* (Cole & Minckley 1966), an interesting range extension from the only previously known localities in the Cuatro Ciénegas basin (Botosaneanu et al. 1998).

Local residents report periodic massive surface discharges from this cave during heavy rains and continuing afterward for a day or two. At times, specimens of *P. phreatophila* are said to be observed in surface pools downstream in the normally dry arroyo that receives the cave's discharge. We can substantiate the flooding claim since subsequent to the 15 June 1997 retrieval of data from the temperature data logger mentioned above, a large discharge from El Potrero 2 (below) removed the device from that cave. It had been tethered with heavy nylon cord to a stone weighing 2–3 kg, indicating considerable hydraulic scour of that system. Locals reported that both Potrero 1 and 2 flowed similarly during that event.

El Potrero 2: This may be the site that Carranza refers to as being 30 m distant from, and 1.5°C warmer than, the main pozo (which we believe to be our El Potrero 1), on the two days of his visit. While we did not find another pozo as near as 30 m to El Potrero 1, this modified natural cave is approximately 100 m from that pozo, on the far bank of the arroyo at the base of a small cliff. The entrance has been altered by shoring it up with concrete and covering it with a hinged steel lift door that is typically padlocked. A date in the concrete indicates the construction was done in 1952, two years prior to Carranza's visit. Once inside, a ladder leads down about 4 m to the floor of a 5 m-diameter room, filled with about 1 m of water at the time of our team visit. A 4 m crawlway just above the water surface led to another room where the passage continued underwater. This narrow passage was explored to a depth and penetration of approximately 10 m, but was seen to continue.

The passage is 1 m wide by 3 m long, with bedrock walls and ledges. Isolated small accumulations of silt and surface debris, such as twigs and sticks, were noted at intervals. In addition to specimens of blindcats taken during the team's visit, the same invertebrates taken in El Potrero 1 were collected here. Invertebrates were taken near or on the sticks, and blindcats were noted to be in cooler water, also near these piles of organic debris. Two water masses differing in water quality were noted in the cave, a surface layer (temperature = 29.15°C, pH = 7.92, the highest recorded for any blindcat locality, dissolved oxygen = 3.48 mg l^{-1}, specific conductivity = 0.72 mS cm^{-1}, redox potential = 344.18 mV extending to 3.6 m depth) and a transition layer (temperature = 28.25°C, pH = 7.79, dissolved oxygen = 1.76 mg l^{-1}; conductance and redox = upper layer) from 3.7 to at least 5.4 m or more (Botosaneanu et al. 1998). The difference in water chemistry parameters between Potrero 1 and 2 indicate at least very limited or perhaps distant connections between the two water bodies, at least during periods of normal water levels.

El Socavón area

Though Carranza (1954) failed to collect blindcats at any site other than El Potrero, he visited this site and mentioned that local residents reported the presence of blindcats here. We explored three sites in close proximity: El Socavón, and two apparently un-named local sites that we named 'above El Socavón 1' and 'above El Socavón 2', all of them in lower Cretaceous limestone of the Aurora formation. The first two are clearly hydrologically linked, as indicated by historic accounts, and corroborated by our explorations. According to an unpublished report by Rodriguez Guerra on file in the Múzquiz municipal water supply office, in 1888–1890 a long, nearly horizontal passage (El Socavón) was excavated in an attempt to de-water a flooded lead and silver mine, Mina de San Juan. The workers intersected a large water-filled chamber before reaching the mine, thus flooding the Socavón with 2000 l s^{-1} stopping the project. We named what we believe to be the point at which the Socavón hit the natural passage, 'above El Socavón 1.' The site can now be accessed from the surface. Water at above El Socavón 1 is now permanently diverted through the Socavón tunnel to surface at what is now known locally as 'El Socavón'. Though the connection between El Socavón and above El Socavón 1 has never been proven (as no one lives to tell exactly where, from the mine side, the breakthrough occurred, and no one has traversed the entire, now-submerged passage), our underwater survey data, a previous survey deposited in the municipal water supply office in the plaza in Múzquiz, combined with the striking similarity of water chemistry data (below) strongly corroborate such a connection.

El Socavón: This is the downstream outlet of water from above El Socavón 1, and is now the municipal water supply for the city of Melchor Múzquiz. The large pool just beyond the entrance to the flooded tunnel is covered by a concrete, steel-roofed building (ca. 10 m × 10 m × 3 m high) from which water is diverted. The submerged tunnel is about 2 m in diameter and continues upstream for about 130 m to a breakdown constriction which has been passed by divers using streamlined equipment to counter the high velocity flow (recorded at 200 l s^{-1} in a 1981 unpublished report by Rodriguez Guerra on file in Múzquiz municipal water supply office).

The floor of the passage is rock and breakdown. Blindcats have been taken from the building and city's diversion structure in the past (TCWC 5144-1) and we collected them from the submerged passage upstream of the building and downstream of the breakdown constriction. Water chemistry data (temperature = 26.75°C, pH = 7.77, dissolved oxygen = 4.51 mg l^{-1}, specific conductivity = 0.64 mS cm^{-1}, redox potential = 350.63 mV) are taken from a single point, as they are expected to be homogenous in this high flow system. A native surface catfish, *Ictalurus lupus*, was taken far into the passage, syntopic with *Prietella*.

Above El Socavón 1: This is apparently the natural spring or cavity that was accidentally diverted to El Socavón in 1890. Two entrances are within 5 m of each other. One is shored up with stonework, and a vertical drop of about 10 m leads directly into a pool of water. The second leads to a short climb down and vertical drop to the same pool, which, at the time of our visit, filled a 4 m diameter passage, penetrating 13 m to a depth of 9 m. In the wall of this passage, about 1 m from the water surface, the drain hole that originally flooded El Socavón was obvious. Through this small drain hole, which is now partially braced with timbers, a diver can look downstream to see that the water emerges on the other side as a waterfall into air-filled passage. Locals report that at times of extremely high discharge, water still flows from this spring, indicating that discharge of the system occasionally exceeds the hydraulic capacity of the drain hole.

The floor of the passage consists of organic debris fallen from the entrance covering cobbles from which a moderate flow emanates. Blindcats were collected from an adjacent silt bank. Water chemistry is essentially homogenous, as expected given the large discharge: temperature = 26.78°C, pH = 7.77, dissolved oxygen = 2.77 mg l^{-1}, specific conductivity = 0.64 mS cm^{-1}, redox potential = 348.69 mV. Differences in dissolved oxygen between here and El Socavón are likely due to the aeration provided by the intervening drain hole.

Above El Socavón 2: This is a flooded mine several hundred meters from El Socavón 1, and it is unknown how it is hydrologically linked to the other El Socavón area sites. It may be part of the old 'Mina de San Juan' mentioned by Rodriguez Guerra (unpublished data). One of our divers experienced a serious passage collapse while diving. We advise that future explorers exercise considerable caution in this site.

Silt-bottomed tunnel with abundant, scattered timbers fallen from the roof. Our brief exploration produced both a single blindcat specimen and troglobitic amphipods.

**La Tembladora*

Two hand-dug, vertical wells, 1–2 m in diameter, and less than 10 m deep have walls of un-mortared rockwork descending to intersect natural bedrock joints filled with water which has been about 1 m deep at the time of our visits. The joints, less than 0.3 m wide, and too small to be explored, can be seen continuing horizontally. A large spring is a few kilometers distant. The natural joints have bedrock walls with silt-covered floors and ledges. Flow was unnoticeable. Though no specimens have been collected here, the well owners provided reliable reports of blindcats being captured incidentally in their well buckets, and report that at one time they held two specimens alive for us for a week or more before releasing them.

Ojo del Yermo

The entrance to this cave is described as a 45 m vertical shaft that intersects a horizontal stream channel. At one end of the channel is a debris constriction followed by a small sump. At the other end of the stream channel is a lake with large diameter submerged passage explored to 46 m depth and seen to continue. Water level is reported to be highly variable. At least once water was partway up the shaft when a diver attempting to dive to the intersecting horizontal passage encountered swift, life-threatening currents. Descriptions indicate large diameter passage that in some places has considerable flood debris, and water that is extremely clear and deep. Explorers report abundant blindcats in the lake and its submerged passage. The smaller sump beyond the debris constriction reportedly had no blindcats. A single specimen of *P. phreatophila* (TNHC 12100) was collected here in 1986 by divers who provided the site description we relate above, but we have not been allowed access by the landowner.

**Noria de San Pedro*

This well, built in 1918, was originally a narrow joint through which water would sometimes flow to the surface. The joint was manually enlarged and shored up with rocks in a square cross section to a depth of approximately 25 m from the surface. Now it is about 1.5 m in diameter and can be easily entered with a rope. At the bottom is a silt ledge from which a natural water-filled crack 2 m long and 0.5 m wide can be seen. Dives were attempted on two different occasions, once getting to a depth of 10 m, but both were aborted due to the narrow passage configuration and heavy siltation problems. According to locals, water sometimes flows out of the top of the well for weeks. What can be seen from the silt ledge at the bottom of the well is a vertically oriented water-filled crevice, 0.5 m wide by 2 m long, extending as far as we could see (using masks, fins, and dive lights) through very clear water. After an initial constriction just underneath the water surface, the passage widens to more than 1 m and appears to continue to enlarge. Walls are bedrock with ledges covered with silt. Locals report that blindcats and other surface fish have shown up in the well bucket during or after rain events that raise the level of the water in the well, or even make it flow out over the surface. Though blindcats have never been collected here, the combination of convincing accounts from locals and proximity to Sótano de Amezcua lead us to include this as a known site. A single cirolanid isopod was taken from here. Water chemistry data are: temperature = 23.99°C, pH = 7.14 and dissolved oxygen = 7.01 mg l^{-1}.

Sótano de Amezcua

The entrance to this cave is in the bottom of a 20 m deep sinkhole in the Segovia Limestone. A 70 m vertical shaft leads into a large chamber with a rocky bottom stream crossing alongside. The stream passage can be explored both up and downstream. Upstream the air-filled passage terminates quickly in a sump pool ('catfish parlour'), while the downstream passage can be explored approximately 200 m through a crawlway (= BBB Lake) that intersects canyon passage leading to the downstream sump. Both sumps have been dove, but only the upstream one successfully traversed by divers, who found it to continue at shallow depths (5–10 m) to connect after about 100 m to air-filled canyon passage which again sumps (thanksgiving sump) and re-emerges in an air-filled chamber before sumping a third time (Figure 3). Blindcats were discovered here in 1992, and many visits have been made since, both by members of our team and others. This, plus two years of continual temperature data, extensive SCUBA explorations and thorough cave survey, as well as an ongoing capture-mark-recapture study of the blindcats, make this now the most-studied *Prietella* locality.

Blindcats in Sótano de Amezcua have been taken from silt-bottomed pools while aquatic crustaceans have been collected in riffles of the downstream section of cave, particularly those that lack fish and have bits of organic debris such as twigs and sticks. The aquatic fauna includes at least two families of isopods, Cirolanidae: *Cirolanides texensis* (identified by Botosaneanu, Iliffe personal communication), Asselidae: *Lirceolus* (Reddell personal communication), and amphipods (Botosaneanu et al. 1998).

Upstream: The first sump pool encountered in the upstream direction from the entrance, catfish parlour, is the most accessible and apparently permanent blindcat habitat. The pool is 2 m × 4 m × 0.5 m deep, and silt floored. Blindcats have been observed here on every visit. Typically flow is unnoticeable in the pool, and once the silt bottom is disturbed, it can take days for the water to clear. It is expected that blindcats here feed on the sometimes very abundant cave crickets that fall into the pool from the ceiling and walls. Water temperature in this pool, measured every two hours between March 1997 and August 1999, ranged from 21.47–24.69°C. Continuing upstream from this pool is a 100 m section of submerged passage that is largely silt-floored, except for some constrictions that have a gravel floor. Throughout this pooled passage blindcats have been seen at depths of 0.01–5 m. The upstream, air-filled canyon passage is also silt bottomed, and when explored by members of our team on two occasions had very shallow trickling water. No blindcats have been seen in this reach but a small pool just below the second ('thanksgiving') sump provided our most upstream observations of blindcats. During the single exploration of the underwater passage beyond 'thanksgiving sump', no blindcats were found. All passage above the sump at 'catfish parlour' appears to have comparatively very low invertebrate

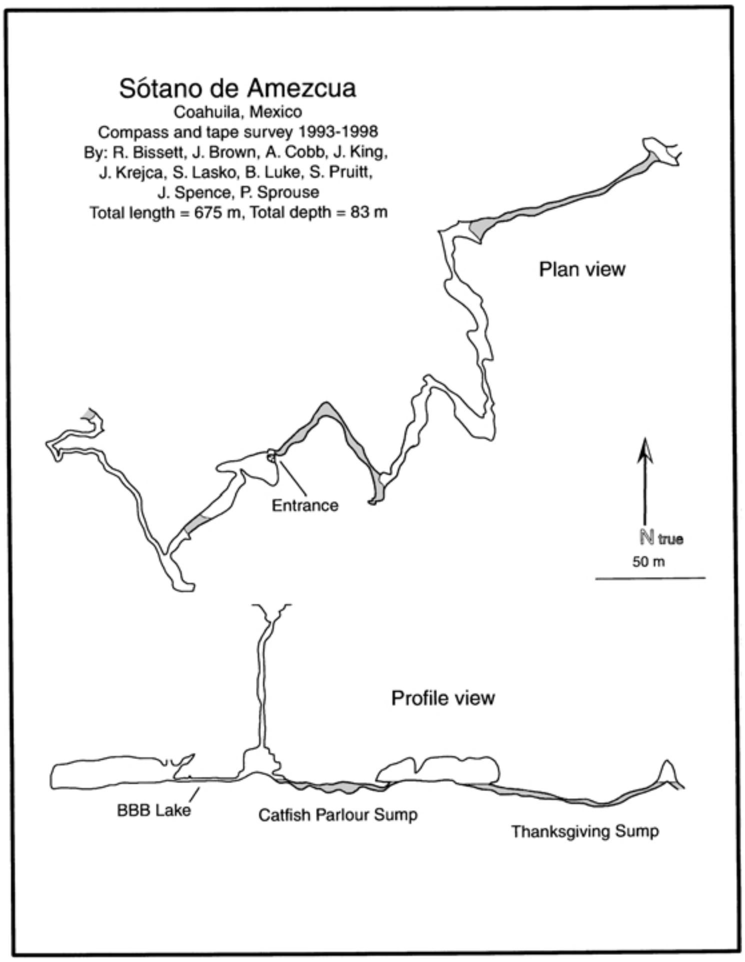

Figure 3. Map of Sótano de Amezcua.

population densities, and thus probably very limited food for blindcats.

Downstream: Between the entrance chamber and the downstream sump, the stream is typically very shallow (0.01–0.1 m) with riffles. Substrates include calcite, gravel and cobbles of various sizes. Sometimes flows drop into the gravel such that BBB Lake is entirely dry, while other times this low-ceiling section of passage is nearly or entirely submerged. A single blindcat was seen twice in this section, in a small pool in the upper canyon passage. It is in the canyon passage that most of the aquatic invertebrates were collected. Our explorations end at the downstream sump pool, which is silt and gravel bottomed, with a surface of about 5×2.5 and 2 m deep. Blindcats have been seen here on every visit, often swimming under calcite rafts floating on the surface of the heavily mineralized water, though at times these rafts are absent.

Prietella lundbergi localities

Manantial de San Rafael de los Castro

This cave spring is formed in middle Cretaceous dolomitic limestone of the El Abra formation. The entrance is a 2 m by 5 m opening bisected by a natural bridge. A 4 m drop leads to water, where a pump has been recently installed. The submerged entrance cave area is wide and maze-like, including some pits dropping to 16 m below water surface and at least two air-filled rooms. Beyond this area, a narrow slot can be followed to 45 m below water surface, where the passage levels then rises to 23 m, before finally plunging to 90 m and continuing beyond our explorations. The site has been well explored, yet no blindcat specimens other than the holotype have been collected or seen. Our explorations began in April 1994, when two divers spent two hours in the cave, penetrating to 40 m maximum depth, collecting invertebrates, but observing no cave fishes. During our 1997 explorations, four divers spent many additional hours in this cave during two days of diving, and finally, the second author and another diver dove the site again in early January 2000, reaching 90 m depth.

The passage diameter varies from 1–10 m, and substrates are gravel, breakdown, bedrock and silt. Though this is the type locality for the species, six dives subsequent to collection of the type specimen failed to yield additional specimens or even sightings. Troglobitic invertebrates are extremely abundant here, including two stygobitic isopods, a cirolanid, *Sphaerolana interstitialis* (Botosaneanu et al. 1998), and a potentially new species of asellid isopod, *Mexistenasellus* (J. Reddell personal communication), as well as troglobitic amphipods and a troglobitic shrimp, *Troglomexicanus huastecae*, for which this is the type and only known locality (Villalobos et al. 1999). Juvenile shrimp are usually on silt, while adults are seen in the water column. Isopods are typically on rocks and amphipods in the water column. Since this is a flowing spring (though discharge is often quite small), we found little variation in water quality with temperature = 27.3°C, pH = 7.47 (the lowest for any blindcat site), dissolved oxygen = 0.9 mg l^{-1} (the lowest for any blindcat site), specific conductivity = 0.76 mS cm^{-1} (the highest for any blindcat site), redox potential = 335 mV (the lowest for any blindcat site) (Botosaneanu et al. 1998) except for notably lower temperature in a section of the cave to the left of the entrance. The lower temperatures may indicate that this may be a dead end passage where cooler water from the entrance settles. The temperature, pH, dissolved oxygen, and redox potential observed were the lowest, while specific conductance here was the highest, of all *Prietella* localities we sampled. In surface waters below the spring we observed (our permit did not allow collections of surface organisms) fishes previously recorded from the area (e.g. Darnell 1962). Divers reported individuals of an unidentified bass and a large surface catfish extending far into the dark zone of the cave.

Cueva del Nacimiento del Río Frío

First described by Russell & Raines (1967) the entrance to this cave is an inconspicuous 1 m diameter hole in a dry arroyo very close to the Nacimiento del Río Frío upstream from Poza Azul. Quickly the passage diameter opens up to 4+ m diameter, continuing about 50 m to a 40 m vertical drop into water. The passage continues underwater to a depth of 60 m, then immediately turns upward to return to the water surface below a large air bell (Figure 4). The submerged passage is 3–10 m in diameter and blindcats were found only at depths ranging from 50 to 60 m. Other aquatic fauna includes the troglobitic shrimp *Troglomexicanus tamaulipasensis*, for which this is the type and only known locality (Villalobos et al. 1999), the parasitic (on *Speocirolana bolivari*) branchiobdellid worm, *Cambarincola acudentatus*, as identified by Stuart Gelder (Tom Iliffe personal communication), troglobitic cirolanid isopods *Speocirolana bolivari*, and *S. pelaezi,* mysids, shrimp (Atyidae), and large snails (Botosaneanu et al. 1998). At the time of our visit, the cave contained two distinctly different, but homogeneous water masses separated by a sharp boundary layer. The upper layer extends from the surface to 39.8 m, while the lower layer begins at 41 m and continues to at least 45 m. Overall organisms were more abundant in the lower layer. Water chemistry data for the shallow layer and deep layers, respectively are: temperature = 21.52°C and 21.63°C, pH = 7.76 and 7.72, dissolved oxygen = 3.4 and 4.4 mg l^{-1}, specific conductivity = 0.43 and 0.52 mS cm^{-1}, redox potential = 361 and 363 mV. Redox potential here was the highest recorded for any blindcat site (Botosaneanu et al. 1998). Due to substantial differences in water quality, especially temperature and specific conductance, lack of obvious outflow from the cave, and failure of divers to detect currents, we conclude that cave water represents an isolated, perched sump, unrelated to water emerging from springs 200–1500 m from the cave entrance (Villalobos et al. 1999).

Sites examined where no *Prietella* were found

Sites listed here are all those visited by our team which appeared to have habitat which might harbor blindcats, or showed promise of providing access to such habitats, but at which our explorations failed to find specimens. We do not mention here other sites visited which appeared unlikely to have, or have had in the

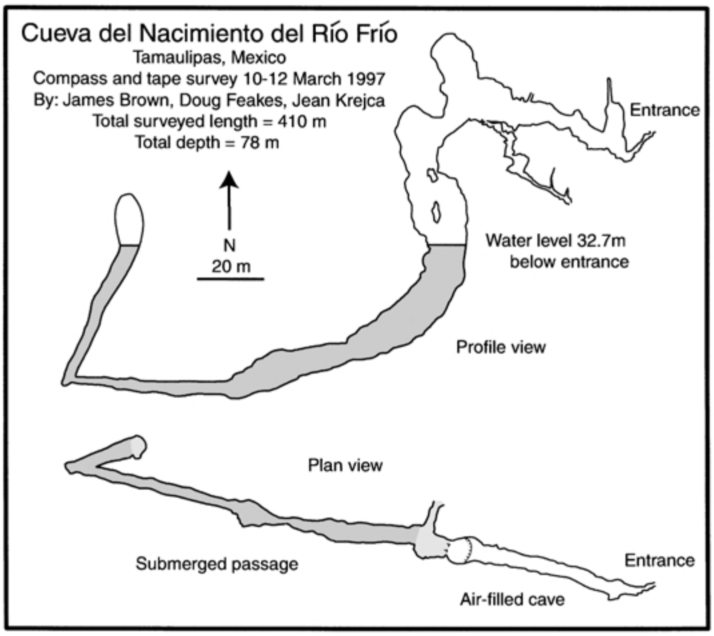

Figure 4. Map of Cueva del Nacimiento del Río Frío.

past, suitable habitat. Invertebrates collected at many of these sites will be reported upon elsewhere. This list is provided so that readers might fully understand the extent of our explorations and for the benefit of future researchers. We fully expect that blindcats may one day be found at least in some of these.

Cueva de la Espantosa

This is a 1–2 m diameter, silt floored spring cave carrying a small stream. It can be followed for about 30 m until reaching a sump. Though no blindcats have been seen, this site warrants a dive to check the submerged passage beyond the sump. This is possibly a new southernmost locality for the troglobitic cirolanid isopod, *Cirolanides texensis* (Iliffe & Botosaneanu personal communication).

Cueva del Nacimiento San Rafael de los Castro

In the sierra immediately above Nacimiento San Rafael de los Castro, within a couple hundred meters of the spring, a natural bridge spans a 15 m vertical drop to the bottom of a large open-air pit floored with an impressive layer of small mammal, reptile, and bird bones. Cave passage can be followed for approximately 100 m to a breakdown terminus. No suitable fish habitat was seen.

Cueva el Venado

A cave with a 1.5 m entrance from which water flows. About 5 m into the cave the passage ends and the water can be seen issuing from an un-enterable hole near the ceiling.

Cuatro Ciénegas area

Rumors among locals of blindcats in some of the springs of the Cuatro Ciénegas basin, and stygobitic organisms, including four species of isopods, two amphipods and four snails known from cave-like microhabitats of this basin (Reddell 1981, Cole 1984, Hershler 1984), make it seem likely to harbor blindcats. Our dives at the only sites with accessible passages, however, yielded no troglobites. Mojarral East (Minckley 1969) is a body-sized spring outlet in about 7 m of water that can be entered only about 3 m before becoming too constrained for divers. Mojarral West (Minckley 1969, now locally known as Poza Azul) has a 1.5 m diameter siphon in about 7 m of pooled water which a diver descended 5–10 m, but extremely strong currents make this site too dangerous to enter farther. The most promising site in the basin that we have discovered so far is locally known as La Campana. A pool of water lies about 9 m below a cenote-like, belled-out vertical entrance. Submerged 3–4 m diameter passage extends in two directions a total length of 130 m, terminating in both directions where the silt floor rises to meet the ceiling. No stygobitic organisms were taken from the conduit passages explored at Mojarral East, West, and La Campana.

Cueva Cabrito

This short cave has a 4 m diameter passage followed by a vertical drop of 5 m and ends in a large guano deposit partially covered by highly enriched, deoxygenated and stagnant water at the time of our visit. No suitable blindcat habitat was seen.

Cueva de El Tule

This otherwise dry cave contains a sump with underwater passage that goes beyond two air bells. It was explored to 16 m depth and 130 m penetration and still continues. Isopods were collected.

Cueva de Rancho Las Pilas

The entrance to this cave is located in the wall of a steep valley and leads into about 100 m of 1–3 m diameter passage at the end of which a dome harboring a bat colony was noted. A 5 m drop leads from this room to a 0.5–1 m diameter sandy crawlway that can be followed to a room and a crawlway with flowing water. A troglobitic ricinuleid was found in this wet crawlway. Approximately 100 m of passage was explored.

Cueva La Zumbadora

This cave in the lower Cretaceous limestone of the Aurora formation has been altered with a concrete dam and aqueduct in an attempt to bring water from the cave to the town of La Madrid. A short distance into the cave a sizeable stream is encountered, dropping downstream into a tightly enclosed waterfall, but possible to explore upstream about 100 m to a siphon. Divers explored 150 m more of submerged passage, with a maximum depth of 12 m. Passage diameter is typically 2 m, with bedrock walls and floor. This cave is the type and only known locality for the stygobitic cirolanid isopod *Speocirolana zumbadora*. It also harbors *Sphaerolana affinis*, and a snail (Botosaneanu et al. 1998).

Dandridge Spring

This high flow spring on the Devil's River has about 30 m of 1 m (or less) diameter passage. Troglobites collected include one isopod and a harvestman. Ostracods and some hydrobiid snails were also taken.

El Abra

This cave is a 0.5 m diameter hole in the bottom of a bedrock creek bottom that leads down 3 m to a 1 m diameter horizontal tube carrying a small stream. The stream passage was followed at least 50 m and continues.

El Ebanito

A steep passage, 2–5 m in diameter, descends to a boulder choke some 40 m vertically below the entrance. Water level is highly variable, with the boulder choke at times 5 m above water, while on another visit it was at 37 m of depth. Cirolanid isopods and shrimp have been collected here.

El Sótano

This 10+ m diameter cave can be followed approximately 100 m before two drops, totaling about 40 m, are reached. At the bottom of this vertical section is a sump pool. No blindcats were seen, but this site warrants a dive to check the deeper waters (Proyecto Espeleológico Purificación identification number 118, Peter Sprouse personal communication).

Emilio's Cavern

This small blind pit was explored to a depth of 9 m. No water or suitable habitat was found.

Falcón Well

This 2–4 m diameter well below a windmill was easily entered on rope to water at a depth of about 10 m from the surface. The pool at the bottom was stagnant, water visibility was poor, and there appeared to be no enterable passage or flow.

Goodenough Spring

The third largest spring in Texas (Brune 1981) now sits inundated at 20–30 m depth below the surface of Lake Amistad, a reservoir on the Río Grande. Divers have explored the cave passage to a depth of 65 m, and report strong flow, warm water, good visibility, and organisms such as epigean catfish (R. D. Milhollin personal communication).

Gruta de Carrizal

This is a spring flowing out of dry cave with two sumps inside – one warm and the other cold. The warm water sump and downstream area harbors epigean catfish (*I. lupus*) as well as amphipods. A series of four sumps were explored to a termination in breakdown. Exploration of submerged passage reached 14 m in depth, and 130 m penetration.

Guayalejo Spring

This cave spring is on the south bank of the Rio Guayalejo where it flows through a mountain pass. A cenote-like entrance with a 100 m long submerged cave passage (16 m depth) leads to air filled chambers and possible dry caving leads. A troglobitic cirolanid isopod, likely an undescribed species of *Speocirolana* (Botosaneanu personal communication) was collected.

La Rajada

Also known as El Indio or Los Indios, this is a naturally enlarged joint in a cliff descending about 10 m to a small pool of water 1.5 m deep with a deep mud bottom. A windmill above the entrance extracts water from the pool. No cave passage or troglobitic organisms could be found.

La Vinata Well

This is a hand-dug well fitted with a diesel-powered pump that sits in a little house adjacent to the well. The pump is no longer operational and excessive grease from it coated the walls and surface of the water at the bottom. A ladder leads down about 10 m to water no more than 2 m deep. There is evidence, including reports from locals, that indicate that this well flows during heavy rains.

Manantial La Penita

This municipal water source for Ciudad Victoria consists primarily of springs that are pumped into the city. We visited first a small cave in the limestone wall of the creek bed. The entrance and passage has been modified with steps and concrete platforms connecting to a 1–2 m diameter passage that drops 4–5 m to water with sumps in both upstream and downstream directions. The site was dove for a short distance, but no aquatic fauna was found. The second site explored here was a large concrete box buried in the stream cobbles at the edge of the stream bed just across from the cave. A small steel door allows entry to a 4–5 m drop to a small creek flowing over stream cobbles and gravel through a small room. Troglobitic cirolanid isopods were collected.

Nacimiento del Río Frío

This series of springs forms the Río Frío, with the uppermost springs being about 200 m from the entrance to Cueva del Nacimiento del Río Frío (above), with many more outlets extending downstream to Poza Azul, though none were found which could be entered for exploration. Continuing downstream as far as La Florida are more spring outlets. Water chemistry clearly indicates that these springs are not connected to the water in Cueva del Nacimiento del Río Frío.

Nacimiento del Río Sabinas

First explored by Exley (1979) and others, our 1994 expedition dove this site again to 40 m depth, but failed to collect or observe stygobites.

Nacimiento Kikapoo

This heavily vegetated spring pool forming the headwaters of the Río Sabinas had no accessible passage, but significant discharge indicates substantial subterranean aquatic habitat.

Ojo Encantado

This is a resurgence cave at the bottom of a deep canyon. Just inside the 10 m diameter entrance is a long, deep pool where we collected cirolanid isopods preliminarily identified as *Speocirolana pelaezi* and *S. bolivari* (Botosaneanu personal communication).

Water level fluctuates extremely here, such that sometimes water comes out of the entrance as a spring and the cave can not be entered without diving, while other times the water is about 10 m below the entrance. Passage continues upstream for at least 100 m.

Poza San Miguel

This is a large spring pool diveable to about 14 m where a narrow bedding plane constriction prevents further exploration. We observed several epigean fishes in the pool, including *Gambusia* sp., *Lepomis* sp.

Purificación area caves

Many caves have been explored in this high altitude karst plateau in the Sierra Madre Oriental west of Ciudad Victoria, including the country's largest, and some very deep systems such as Sistema Purificación, Tecolote, Río Corona, Sima Chupacable, and Calenturas. Cavers and biologists have explored and collected these sites for many years and have found the aquatic fauna limited to troglobitic cirolanid isopods *Speocirolana bolivari* and *S. endeca,* as identified by Botosaneanu (T. Iliffe personal communication). The combination of little food input and high elevation make these caves perhaps less likely than others to harbor blindcats.

Richter Cave

This is a 4 m deep blind pit located up the hill from Dandridge Spring. No water is present. Fauna included a harvestman (*Lieobenum*), a spider (*Cicurina varians*), a Texas cliff chirping frog (*Syrrhophus marnockii*), and small mammal bones.

San Felipe springs

The east spring (= San Felipe Spring #3 in Brune 1981), with several large pump intake structures extracting water for the city of Del Rio, was dove to a boulder constriction at a depth and penetration of 10 m. The west spring (= San Felipe Spring #2 in Brune 1981), rumored to harbor blindcats, was also dove to about 10 m, to a small restriction where the flow velocity prevented further penetration. The other springs mentioned by Brune (1981), including #1 and #4–10 were field checked and all except for #10 were un-enterable. Permission to dive San Felipe spring #10 could not be obtained.

Springs near El Nacimiento de San Rafael de los Castro

Following rumors of other springs and caves, we spoke with locals who described all of the caves on the N side of the Cañon La Servilleta as dry and formerly mined for guano. The canyon was partially checked for springs, and none were found. A small dammed spring head at La Presa was checked but appears to be inaccessible.

Tinaja Azul

This small spring is pumped by a windmill. The entrance has been shored up with concrete to 1–2 m diameter. Water depth is about 1 m, with a silt and cobble floor. Submerged passage continues horizontally from the floor of the spring as a low, inaccessible crack along a bedding plane. Locals reported past sightings of blindcats here, but we saw only epigean *Astyanax*.

Tiro el Palmito

This mine shaft is in the lower Cretaceous limestone of the Cupido formation (= Sligo Formation in Texas). A railroad track drops 50 m vertically at a 45 degree angle through the 1–3 m diameter tunnel. The pool at the bottom was explored by a diver for only a short distance because visibility was very quickly reduced by ceiling debris dislodged by the diver's bubbles.

Vertical mine shaft near El Portrero

This 1.5 m diameter mine shaft begins horizontally then intersects a vertical shaft about 25 m deep. The shaft intersects water, but was cluttered at various levels by precariously perched, fallen timbers, and thus judged too dangerous to enter.

Abundance

In general, vertebrate troglobites in temperate environments are rare relative to epigean organisms. The desert landscape that overlays most of the range of *Prietella* probably contributes little energy to the system in the way of organic debris, and such input may be largely restricted to rare flood events. It is unusual to see more than six blindcats on any given visit to one of these sites, and it is easy to see that higher abundances are near cave entrances that serve as energy input points. The most recorded specimens collected from any site are from Carranza's (1954) collection of 66 from El Potrero 1. Never have we seen abundance approaching this, though on our first visit to Sótano de Amezcua, we collected 25 specimens from the two sumps and intervening small pools. Preliminary capture-mark-recapture data analyzed using the Fisher-Ford estimation and subsequently taken during nine sampling periods over 13 months in the upstream and downstream sumps of Sótano de Amezcua indicate a fairly small population with 9–48 fish in each sump. At Ojo del Yermo, however, divers reported on the order of many tens of blindcats. It is almost certainly the case that sites we have been able to access represent a miniscule proportion of the total habitat available to these organisms, and the potential of an energy source in the deep aquifer, such as the one that may exist below San Antonio in Texas (Longley 1981), may sustain reasonably large populations.

Laboratory observations

Transport and laboratory conditions

Live specimens of *P. phreatophila* have been maintained in a variety of aquaria and wading pools in the first author's laboratory nearly continually since 1992. Except for occasional isolation of individuals, all have been kept in tanks housing 2–10 individuals. All specimens have been maintained in dechlorinated tap water in tanks with under-gravel and/or external filters, and a diversity of large, highly porous limestone rocks and laboratory flasks of assorted sizes and shapes intended to provide cavities such as might be used for reproduction. Water temperature has typically been maintained at laboratory temperature, a relatively constant 21–22°C, but aquarium heaters have been employed to hold selected specimens at constant and varying temperatures in the range of 21–27°C.

Transport to the laboratory from the field has evolved with the first specimens collected by cavers being carried in ice chests to more recent collections of the first author with transport for up to four days in plastic bags filled with pure oxygen and water from the habitats in which the specimens were captured, together with Stress coat™ and small pieces of Polyfilter™ to remove wastes. These last measures seem to reduce problems and reduce mortality, but in general, even under the best of conditions, specimens seem to suffer fin abrasions and other transport-related damage. Hemorrhaging between fin rays is commonly seen following transport. All recent collections have attempted to minimize transport time and distance, with consequential marked reductions in mortality.

Diet in captivity

Wild-caught specimens readily adapt to, and seem to do well on, laboratory diets consisting of prepared flake foods (Tetramin™), supplemented by occasional frozen blood worms, mosquito larvae and adult brine shrimp.

Parasites and diseases

One specimen was brought to the laboratory from the wild with what appeared to be a nematode encysted in the epaxial musculature. The specimen survived many months, but died within a day of rupture of the cyst. The parasite could not be found in the aquarium, which contained other blindcat specimens which may have consumed it, and which appeared to have attacked the site of the rupture, increasing trauma to the specimen. On several occasions captive individuals have developed bacterial infections with initial symptoms of slight ulceration in fin membranes and/or fin erosion, progressing to liver discoloration (visibly yellow as seen through the ventral body wall), septacemia and external ulceration. Such infections proved difficult to treat with a variety of antibiotics tested, but if treatment began early enough some individuals responded to long term 120 mg l^{-1} baths of Chloramphenicol. Fin erosion and associated hemorrhaging between fin rays (above), also responds to Chloramphenicol baths.

Light sensitivity

P. phreatophila specimens we have observed appear incapable of perceiving light through any remnant eyes they might have (we have not done dissections or histologic sections for detailed examination of eye morphology). In total darkness, they show no obvious reaction to the turning on and off of a 500 W bulb held within 5–10 cm of their head. We are currently conducting rigorous light sensitivity experiments with *P. phreatophila*, but most specimens kept to date have been held in normal laboratory and office spaces lit for at least 8–12 hours daily with no obvious adverse impacts. Recently, however, four individuals have been maintained in total darkness for six months.

Sensory biology

P. phreatophila obviously has acute auditory sensitivity, reacting immediately to taps on aquarium glass and other laboratory noises. Other observers of specimens in Sótano de Amezcua have reported individuals feeding on crickets thrown onto the surface of the water by swimming around the prey in a path with continually decreasing radius until it is encountered and consumed; a behavior likely mediated by lateral line function.

Chemosensory functions appear to be well developed in *P. phreatophila*, as attested to by the rapidity with which animated searching behavior begins after non-moving foods (frozen blood worms, brine shrimp, mosquito larvae, or flake foods) are placed in their tanks. It is obvious that odors or tastes given off by these foods are very rapidly perceived. Attempts to quantify olfactory sensitivity to a variety of amino acids and steroids in the laboratory of Norman Stacey (University of British Columbia) detected very low responses to these substances, but results may have been affected by a variety of technical difficulties including the need to perform surgery to install electrodes, and prior treatments of infections with antibiotics (Norman Stacey personal communication).

Starvation tolerance

Individuals with strikingly low, but unquantified, condition factor have been collected (Figure 5). All *P. lundbergi* collected were in this condition, but not as extremely low as were some *P. phreatophila* collected together with individuals in 'normal' condition. Individuals in the laboratory have been intentionally not fed for as long as 44 months, during which time condition factor obviously decreased, but not to levels equal that of some specimens obtained from the wild, which were far more emaciated. When food was made available, these individuals generally quickly resumed feeding and condition factor increased.

Jaw locking

On several occasions, aggressive encounters involving extended periods of two individuals biting one another's jaws have been observed, (Figure 6). All such encounters have been observed following movements of individuals to new tanks that result in new combinations of individuals coming into contact with one another. These encounters take the form of two individuals biting at one another and then locking jaws. The two specimens will then often remain in mouth to mouth contact for many hours, during which they occasionally swim and writhe vigorously, but briefly, pulling the other fish with them. These periods of activity are interspersed with extended periods during which both specimens rest motionless but maintain their grip on the other. Opercular movements are often exaggerated and accelerated while specimens maintain these jaw locks, indicating obvious respiratory stress. Both individuals may suffer abrasions to the mouth, barbels, nares and orbit regions produced by the teeth of the other individual. Specimens involved in jaw locks are not always of equal sizes. In some cases heads of smaller individuals have been seen to be nearly completely inside the mouth of the larger specimen during these encounters. Jaw locking incidents typically last < 30 min, but at least one jaw lock was maintained continuously for > 12 but <18 h, with only brief separations of 2–3 s, during which jaw lock position was altered slightly. In all cases, specimens involved in jaw locking appeared to be males, but sex was not subsequently verified by dissection. We assume these

Figure 5. Photographs showing varying conditions of *Prietella*.

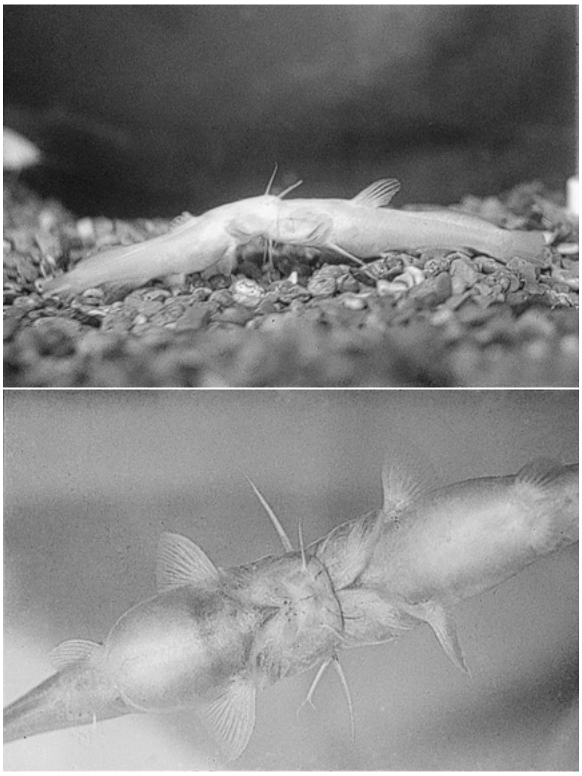

Figure 6. Photographs showing jaw-locking behavior in *Prietella phreatophila*.

encounters to be related to establishment of social dominance hierarchies. Once two individuals have jaw locked, subsequent jaw-lockings between them have not been observed, indicating that perhaps long-term dominance relationships are established by jaw locking shortly after individuals first come into contact, and subsequently never again tested.

Periods of inactivity

Specimens, especially larger individuals and those under some form of stress (e.g. infection, lack of food, temperature), are often observed resting motionless on substrates or simply drifting with light currents in their tanks. During these periods opercular pumping rates sometimes drop to low levels (10 or fewer per minute) and specimens often lay on their sides or in inverted position (Figure 7). A light finger tap on the tank glass quickly 'awakens' them and they begin normal swimming. Such behavior likely reflects lack of predators in their habitats, as such behavior would seem to leave them extremely vulnerable to predation.

Figure 7. Photograph showing periods of inactivity where *Prietella phreatophila* lay on their side or inverted.

Failure to induce reproduction in captivity

Typically 4–6 specimens of unverified, but presumably mixed, sexes have been maintained together in the laboratory in hopes that they might reproduce. Assorted substrates such as locally obtained limestone with multiple cavities and conduits of various sizes, as well as assorted sizes of glass laboratory flasks, have been provided should this species be a cavity spawner. Little attention has typically been paid to cavities, however, and reproduction has not yet been observed.

Water changes

Since caves harboring *P. phreatophila* have signs of periodic flooding interspersed with periods of stable or slowly dropping water levels, we hypothesized that floods, which might introduce new organic material from the surface into the cave habitats renewing food resources, may trigger reproduction. In an attempt to mimic floods in the laboratory, we allowed tank water to evaporate for extended periods followed by rapid refilling with de-ionized water. Our several repetitions of such cycles produced no response.

Flow-through well water (Dallas Aquarium)

Our laboratory relies on dechlorinated or deionized municipal water and flow-through tank water supply is not possible. Four specimens were housed for about one year, however, in flowing well-water at the Dallas Aquarium where specimens were fed live invertebrates resident in the aquarium water supply. Behavior remained similar to what had been observed in our laboratory, and no signs of reproduction were noted (D. Schlesser & C. Yancey personal communication).

Hormone injections

Failing to induce reproduction with environmental changes, the first author injected three adult specimens (12–15 g) with Pimozide (500 μg kg^{-1}) and LHRHa (100 μg kg^{-1}) (Prentice & Thomas 1987). The total volume of the intramuscular injections was about 0.07 ml. Specimens seemed unaffected by injections, feeding voraciously within 24 hours. With no obvious response to initial injections, fish were again injected with the same dosage at 72 and 144 hours after the first injections. Again, no response was observed.

Presumptive spawning behavior

As this manuscript was being drafted, one pair of 3 specimens being housed together in a 208 l tank began associating with one another much more closely than is typically observed. Normally, individuals which encounter one another display a fright response and flee in different directions, however, these two specimens began to be seen often in close proximity or touching one another. The presumed male had developed pronounced swelling of the dorsal head region, especially of the tissues covering the orbits. What appeared to be large, yellowish or cream-colored eggs in the posterior, dorsal area of the body cavity could be barely seen through the body walls of the presumed female, which lacked any signs of swelling of head tissues. These two individuals would frequently together enter a 100 ml beaker laying on its side on the tank bottom. The male would flex the posterior half of his body into a u-shaped arch and quiver as the female vigorously nuzzled, nipped and pushed at his anal region with her mouth, often pushing the male against the bottom of the beaker or, if oriented in the opposite direction, pushing him out of the beaker. This behavior would last 18–23 seconds, and was repeated at 10–30 minute intervals throughout approximately eight days with no signs of actual spawning or emission of gametes by either individual. The same behavior was occasionally observed in a nearby, larger beaker, but the one, smaller beaker (one of two equal beakers in the tank) was much preferred. Upon completion of this sequence the two individuals would separate and typically swim only 10–20 cm and rest motionless (as described above) on the tank bottom or in supportive structures provided by limestone.

Throughout this period both individuals fed voraciously. After four days of frequent observations of this behavior, the authors had to leave the laboratory for several days, during which time the behavior ceased. Personnel providing fish care did not notice eggs or any other signs of spawning, but time-lapse video of this period has yet to be analyzed. On return of the authors, the belly of the female was noted to be somewhat less distended than previously, and presumed eggs were not so obvious through the body wall as they were before. Searches for eggs and/or larvae failed to find either, and neither individual showed any signs of mouth brooding.

Evolutionary history, biogeography and conservation status

Position within Ictaluridae

Lundberg (1982, 1992) and previous workers working with morphological data considered *Prietella* to be sister to the genus *Noturus*, to which it bears striking morphological similarities. Preliminary results of phylogenetic analyses of mtDNA sequence data (Garcia de León et al. unpublished data), however, do not tend to support this relationship. We are currently in the process of expanding our molecular data set in attempts to increase phylogenetic resolution.

Intrageneric relationships

Preliminary analyses of mtDNA sequences indicate large genetic distances between *P. phreatophila* and *P. lundbergi*, but relatively little differentiation among populations of *P. phreatophila* indicate probable high levels of interconnections among aquifers from throughout its range.

Conservation status

P. phreatophila was listed as an endangered species in México by the federal government in 1994 (Secretaría de Desarrollo Social 1994), and was listed as endangered by Williams et al. (1989). *P. lundbergi* was described subsequent to the last revisions of the Mexican endangered species list.

P. phreatophila should probably be considered threatened. Its distribution is much more extensive than previously realized, and it can be found at many localities, indicating that it is probably less endangered than previously thought. Populations almost surely extend throughout the extensive aquifer it inhabits, occupying many habitats inaccessible to humans or still undiscovered. The total numbers of individuals in this species is probably very large. The arid region it inhabits, however, is facing rapid human population growth, with resultant increasing groundwater exploitation for municipal, agriculture and industrial uses (Contreras-Balderas & Lozano-Vilano 1994). Our interviews with many local residents clearly indicate that declines in water tables over the past few decades are well known throughout the area. Increasing industrialization and recent proposals to use desert areas as waste repositories also threaten to contaminate aquifers occupied by this species.

P. lundbergi appears to have a very restricted distribution. Habitat at one of the two localities from which it is known is very restricted and totally isolated from surrounding waters. Only one specimen has been taken at the type locality despite considerable effort. Unless it occupies deep aquifers to the east of the localities from which it is now known, or alongside the sierra, it is definitely rare. Its presence there may have gone undetected due to inaccessibility of its habitats and the fact that wells, such as those in which *P. phreatophila* is sometimes found in Coahuila, are not common in much more mesic southern Tamaulipas. Based on what we know about the limited distribution, we recommend that this fish be considered endangered.

Future directions

We continue to search for and explore potential new *Prietella* habitats as possible, and to study *P. phreatophila* in the laboratory. We are conducting phylogenetic studies of Ictaluridae, with focus on the position of *Prietella* within the family (Garcia de León et al. unpublished data), and relationships among its populations using microsatellite DNA techniques. Osteological studies of *P. lundbergi* have been hampered by lack of specimens, however, we recently obtained high-resolution CAT scans of the holotype (low resolution versions may be viewed via internet links[2]). Behavioral observations continue in the laboratory, and we continue attempting to induce reproduction in captivity. The second author's research focuses on phylogeography of blindcats and associated invertebrates (based on molecular genetic techniques) over relatively small geographic areas, and application of such data in hydrology as indicators of inter-aquifer connections. Population studies using capture-mark-recapture techniques and habitat monitoring in Sótano de Amezcua continue.

[2] From http://uts.cc.utexas.edu/∼deanhend/.

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